Incorporating real-world spatial complexity within value transfers & aggregation:

A geographical information systems approach

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Spatially optimized cost-benefit analysis using value transfers

Case study concerns a large area CBA conducted using value function transfers.

Assessing land use change from agriculture to multipurpose woodland across the entire country of Wales.

We use geographical information systems (GIS) software to model the characteristics & spatial distribution of resources & facilitate value function transfer in an easily replicable manner.

Value function transfer
from survey sites (s) to policy sites (p)

Survey sites: $\text{Value}_s = \alpha_s + \beta_s \mathbf{X_s}$

Policy sites: $\text{Value}_p = \alpha_s + \beta_s \mathbf{X_p}$

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Policy sites: $\text{Value}_p = \alpha_s + \beta_s \mathbf{X}_\mathbf{p}$

GIS can help in two ways:

- It can often extend the list of predictor variables ($\mathbf{X}_s$ and $\mathbf{X}_p$)
- It can obtain values for $\mathbf{X}_p$

A constraint of value function transfer is that the explanatory variables (**X**) cannot include information which is only available via large sample surveys at policy sites.

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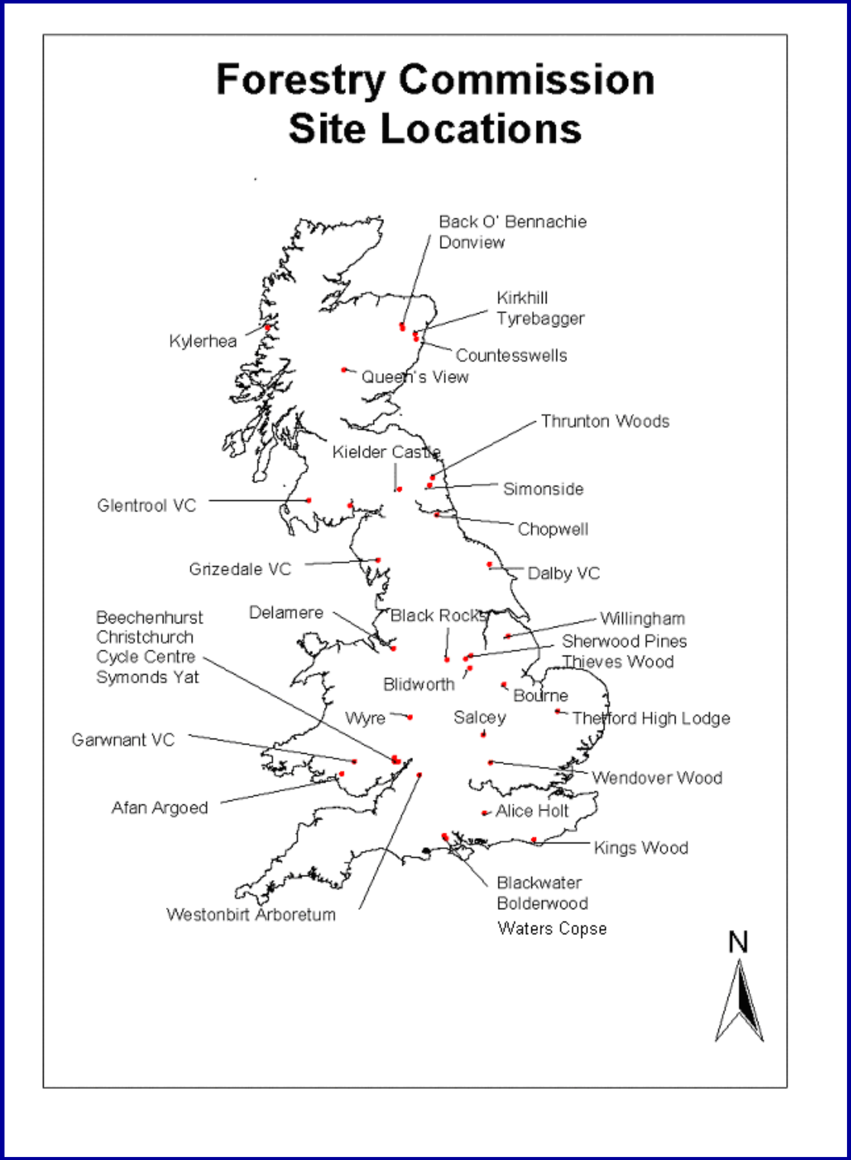
GIS helps us obtain the level of such (**X**s and **X**p) explanatory variables.

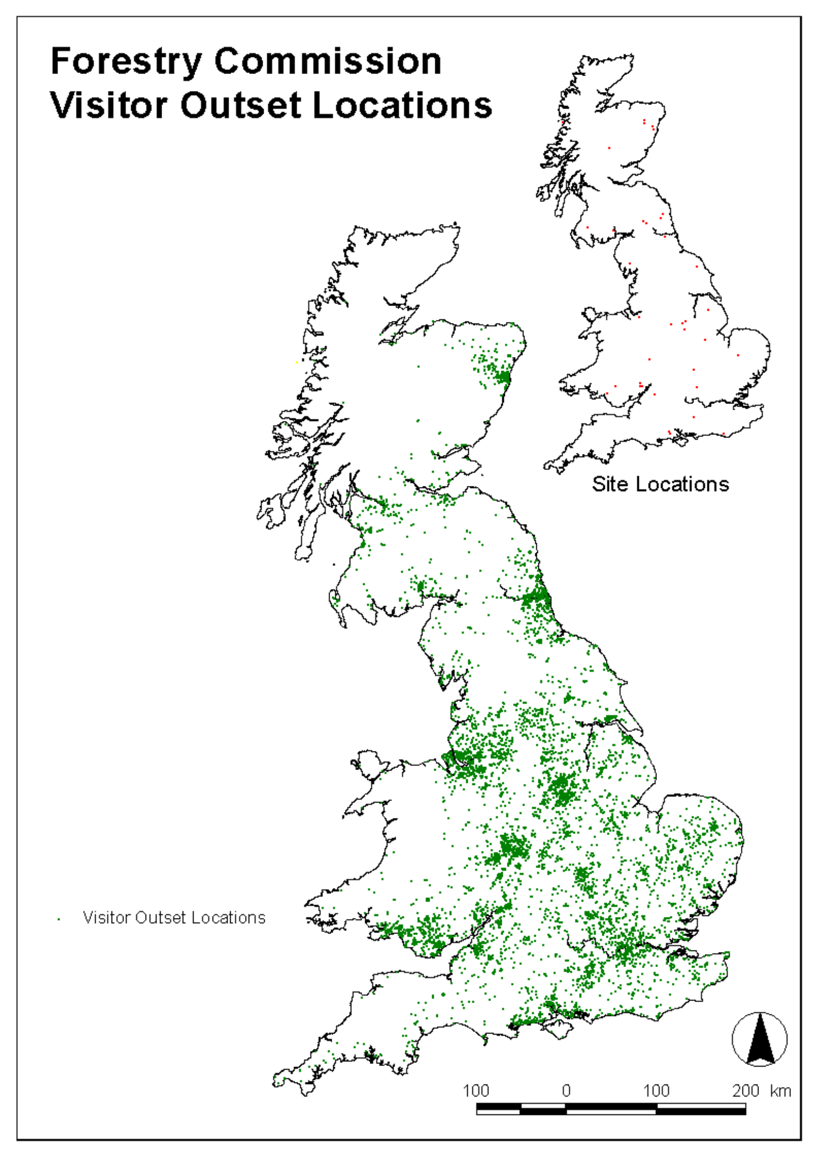
This approach can be applied to the transfer of both non-market and market values as in the following example of a CBA of land use change from agriculture to multi-purpose woodland.

Transferring travel cost recreation demand functions

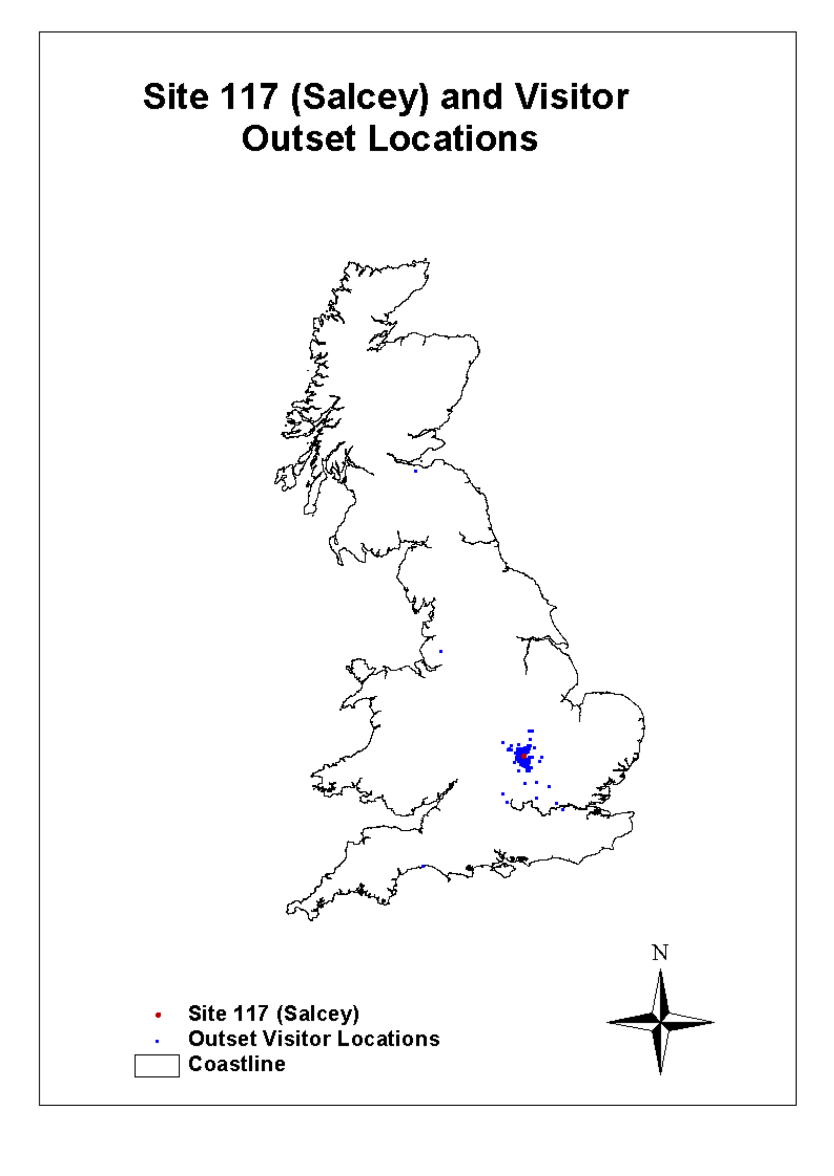
Designing recreation valuation studies for benefits transfer: A GIS approach.

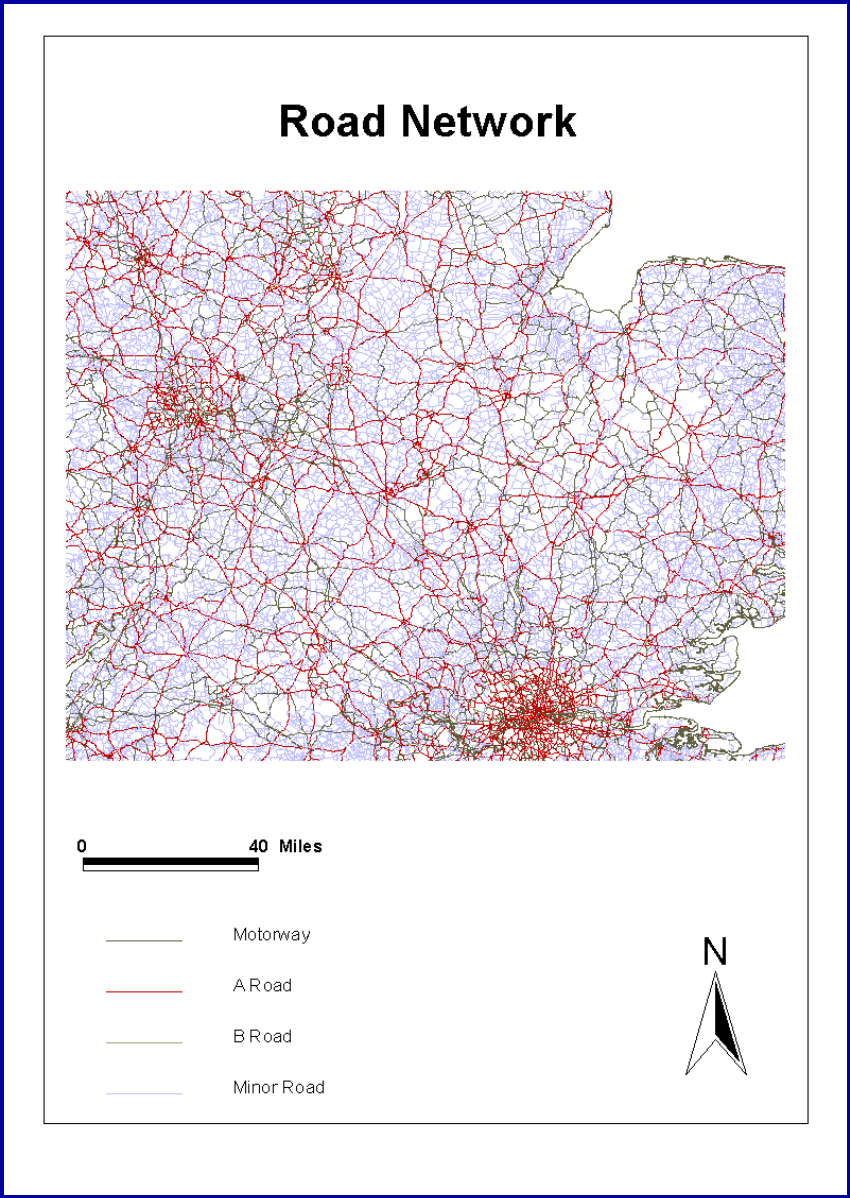
Case Study: Woodland recreation in the UK





Calculating outset locations, travel times and distances for a single site

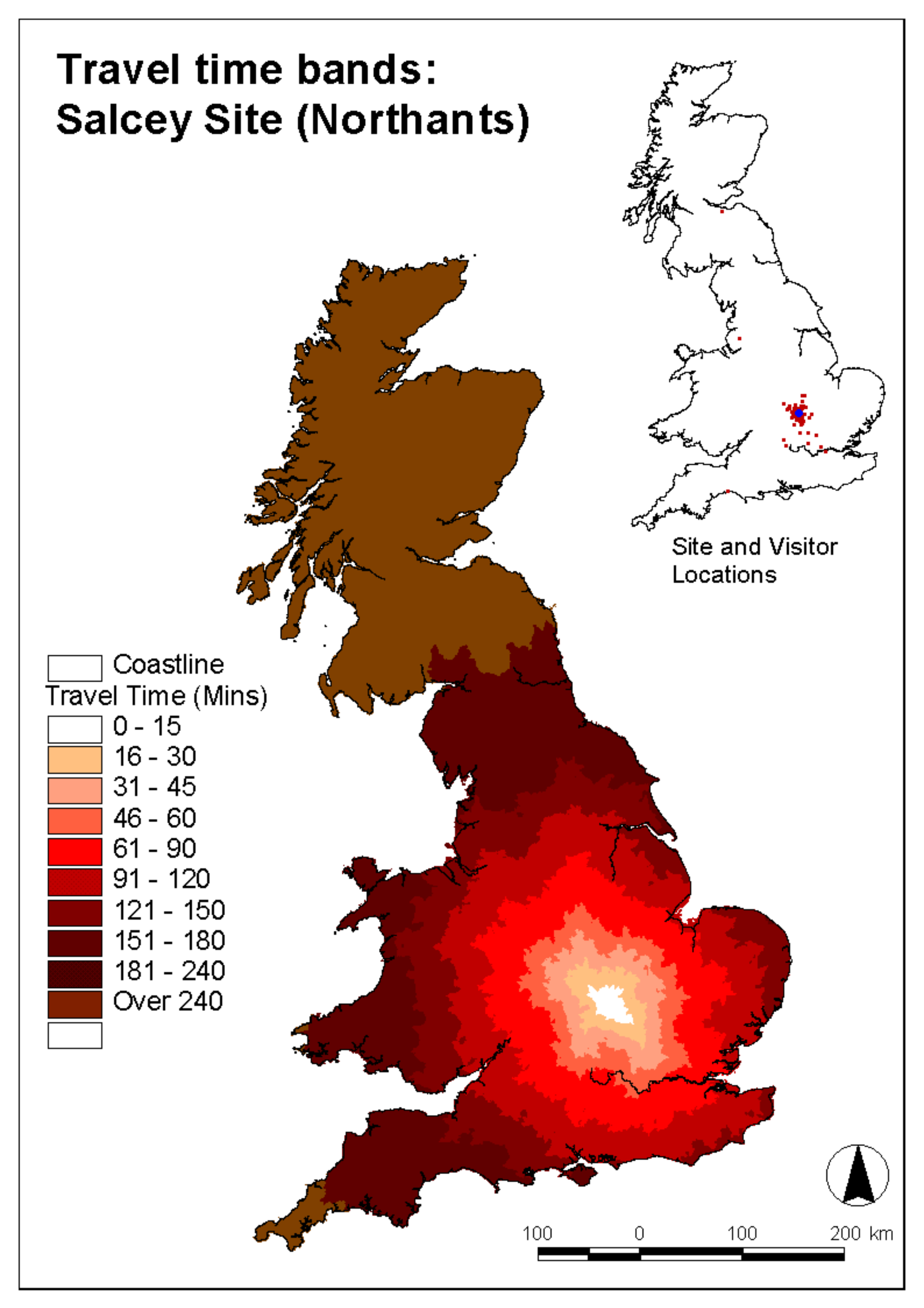


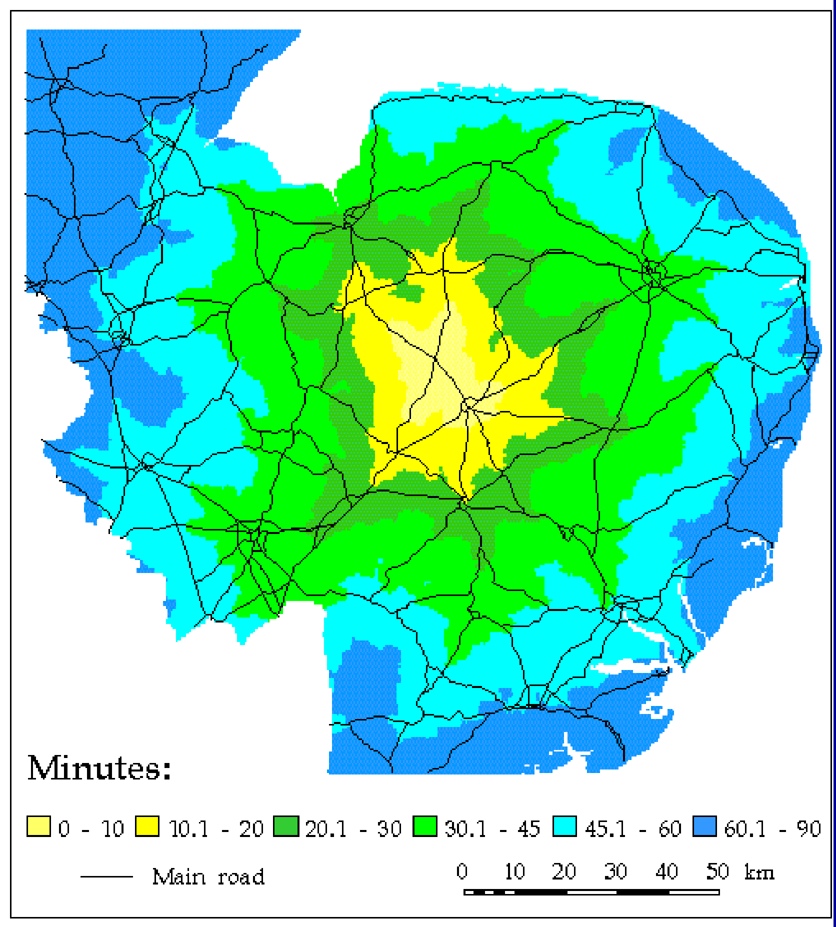


Adjusting the impedance surface for differing road speeds

Road Type	**Average Road Speed (mph)**	
	Rural	**Urban**
Minor Road	14	11
B-Road Single Carriageway	24	12
B-Road Dual Carriageway	36	18
A-Road Single Carriageway	32	18
A-Road Single Carriageway Trunk Road	45	25
A-Road Dual Carriageway	50	25
A-Road Dual Carriageway Trunk Road	54	28
Motorway	63	35

Resulting isochrone maps



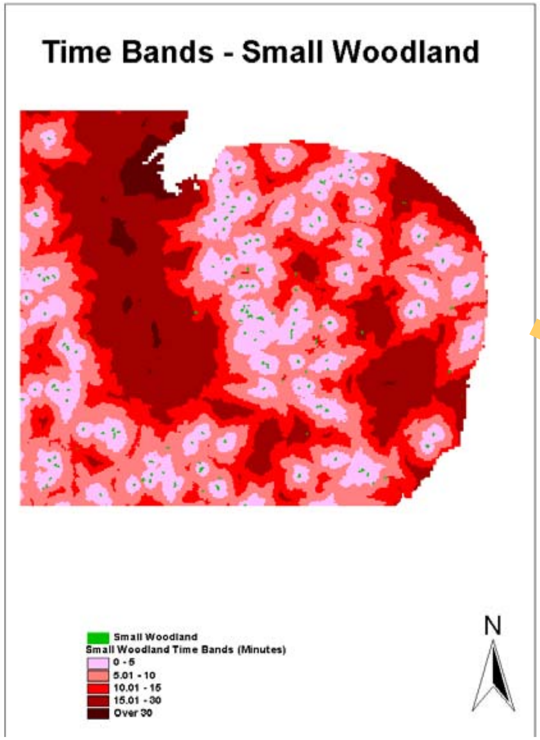


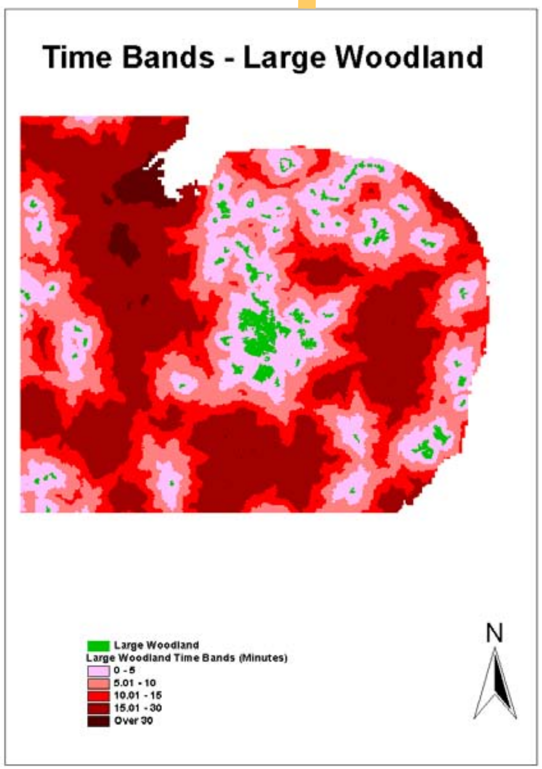
Calculating accessibility of Substitutes/Complements

Countryside/Natural Attractions:	**Developed Attractions:**
• Main Rivers	• Large Towns and Cities
• Woodlands	• Zoos and Wildlife Parks
• Forest Parks	• Theme Parks
• Heathland	• National Trust Properties
• Sandy Beaches	• Historic Houses
• Inland Waterways and Canals	
• Coastal Areas	
• Scenic Areas	
• National Parks	

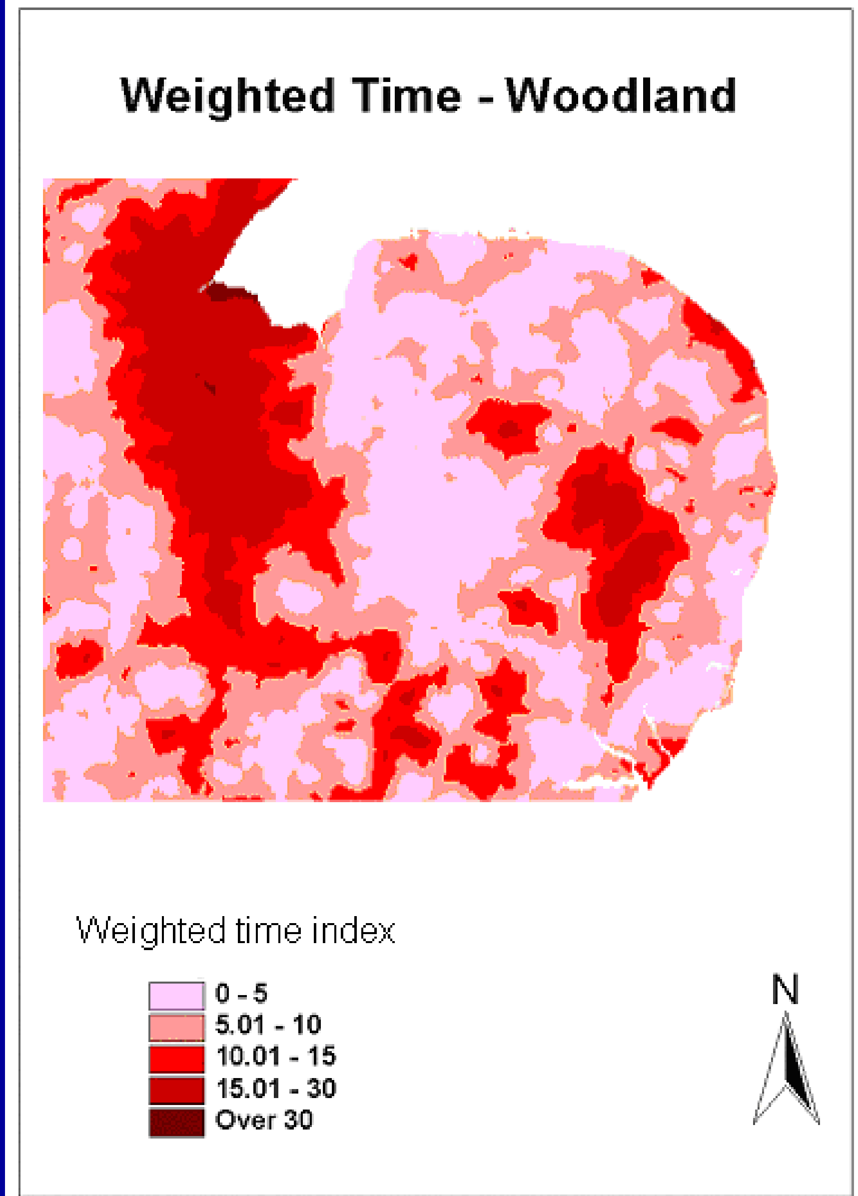
Data sources included: The Institute of Terrestrial Ecology: Land Cover Map of Great Britain
British Waterways: waterway features
Bartholomew's Digital Database: 1:250,000 Digital Database for Great Britain
Other Published Sources

Creating unweighted and size-weighted woodland substitute accessibility measures

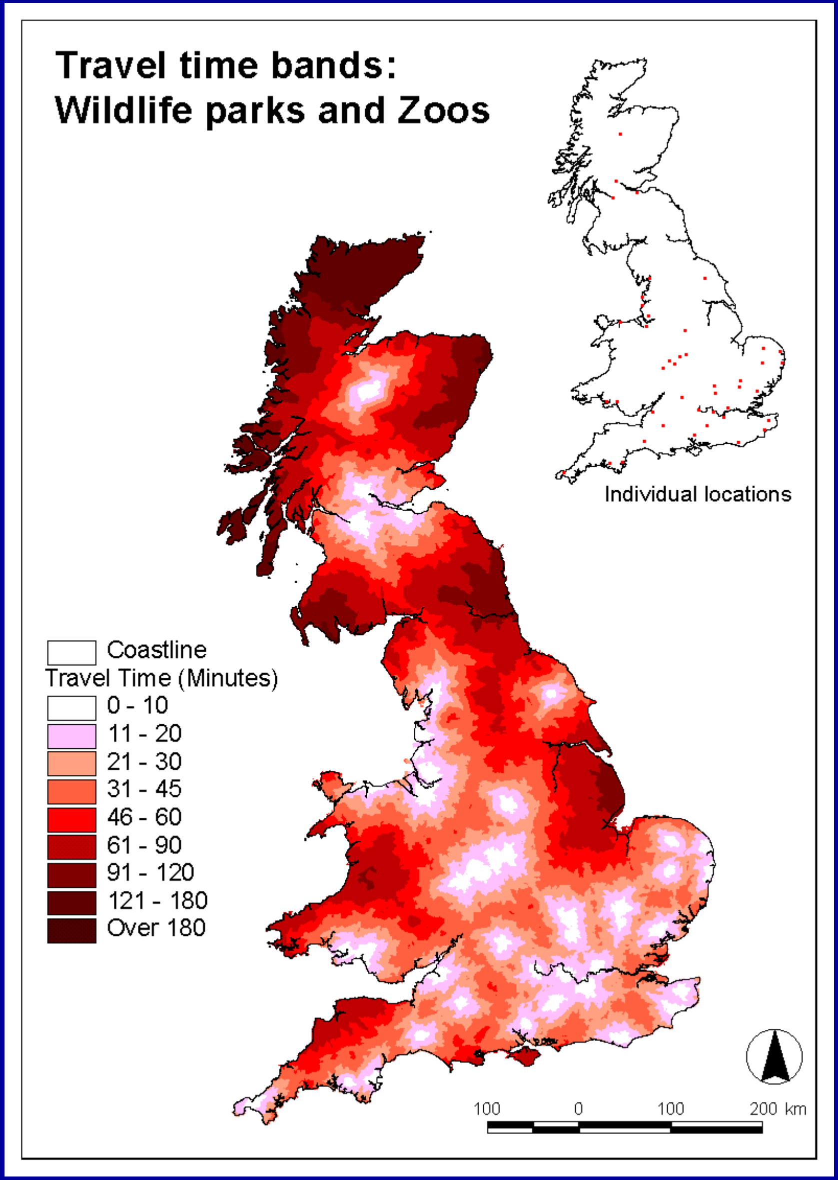


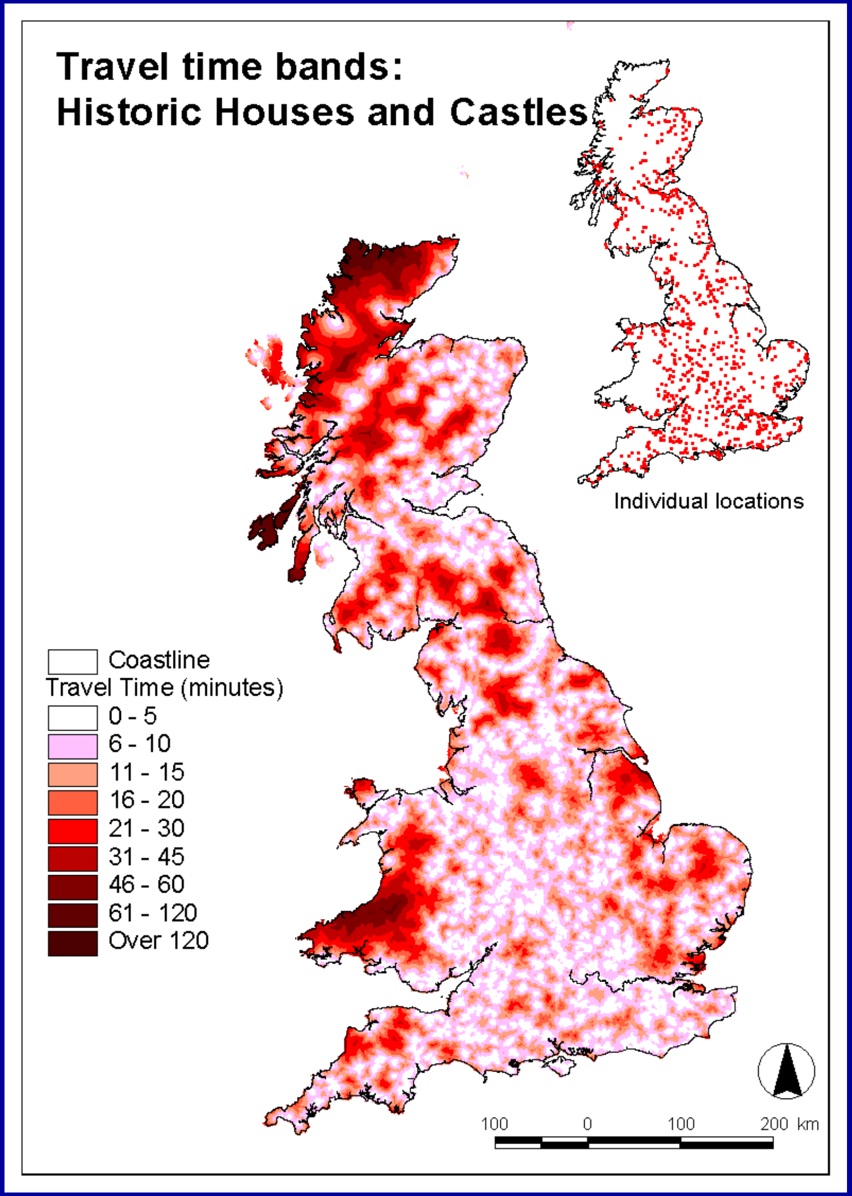


Weight by woodland size



Accessibility measures for non-woodland substitutes/complements





Nationally available explanatory variables used in the multi-level Poisson regression analysis for predicting visitor counts

- Accessibility indicators
- Affluence indicators
- Deprivation indicators
- Higher education indicator
- Ethnic indicators
- Population age indicators
- Coastal indicators
- Water feature indicators
- Woodland indicators
- Scenic area indicators
- Population density and distribution indicators
- Other recreational indicators
- Site Characteristics

Best-fit meta-model of visitors to a sample of Forestry Commission woodland sites across Britain: Using almost exclusively national coverage variables.

Two Level Site Model (All Visitors)				
Variable	**Coefficier**	**SE**	**t value**	**p**
Constant	-11.730	1.775	-6.608	***
Travel time to site	-2.563	0.026	-98.615	***
Travel time to nearest inland water	0.226	0.044	5.199	***
Travel time to nearest heathland	0.170	0.023	7.274	***
Travel time to nearest coast	0.153	0.022	6.888	***
Travel time to nearest National Trust site	0.105	0.040	2.642	**
Travel time to nearest large urban area	0.044	0.014	3.095	**
Percentage of outset district and surrounding districts classified as woodland	-0.048	0.012	-4.105	***
Percentage of outset district and surrounding districts classified as BW canals	-0.018	0.002	-9.588	***
Percentage of outset district classified as households with children	1.157	0.293	3.952	***
Percentage of outset district classified with household head retired	0.668	0.234	2.854	**
Percentage of outset district classified as Social Class 1 or 2	0.703	0.086	8.173	***
Percentage of outset district classified as ethnic	-0.109	0.029	-3.710	***
Early site visitors (7am to 10am)	-0.093	0.030	-3.082	**
Presence of Information Centre at site visited	0.640	0.273	2.341	*
Scottish site indicator	1.485	0.299	4.967	***
$\sigma^2_{u}0$	0.581	0.133	4.368	***
* 0.05 probability				
** 0.01 probability				
*** 0.001 probability				

Providing a test which decision makers will accept: Predicting visits.

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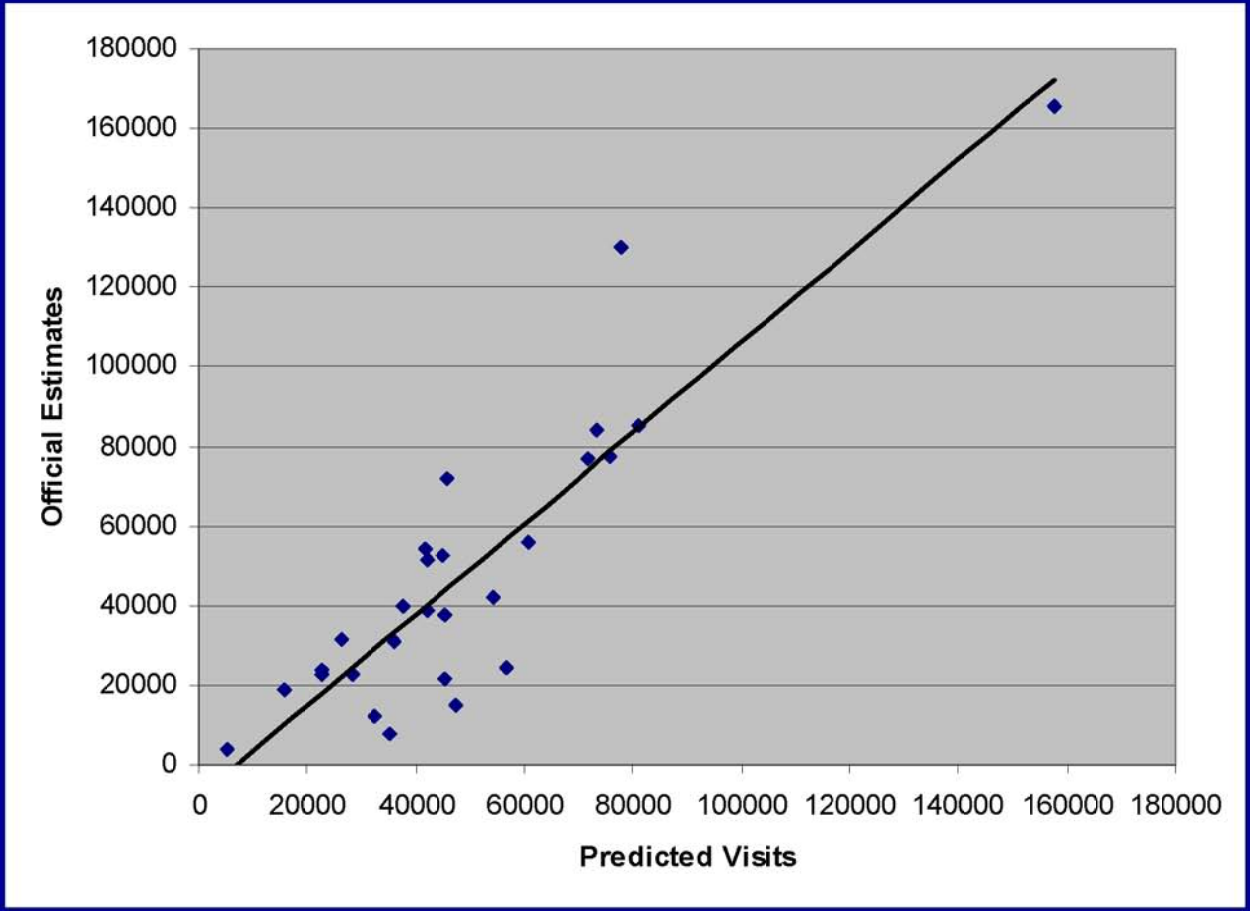
Here GIS generated estimates of arrivals provide a satisfactory predictor of official estimates in nearly 90% of cases

Site name	Official estimate of visits (p. a.)	Predicted visits (p.a.)	Per-Party Consumer Surplus (£ per visit)	Site Consumer Surplus (£ per annum)
Dunwich	18,980	15,957**	1.56	24,828
Two Mile Bottom	22,636	22,678**	2.72	61,676
Kielder Castle	24,243	56,747 *	3.57	202,767
Forest Drive	31,641	26,200**	3.57	93,616
Warksburn	3,794	5,351 *	7.42	39,706
Bogle Crag	14,924	47,475	5.38	255,408
Grizedale	85,181	81,015**	3.48	281,824
Noble Knott	7,543	35,407	3.51	124,149
Whinlatter	55,797	60,838**	3.36	204,571
Blackwater	39,338	37,518**	5.19	147,813
Bolderwood	22,963	28,503**	4.86	182,318
Moors Valley	165,552	157,561**	4.14	652,149
Bucknell	21,360	45,526	1.63	74,117
Salcey	77,650	75,644**	2.23	168,735
Wakerley	51,490	42,354**	2.06	87,456
Dalby	130,151	77,804 *	3.31	257,260
Chopwell	42,298	54,251 *	6.36	344,846
Hamsterley	76,796	71,770**	3.50	251,462
Simonside	12,430	32,526	2.94	95,462
Blidworth Bottom	54,547	41,844**	3.15	131,776
Blidworth Lane	52,754	45,103**	3.16	142,394
Blidworth Tower	37,596	45,288**	2.91	131,660
Chambers Farm	23,605	22,808**	1.92	43,836
Goyt The Street	84,279	73,400**	2.63	193,058
Normans Hill	30,936	35,975**	2.66	95,748
Thieves Wood	72,276	45,617 *	2.66	121,474
Sherwood Centre	38,919	42,325**	1.78	75,430

** = Predictions within 25% of official estimates

* = Predictions within 50% of official estimates

Simple regression analysis: Official estimates = f(predicted visits)



n = 27

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	8105.996	6740.706		-1.203	.240
	Predicted_visit	1.144	.119	.888	9.650	.000

a. Dependent Variable: Official_Estimates

Coefficients[a,b]

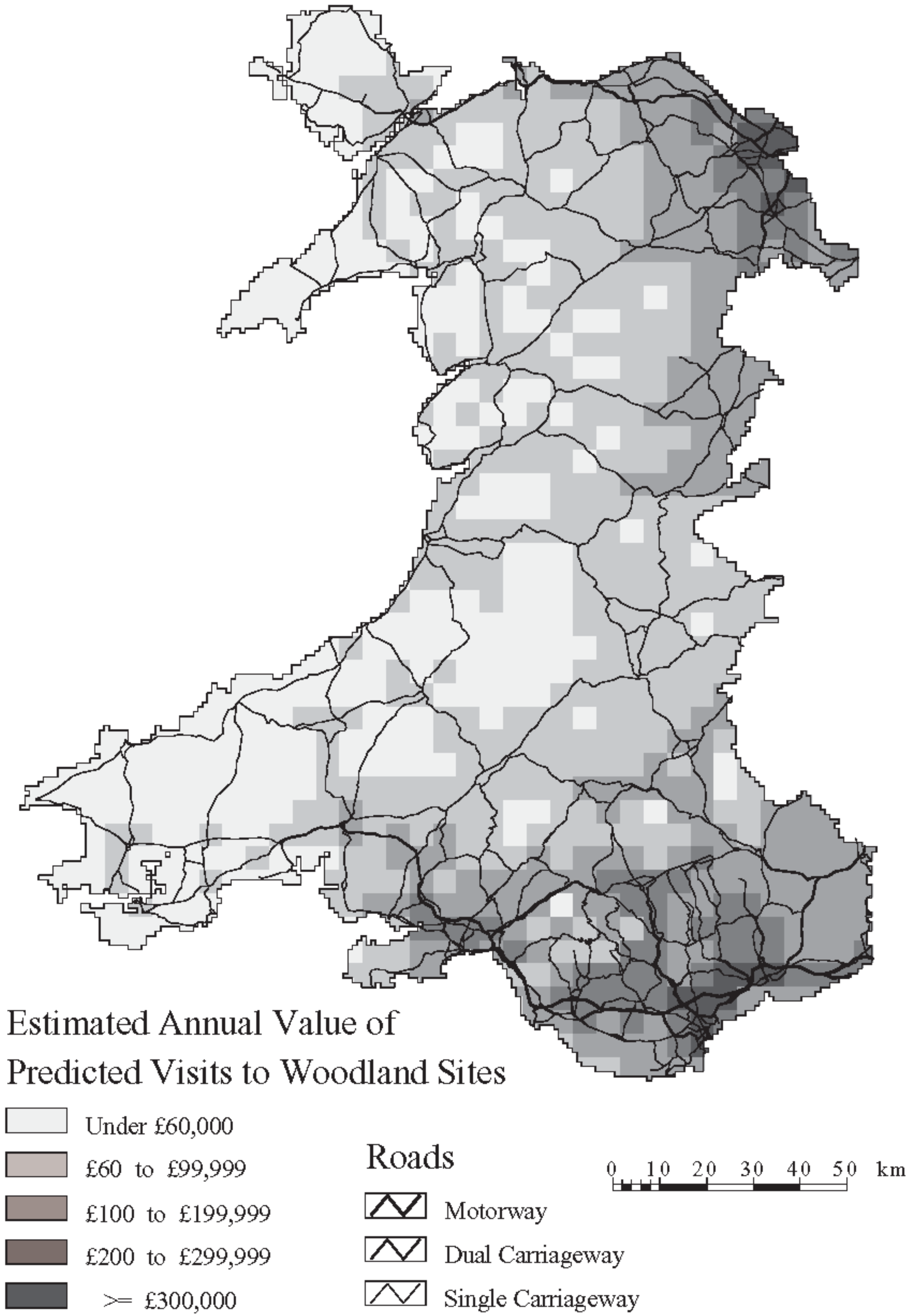
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	Predicted_visit	1.021	.060	.958	17.014	.000

a. Dependent Variable: Official_Estimates

b. Linear Regression through the Origin

Given these results we can use a GIS-based transfer model to estimate the optimal location for a new woodland in terms of the recreational benefits generated.

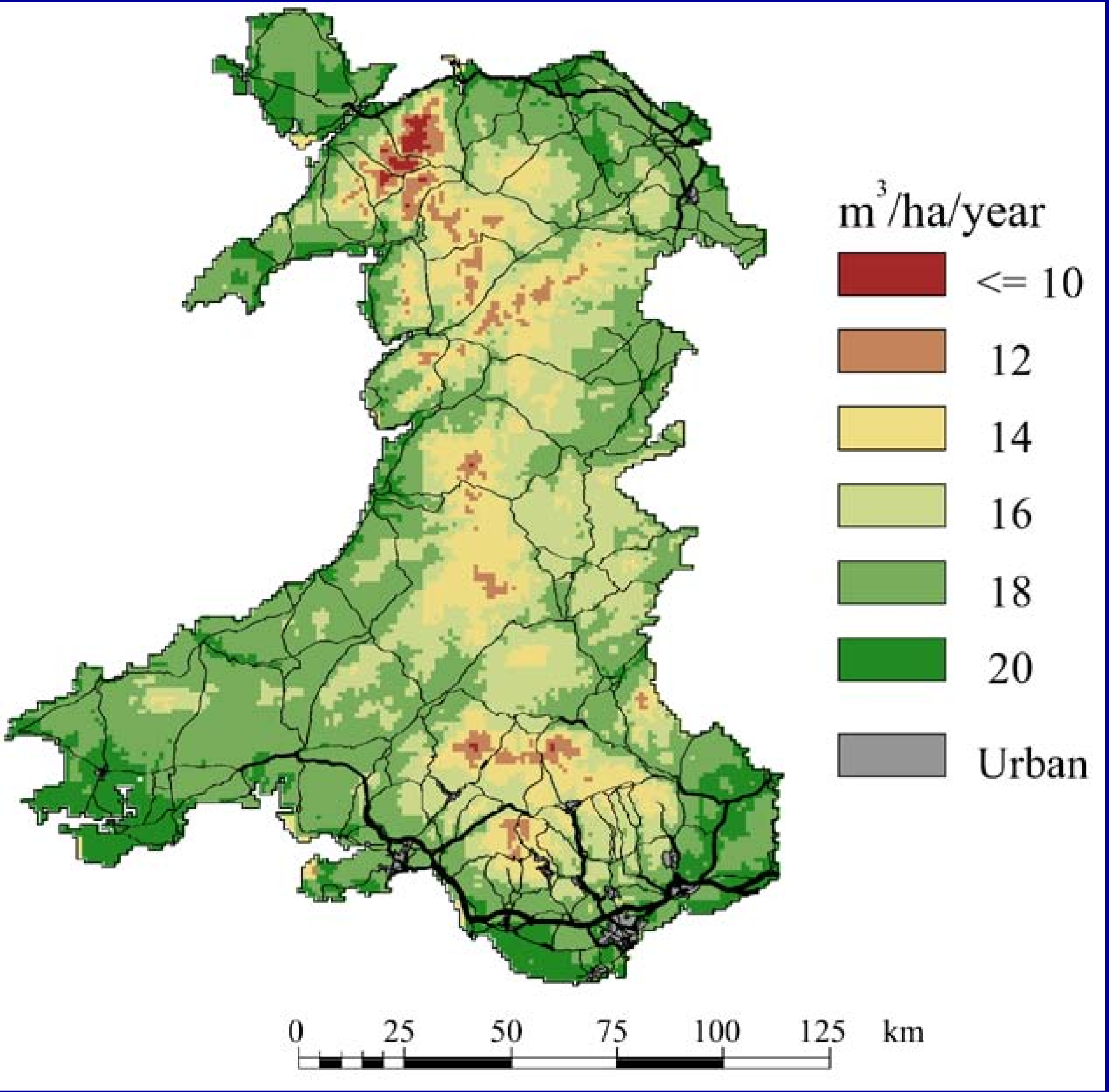
Here we use a transfer function to estimate the number and value of visits generated in each location



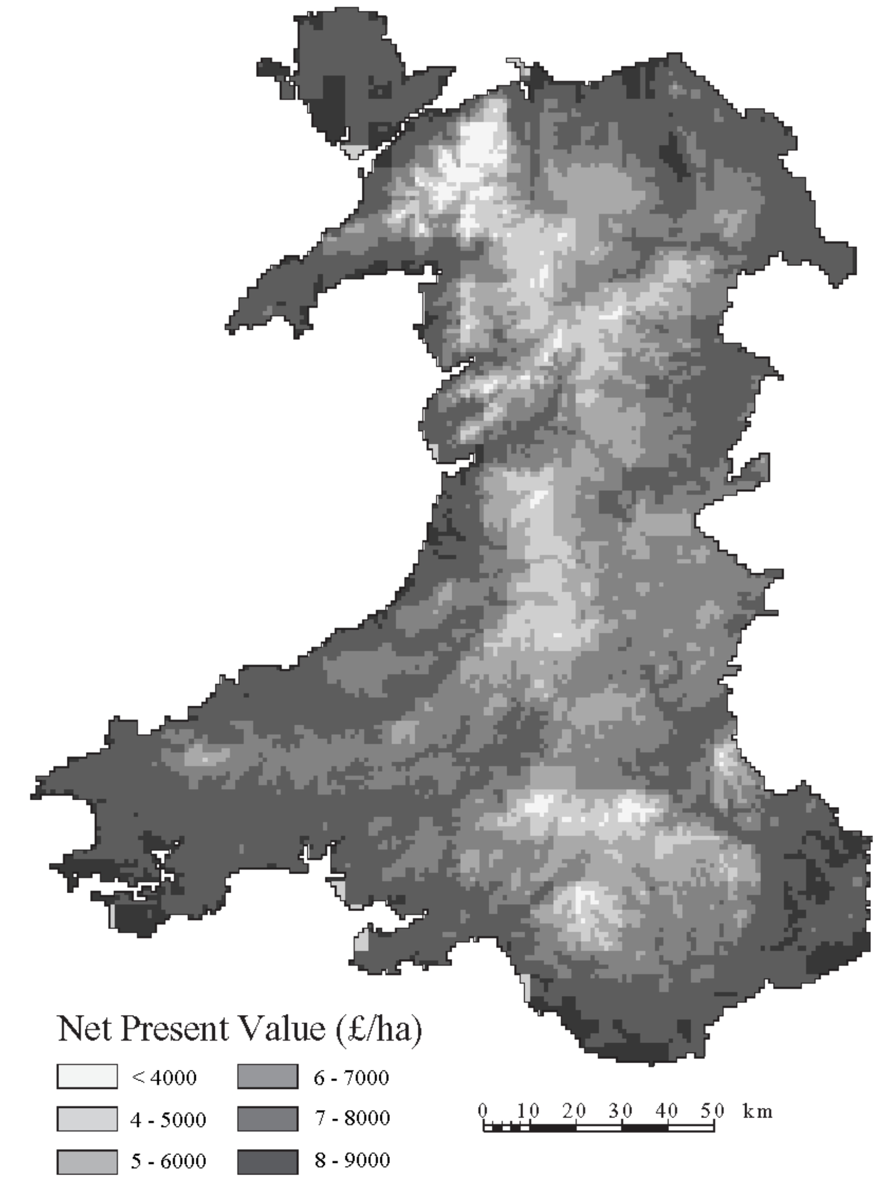
Predicting timber yield and its value

- The GIS was used to integrate data from the Forestry Commission, Soil Survey and various other institutions
- A timber yield function was estimated relating yield class to a variety of nationally available or generatable predictors including: elevation, soil type, topographic shelter, rainfall, aspect, management and other factors.
- This model was then transferred to predict yield for a 500m resolution grid of points covering the entire country of Wales.
- A further model was used to relate timber yield to discounted NPV and annuity values which were again mapped

Estimated annual timber yield class for Sitka spruce in Wales



Net Present Value (£/ha) of estimated Sitka spruce timber yield in Wales



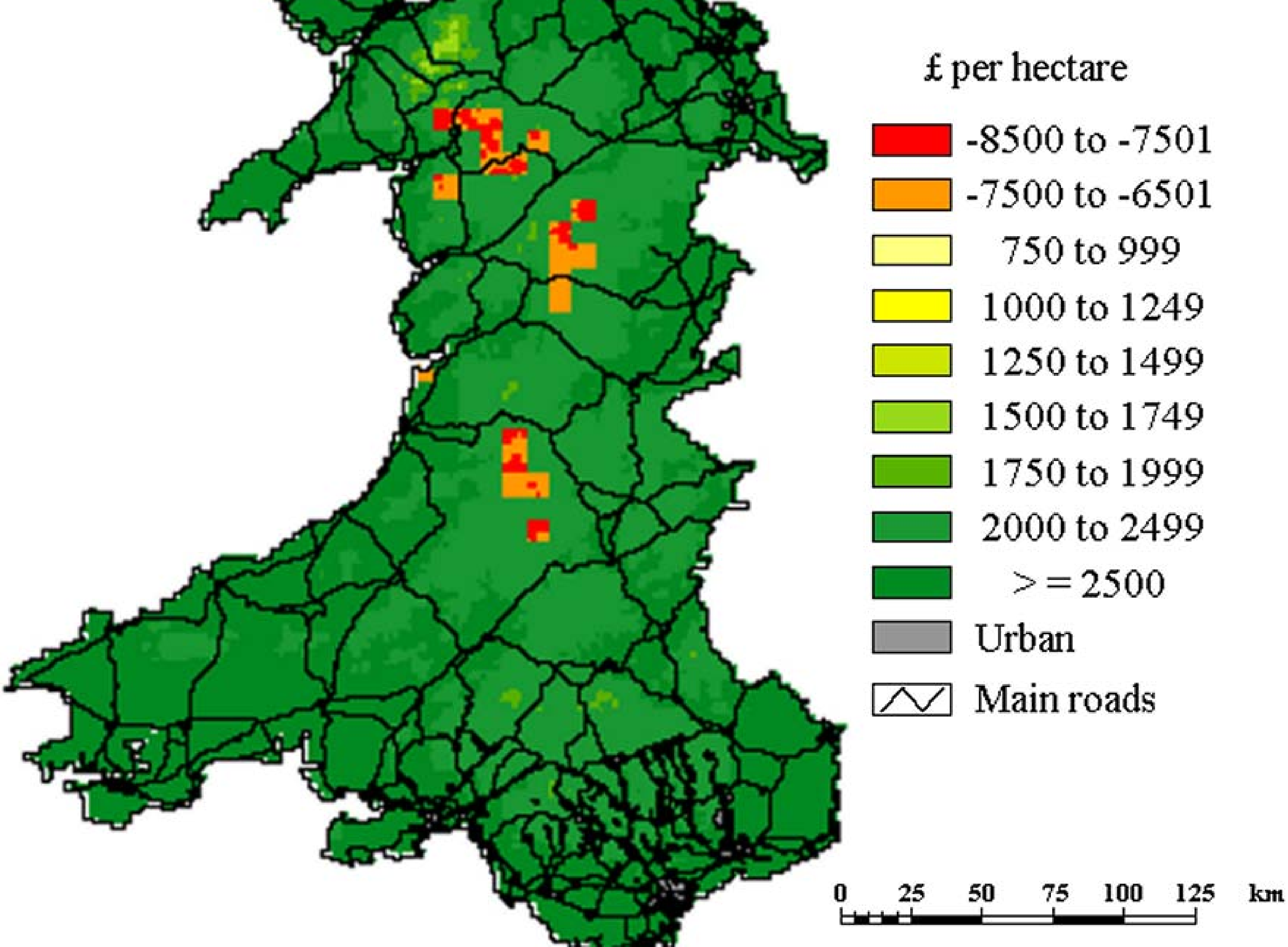
Modelling carbon flux from land use change

The carbon storage and loss arising from land use conversion from agriculture to forestry was assessed using a dynamic, three stage model:

- Carbon storage in livewood
- Carbon liberation from forest products and waste
- Soil carbon gains and losses

Functions for net carbon sequestration and its corresponding value were estimated and transferred across the study area of Wales

Carbon values



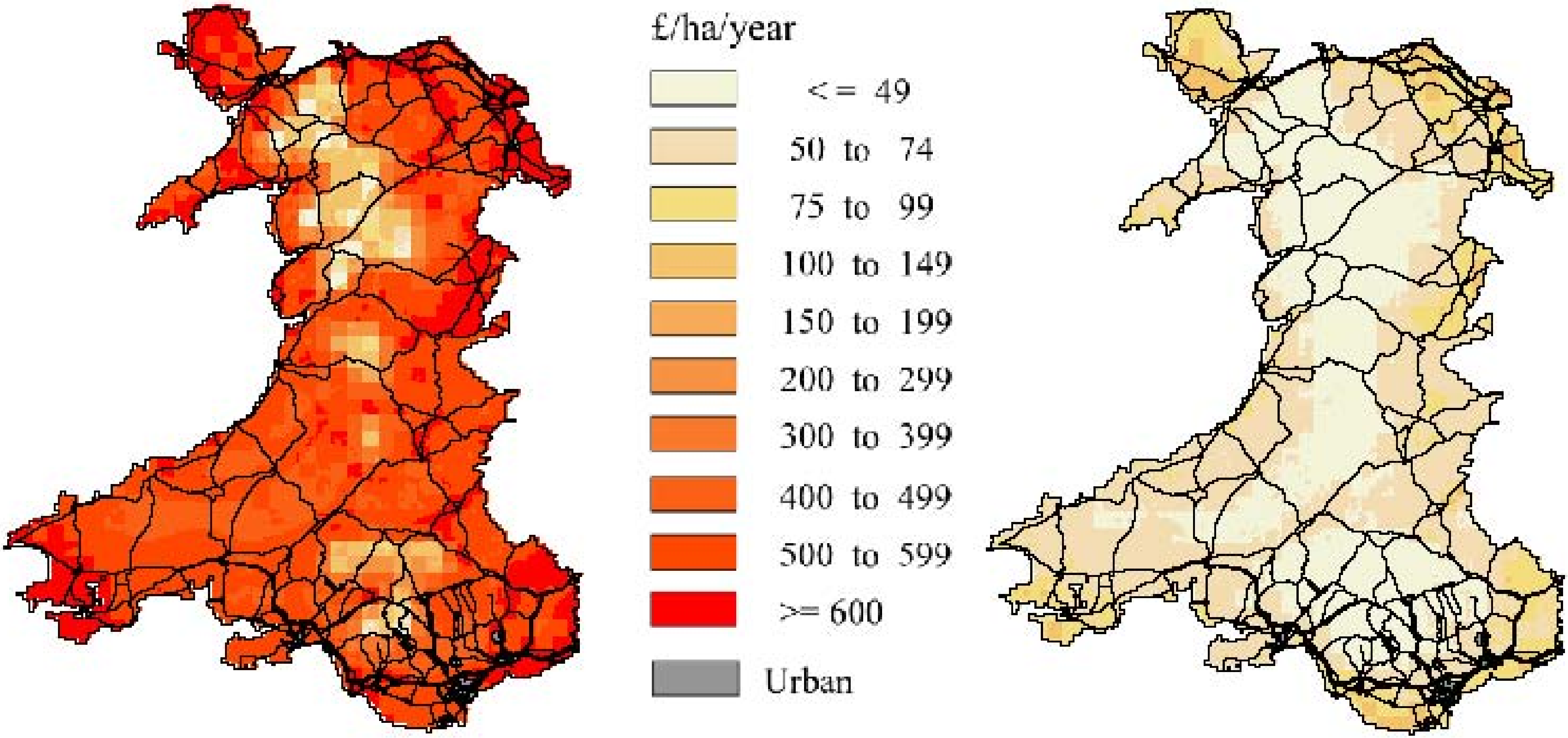
Modelling and transferring agricultural output values

- GIS provides an ideal medium for bringing together the necessary data to model agricultural values.
- Using a sample of farms from across Wales, a two stage, multi-sectoral model of farm profit was estimated
- The GIS holds values for all of the explanatory variables in all of the functions used to predict profit.
- These values are held for a regular grid of points across the entirety of the case study area.
- Consequently we can use the GIS to transfer these functions across the study area predicting profit in all locations and generating maps such as the following

GIS-based transfer model for agricultural output value in two sectors (using two measures)

Predicted farm gate income for dairy farms

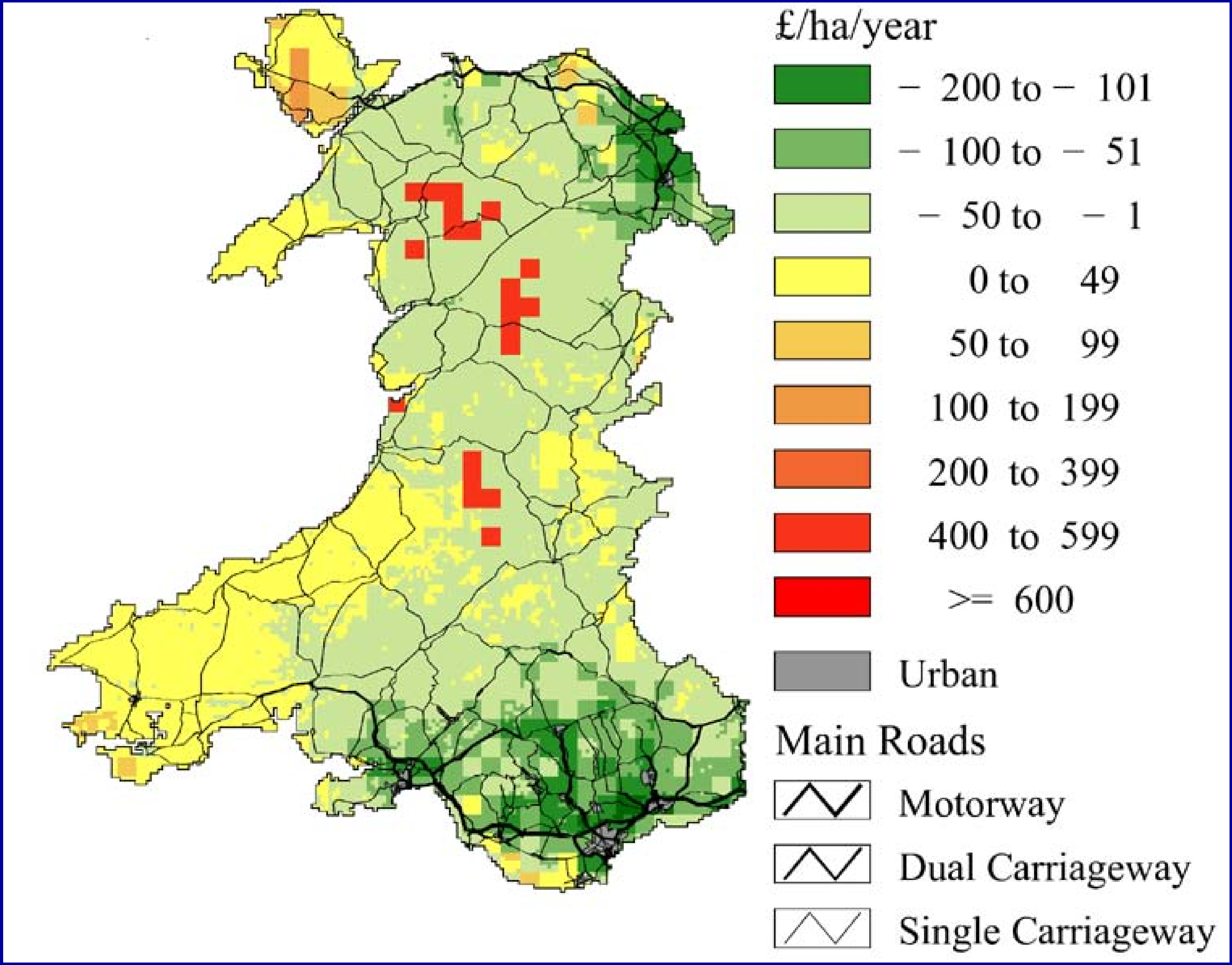
Predicted shadow value for sheep farms



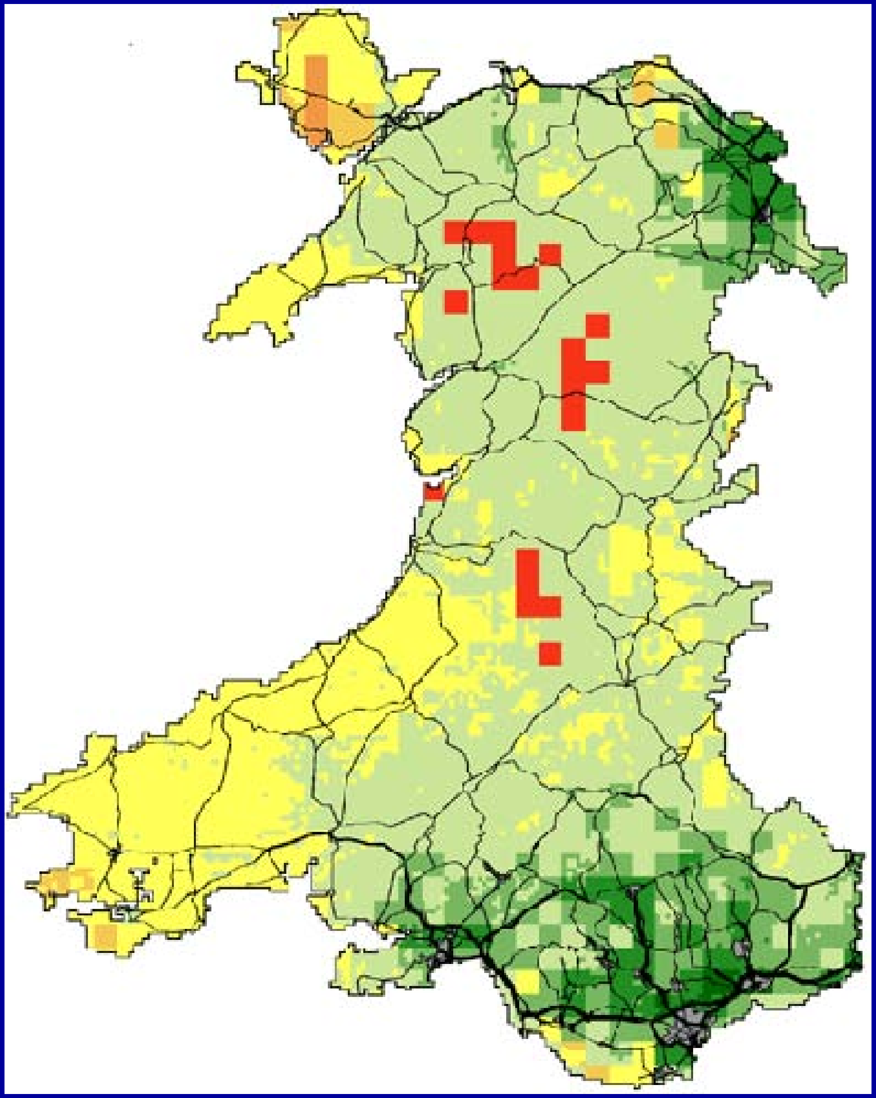
Cost benefit analysis of converting agricultural land to multipurpose woodland

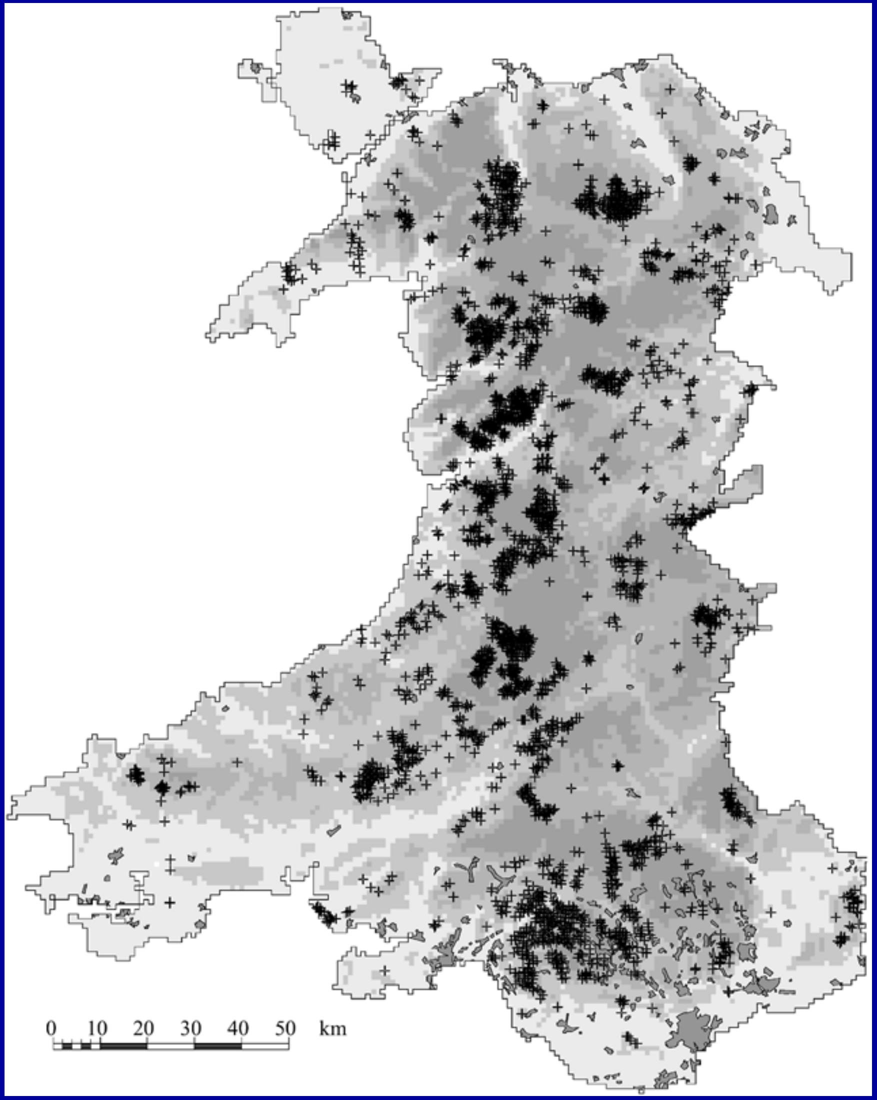
- Analyses of land use values in Wales were synthesised to yield cost-benefit estimates of policy alternatives
- Includes agricultural, timber, carbon flux and recreation values.
- GIS approach is particularly useful for conveying complex outcomes to decision-makers and for identifying optimal locations for applying limited resources.

Agricultural values minus multipurpose woodland values



Comparison of CBA findings with actual location of Forestry Commission woodlands

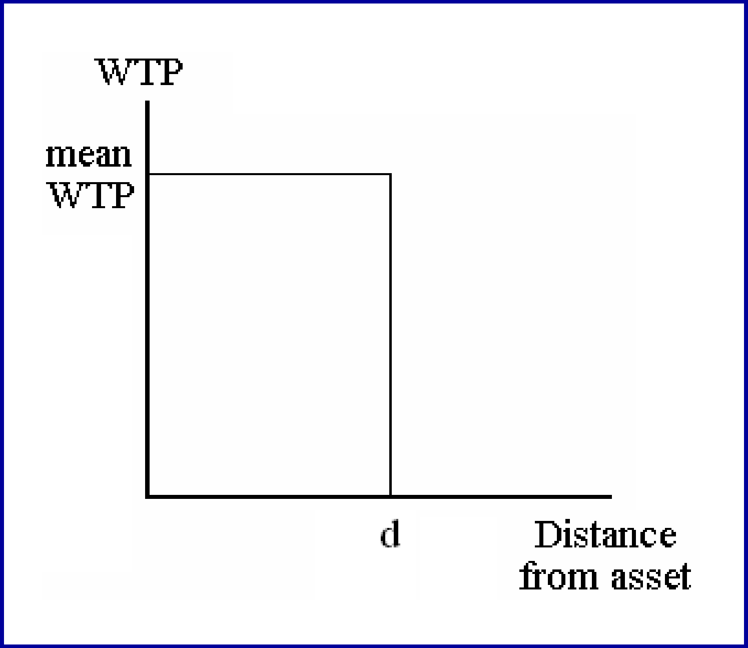




Using GIS to aggregate transferred benefit estimates

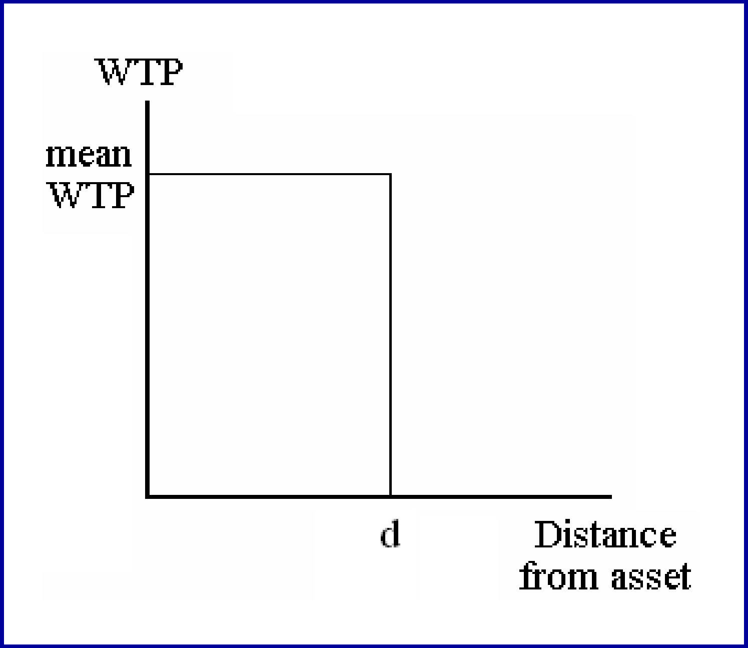
Study prompted by the UK Environment Agency (EA) ‘administrative area’ approach to aggregation of values for a single site as used in their study for the River Kennet tribunal

UK EA ‘administrative area’ aggregation approach



- Assumes that WTP is invariant across space up to distance d and zero thereafter.
- Ignores the distribution of population across space

UK EA ‘administrative area’ aggregation approach



- Assumes that WTP is invariant across space up to distance d and zero thereafter.
- Ignores the distribution of population across space

The use of a GIS allows us to relax both of these restrictive and unrealistic assumptions

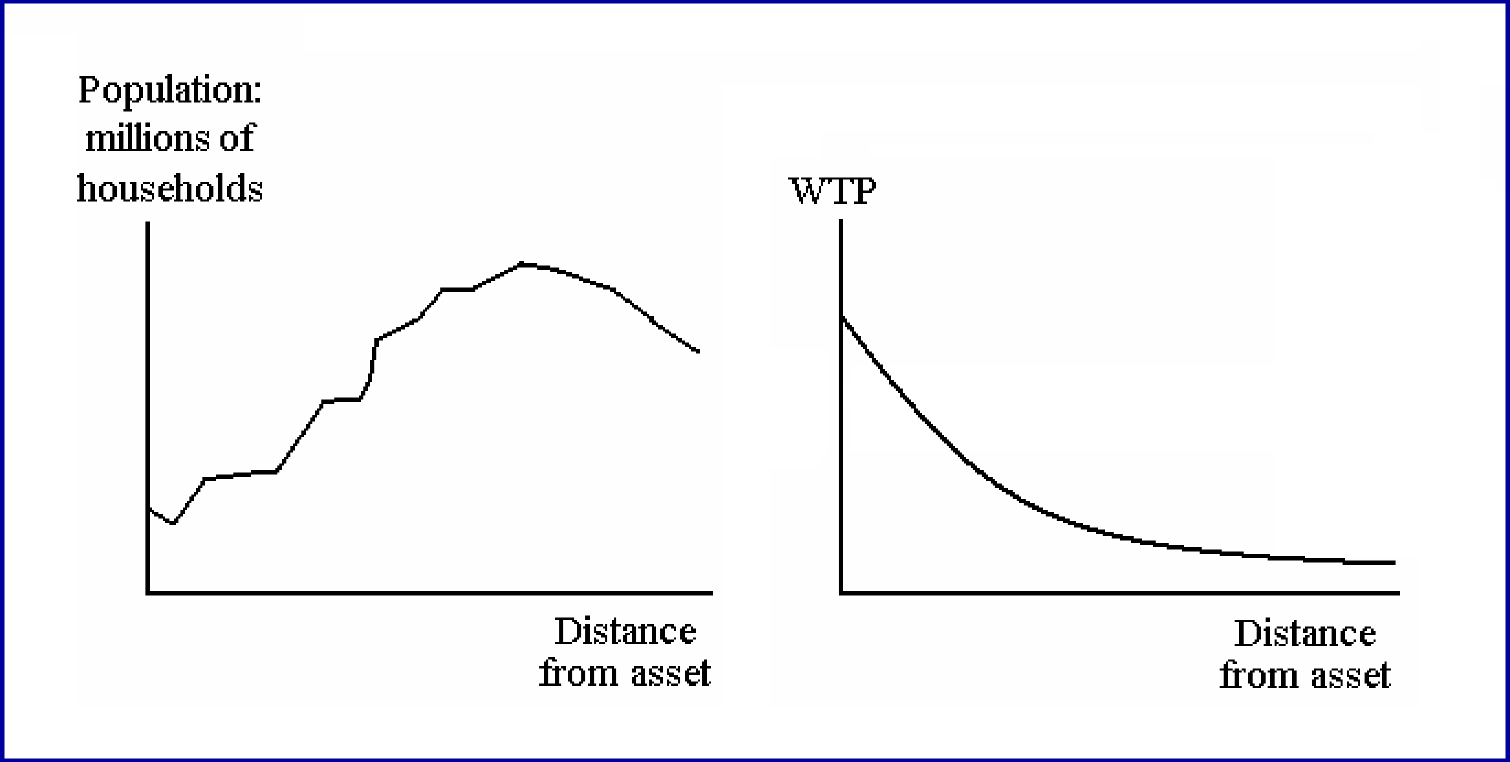
Even a relatively simple model allows a fundamental improvement over the EA approach, say:

$$WTP = f(\text{distance, socio-economics, substitutes})$$

A combination of a household (CV) survey of WTP for an environmental asset (a wetland area) and GIS techniques allows us to parameterise this relationship

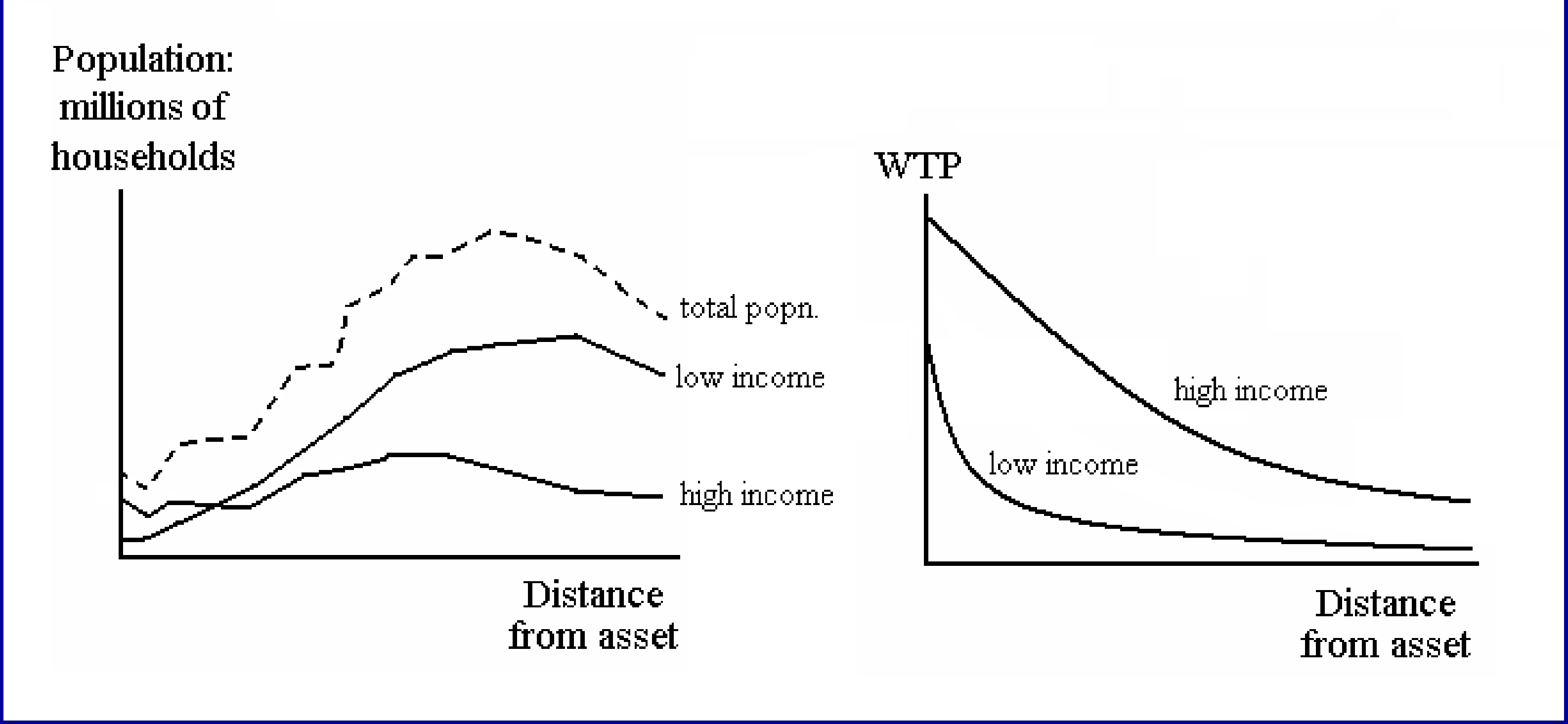
- The GIS uses Census data to assess how population varies with distance.
- Furthermore, by using the GIS to calculate the distance from respondent household to the asset, we can reveal the effect of distance on WTP

WTP = f(distance, socio-economics, substitutes)



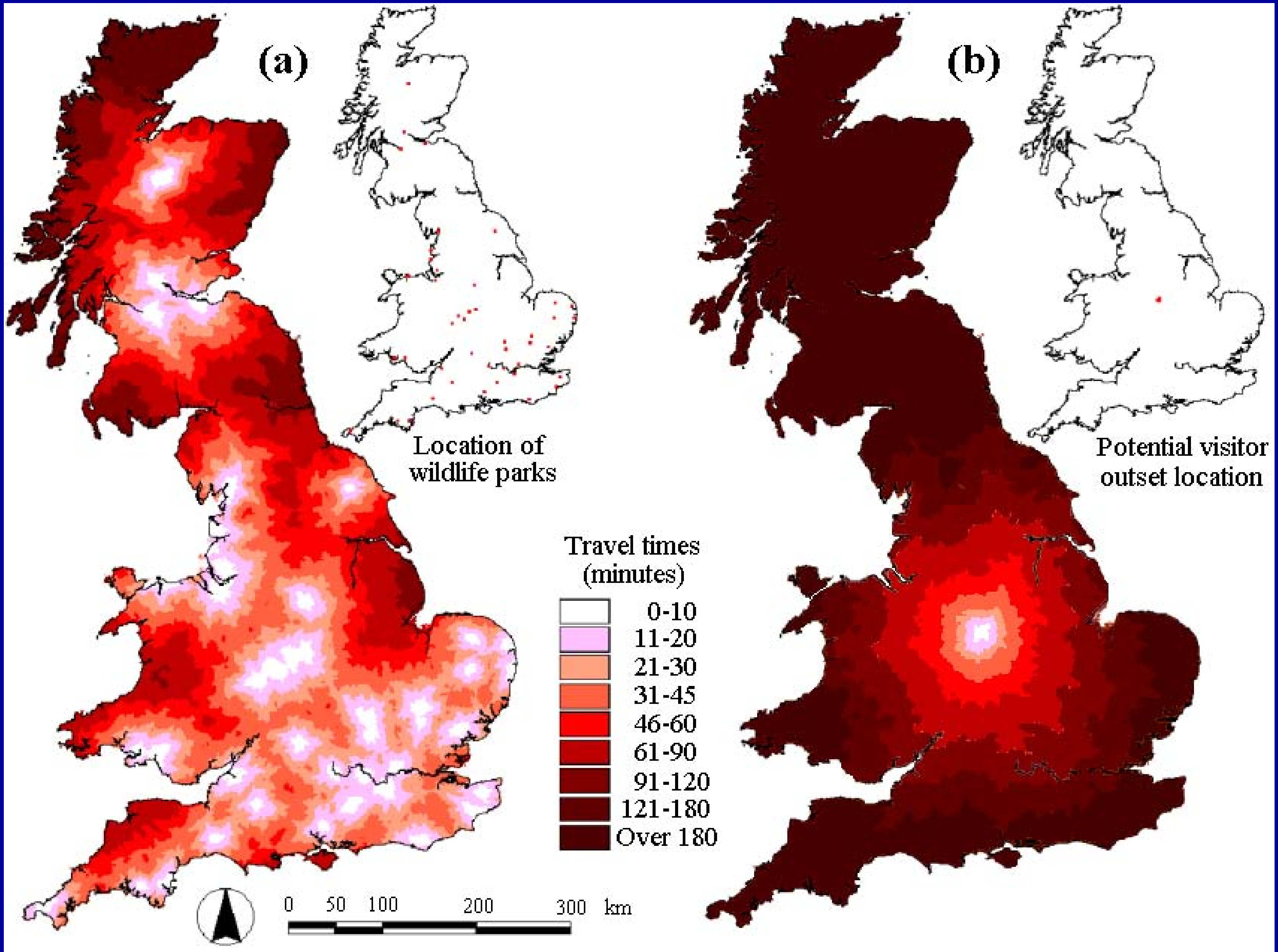
We can now examine the relationship between distance, socio-economic variables and WTP

WTP = f(distance, socio-economics, substitutes)



Using the GIS to assess substitute availability:

WTP = f(distance, socio-economics, substitutes)



Comparison of methods: Aggregate value of preserving the Norfolk Broads wetland estimated using two procedures

Aggregation method	Aggregate value (£ million p.a.)
Administrative area approach	159.7
GIS based approach	25.4

Conclusions

Value transfers, the aggregation of benefits and CBAs of land use all have spatial dimensions.

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The analytical gains afforded by even simple GIS analyses (e.g. even just taking into account the distribution of population) make them highly efficient contributors to the decision making process.

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The analytical gains afforded by even simple GIS analyses (e.g. even just taking into account the distribution of population) make them highly efficient contributors to the decision making process.

A personal view - GIS provides the best hope for viable, defensible value transfers

Further details of this talk can be found in the following publications

Bateman, I. J., Lovett, A.A. and Brainard, J.S. (2003) *Applied Environmental Economics: a GIS Approach to Cost-Benefit Analysis*, Cambridge University Press, Cambridge, ISBN 0-521-80956-8. (paperback version published 2005).

Bateman, I.J., Jones, A.P., Lovett, A.A., Lake, I. and Day B.H. (2002) Applying geographical information systems (GIS) to environmental and resource economics, *Environmental and Resource Economics*, 22(1-2): 219-269.

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Abstract

Many of the analyses undertaken by environmental and resource economics are intimately concerned with spatial variations. This article examines the contribution which Geographical Information Systems (GIS) may provide in incorporating the complexities of the spatial dimension within such analyses. The paper introduces the reader to the types of data handled by a GIS and overviews the practical functionality offered by such systems. A brief literature review is supplemented by a number of more detailed applications illustrating various GIS techniques which may be of use to the applied environmental or resource economist.

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