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# Spatial Economic Valuation: Benefits Transfer using Geographical Information Systems

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A benefits transfer exercise is performed to give a spatial representation to the total economic value of the Rio Bravo Conservation Area in north western Belize. The methodology investigates the use of Geographical Information Systems (GIS) to calibrate economic values from alternative sites for transfer to the site of interest. This is achieved by first mapping the "strength" or "quality" of the natural capital assets in the Rio Bravo, then using these maps to re-calibrate benefit estimates from alternative sites. The results of this process are "economic value maps", showing the benefit value of natural capital assets in two-dimensions. Given the growing interest in the feasibility of transferring benefit estimates the paper demonstrates how GIS may be a powerful vehicle for comparing site characteristics prior to transferring values. The methodology also adds a spatial dimension to existing resource accounting frameworks.


*Keywords*: sustainability, natural capital, benefits transfer, Geographical Information Systems (GIS).

## 1. Introduction

Economic definitions of sustainability have equated non-declining individual well-being with constant consumption, capital substitutability and associated rules on savings and investment (Pearce and Atkinson, 1995). While much attention has been focused on the theory and practice of depreciation adjustments to traditional national accounting systems, much less attention is paid to the appropriate spatial dimension for assessing sustainability and the relationship between the distribution of natural capital and welfare. However, welfare and inequality can be assessed in a plurality of spaces (Sen, 1992), not least in (sub-national) environmental space. With information on the presence

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and value of environmental assets, natural capital may be spatially disaggregated and monitored within specific localities and at a finer resolution than currently possible using adjusted national accounts. The representation of natural capital in space may then be adapted to provide a finer indicator of the welfare effects of regional environmental change.

Spatial economic valuation is not without problems. In common with the difficulties encountered in making environmental depreciation adjustments to national accounts, asset mapping requires extensive information on environmental values. However, typical resource accounting adjustments, for, say, soil erosion, have typically assumed the transferability of point-specific economic depreciation estimates (see van Tongeren *et al.*, 1993), with limited assessment of the spatial variability in factors which give rise to the original estimates. To the extent that generalization occurs over environmentally heterogeneous areas, the neglect of spatial variability may seriously compromise the accuracy of adjusted accounting.

A more fundamental question arises as to the potential to monitor the distribution of capital in addition to investment and depreciation necessary for accounting purposes. The use of Geographical Information Systems (GIS) offers one method of investigating the simultaneous representation of diverse social and physical information relevant to sustainability in an alternative spatial resource accounting framework. GIS may also be assessed as an appropriate vehicle for undertaking benefits transfer.

## 2. Benefits transfer

The growing sophistication of economic valuation methodologies is matched by the cost of conducting new studies for site-specific environmental change. There is, therefore, considerable interest in the cost-saving potential for generalizing values from one site to another when environmental and socio-economic conditions are suitably similar. The advantages of benefit transfers have been recognized by a number of environmental agencies and there is growing research interest in the potential development of "off-the-shelf" values libraries.

Reviewing the potential for transfer, Krupnick (1993) notes the feasibility of transferring some environmental impacts as a result of the existence of reliable statistical information. Benefits transfer for health programmes, for example, is facilitated by good epidemiological studies and information on the costs of mortality and morbidity. Recent experiments for water quality and water-based recreation have adopted varying approaches, transferring unit values derived from reviews of several similar studies (Boyle and Bergstrom, 1992), or, more controversially, transferring travel cost demand valuation equations between sites (Loomis, 1992). The "less than ideal" nature of recent transfer attempts is widely recognized and numerous methodological problems have been identified (Smith, 1992; Boyle, 1994; Bergland *et al.*, 1995). In particular, comparison of the scale of damages, the role of substitutes and the extent of affected populations will typically not be replicated over two sites. In essence, the validity of transferring benefit estimates for non-market goods cannot be separated from the debate about the validity of the valuation methods from which values originate.

A more rigorous validation of transfers involves a meta analysis approach to assess the explanatory power of factors causing divergence over the welfare estimates of the studies used as the basis for a transfer (see Smith and Kaoru, 1990; Smith and Osborne, 1994). A problem with meta analysis, however, is that there are insufficient studies to serve as observations for reliable statistical inference. Moreover, those that do exist

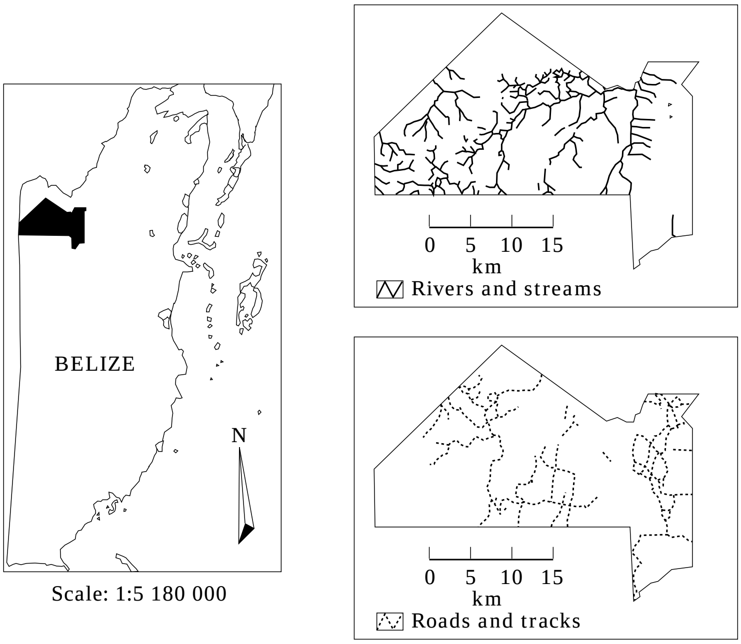



Figure 1. Location map of the Rio Bravo Conservation Area.

often use diverging methodologies to estimate the same type of effect, with poor studies often not being excluded.

## 3. Economic values in GIS

Geographical Information Systems are widely used for environmental planning and monitoring but seldom for environmental valuation. Technological advances in computer hardware and GIS software have encouraged a rapid growth in environmental GIS applications. This growth has paralleled the development and use of economic valuation methods such as travel cost and contingent valuation of non-market values, for ultimate use in benefit-cost analysis, damage litigation and, potentially, in innovative measures of well-being.

Although exercises in valuing natural capital are becoming more widely used and accepted by development agencies (e.g. World Bank), studies typically derive point estimates which are aspatial.

We aim to illustrate the importance and potential of using GIS to adopt a spatial approach to economic valuation of the environment, and, in particular, to demonstrate the utility for transferring site-specific benefit estimates. The primary aim is to present natural capital in two dimensions, in the form of "economic value maps" which include non-market values. The secondary aim is to examine the spatial effects of changes in economic value on these maps and in judging the use of GIS for transfer.

## 4. The study area

The Rio Bravo Conservation and Management Area (or Rio Bravo) contains about 100 000 ha of tropical rainforest, swamp/marsh and savanna, and is situated in the north west of Belize (see Figure 1).

The Programme for Belize (PfB), a non-profit organization initiated by international conservation agencies, aims to develop the Rio Bravo on a sustainable basis by using income from eco-tourism and extraction of forest products to finance the conservation and research programme (PfB, 1991). The PfB is currently developing a resource management strategy for the area, as well as pursuing on-going scientific research.

## 5. Environmental assets in the Rio Bravo

Reflecting the concern over tropical deforestation, a growing literature has addressed the economic rationale for forest conservation over development. Valuation studies have concentrated on specific aspects of total economic value, such as the quantification of direct values of non-timber forest products and recreation values, or indirect benefits of watershed protection and carbon sequestration. Few studies have dealt with Belize, and none with the Rio Bravo area. Noting the absence of sufficient area-specific studies, the feasibility of transferring estimates from suitably similar sites is particularly relevant to an economic assessment of land use in Rio Bravo. The selection of the following environmental assets was dictated by the availability of spatial and economic data.

### 5.1. DIRECT USE ASSETS

The direct uses identified in the Rio Bravo are mostly hypothetical and would probably require capital investment for harvesting and market development in order for their potential to be realized. The direct use assets selected in the Rio Bravo were: non-timber products (*Manilkara quianensia*, *Inga* spp., *Brosimum rubescens*), for which value information was provided in a study by Peters *et al.* (1989); allspice and chicle; medicinal plant (*Agondra racemosa*, *Simaruba glanca*, *Bursera simaruba*) values from Balick and Mendelsohn (1992); genetic material and tourism.

### 5.2. INDIRECT USE ASSETS

These are environmental goods and services from which humans benefit indirectly. The following indirect use assets are attributed to the Rio Bravo area and require no capital investments to maintain their productivity: carbon storage, soil conservation and flood control.

### 5.3. OPTION AND EXISTENCE VALUES

A crude minimum bound on option use may be calculated as the sum proportion of future use plus indirect use values. Transferring non-use values is more problematic as the literature is still unable to determine the factors influencing responses to contingent valuation surveys, which remain the only method of quantifying existence value. We might reasonably assume that a representative sample of the Belizian and world populations may express a willingness to pay an arbitrarily small existence value to conserve the reserve, the exact amount possibly determined by comparison with a study of the existence value of the Amazon (Pearce, 1990). Alternatively, another indication of existence value may be determined by the amount donated to the PfB by companies and individuals for maintaining the same levels of biodiversity and ecosystem conservation in the future.

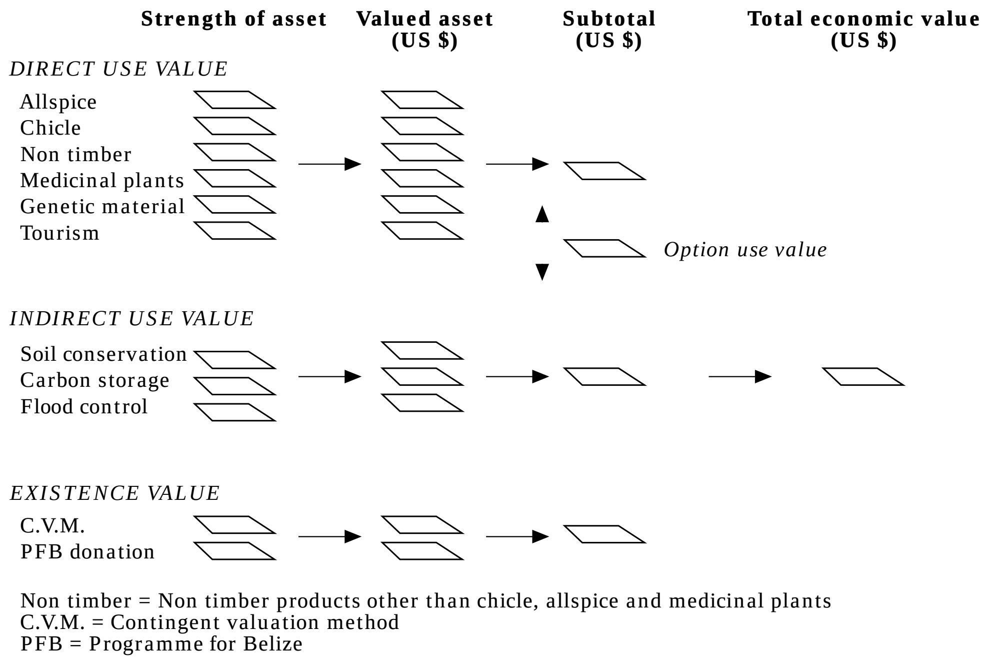



Figure 2. A spatial representation of natural capital in the Rio Bravo.

## 6. Methodology for spatial economic valuation

Previous economic valuation exercises have largely been aspatial, that is, they compute area specific values which are deemed appropriate for whole regions as per ha figures. For example, Ruitenbeek (1989) estimates the value of the "flood control" asset of the Korup forest in the Cameroon as $23/ha. These studies assume a spatial homogeneity within the study region which is clearly unrealistic because the characteristics of environmental assets vary across space. In order to remedy this situation, the study adopted a novel spatial methodology, a full account of which is presented in Eade (1994).

At any point ($x$, $y$) or cell ($x_1..x_n$, $y_1..y_n$), the characteristics (soil, vegetation, tourism values etc.) of the environment at that point determine the "strength" or "quality" of the good or service provided by the environment. The total economic value of an asset in a cell is dependent on the strength or quality of the asset in the cell. Therefore, if a particular area is divided into many cells, and the strength of each is estimated and multiplied by a corresponding economic value, then what emerges are "economic value maps" showing the spatial distribution of natural capital. This representation of environmental assets as single data layers (maps) in a GIS is shown in Figure 2.

## 7. Mapping the strength of natural capital in the Rio Bravo

The factors which were considered to affect the strength of the assets were identified (see Table 1). Ideally, the strength values of the assets would have been measured as ratio values. In practice it was necessary to use ratio, interval and nominal values

Table 1. Factors affecting the strength of the environmental assets

| Environmental asset | Factors affecting the strength of good or service |
|---|---|
| Allspice | Presence or absence of allspice producing trees |
| Chicle | Presence or absence of chicle producing trees |
| Non-timber products | Quantity of productive vegetation |
| Medicine | Quantity of productive vegetation |
| Genetic material | Biodiversity |
| Tourism | Distance to and visibility from tourists |
| Carbon storage | Biomass |
| Soil conservation | Potential soil loss |
| Flood control | Drainage characteristics of the soil |
| Existence value (CV) | Biomass and quantity of wildlife |
| Existence value (PfB) | Presence in the Rio Bravo |

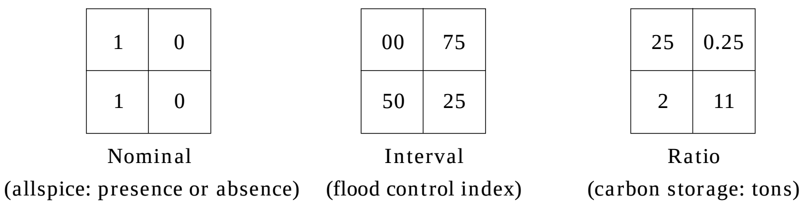



Figure 3. Mapping the strength of environmental assets.

because of data limitations (see Figure 3). Estimates of the strength of the assets were made cell by cell and judged by environmental characteristics in each cell. These characteristics were obtained by converting digital thematic maps (vegetation, soils, roads, rivers) and a digital terrain model (DTM) to raster grids composed of 50 m cells. A resolution of 50 m was chosen to allow for storage and processing time limitations and the coarseness of the original thematic maps and DTM.

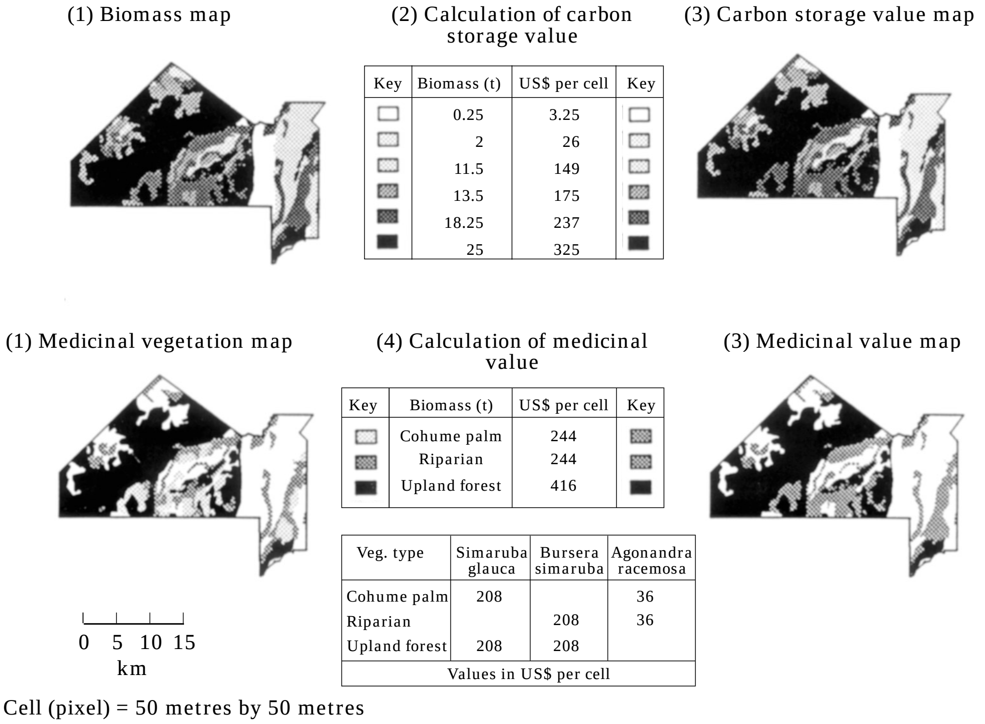
### 7.1. Mapping the strength of extractive non-timber products

For each cell, the number of plant species identified as having market value was estimated using a vegetation survey of the area (Brokaw and Mallory, 1993). Cells were assigned strength values for chicle, allspice, medicine and other non-timber assets, depending on the quantity of productive vegetation in the cell. In the case of allspice and chicle, the strength value was either “present” or “not-present” (see Figure 3). Similarly, for medicinal plants, only the presence of particular species was noted (see Figure 4).

For other non-timber assets, where better data were available, the annual production in number of fruits was estimated.

### 7.2. Mapping the strength of indirect use and genetic material assets

The strength of the soil conservation asset in each cell was measured by the amount of soil loss which could occur following the removal of vegetation. A worst case scenario




| Key | Biomass (t) | US$ per cell | Key |
|---|---|---|---|
| | 0.25 | 3.25 | |
| | 2 | 26 | |
| | 11.5 | 149 | |
| | 13.5 | 175 | |
| | 18.25 | 237 | |
| | 25 | 325 | |

| Key | Biomass (t) | US$ per cell | Key |
|---|---|---|---|
| | Cohume palm | 244 | |
| | Riparian | 244 | |
| | Upland forest | 416 | |

| Veg. type | Simaruba glauca | Bursera simaruba | Agonandra racemosa |
|---|---|---|---|
| Cohume palm | 208 | | 36 |
| Riparian | | 208 | 36 |
| Upland forest | 208 | 208 | |
| Values in US$ per cell | | | |

Figure 4. Mapping the strength and economic value of carbon storage and medicinal plants.

was assumed where all vegetation would be cleared to leave bare ground. The Universal Soil Loss Equation (USLE) was performed in each cell to give an estimate of soil loss in tons.

A worst case scenario was also envisaged with flood control, where all vegetation would be removed. Assuming constant levels of evapotranspiration and rainfall in the area, the volume of run-off (flooding) then depends on initial soil moisture. Because no data were available for initial soil moisture, a drainage index was used to estimate the effect of different soils on run-off. Using the FAO-UNESCO (1977) world soil survey, soils were classified as very poorly drained, poorly drained, well drained or very well drained, with poorer drainage resulting in greater run-off and potential flooding. These classes were then assigned arbitrary values, so that cells contained a strength value of 25, 50, 75 or 100 (see Figure 3).

The strength of the carbon storage asset was assumed to be dependent upon vegetation biomass in each cell. Estimates of vegetation biomass obtained from Brokaw and Mallory (1993) and Collinson (1988) were used to produce the biomass map shown in Figure 4 (see also Figure 3).

In the absence of any detailed data concerning the genetic characteristics of the Rio Bravo vegetation, a surrogate index of genetic "quality" was obtained from biodiversity (species/ha) data given in Brokaw and Mallory (1993) and biomass information presented in Brokaw and Mallory (1993) and Collinson (1988). Using this genetic index, cells were assigned values ranging from 10–100, with "100" representing the highest genetic value, containing greatest biodiversity and biomass.

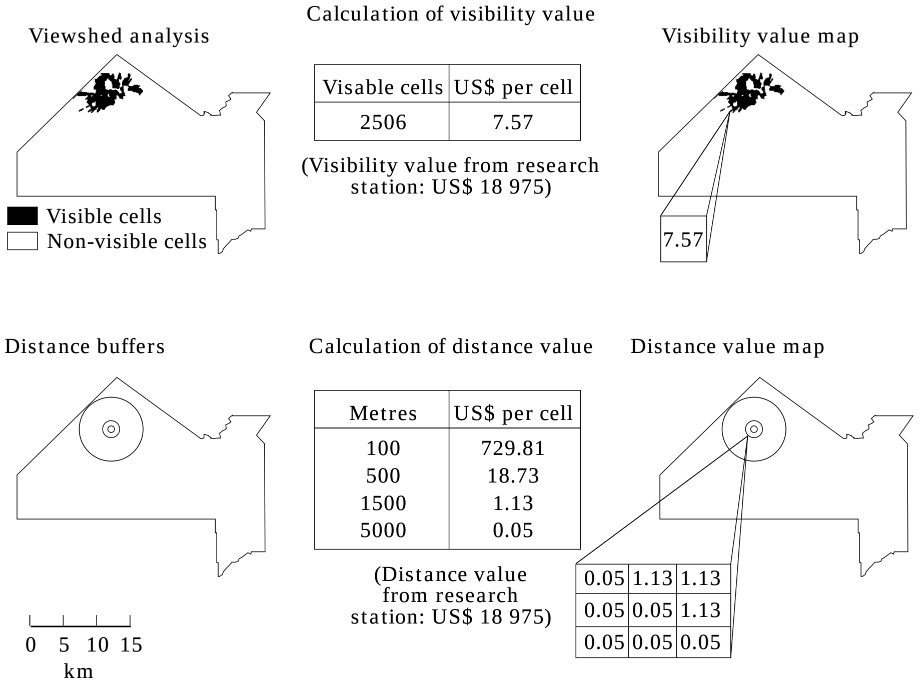



Figure 5. Mapping the strength and economic value of tourism for the research station.

### 7.3. MAPPING THE STRENGTH OF TOURISM ASSETS

We assumed that some cells in the Rio Bravo were likely to be of more value for tourism than others. The indicators of the cells' value (or strength) for tourism were distance and visibility from tourist areas, the strength of a cell's tourism value decreasing with distance from tourist areas and increasing with visibility from tourist areas.

The areas in the Rio Bravo which were considered likely to be frequented by tourists (lodgings, nature trails, information/research centre, Mayan ruins) were mapped as separate grids. These tourist area grids were then used as observer points for viewshed (or visibility) and buffering analyses, as shown in Figure 5. The viewshed analysis used the DTM to determine which cells could be seen by line of sight from the observer points. This analysis did not account for the height of vegetation. Buffer intervals of 100, 500, 1000 and 5000 m were chosen arbitrarily. For each cell, values for visibility from, and distance to, the tourist areas indicated the strength of its tourism value.

### 7.4. MAPPING THE STRENGTH OF EXISTENCE VALUE ASSETS

The strength of existence value was assumed to be dependent upon the amount of biomass and presence of ungulates (tapirs, peccaries and deer) and monkeys. Fragoso *et al.* (1990) identified the location of several spider and howler monkey groups in the Rio Bravo. The locations of these sightings were buffered to simulate their home range areas, found in Wolfhiem (1983). Cells within the home range area were assigned a value corresponding to the monkey population in the home range area.

Vegetation types were assigned "ungulate values" according to the number of signs

TABLE 2. Valuation sources for natural capital in the Rio Bravo area

| Environmental asset | Annual benefit (US$) | Source of pricing mechanism |
|---|---|---|
| Allspice | 17 500 (whole area) | PfB 1991 (scenario after 1994–95) |
| Chicle | 50 000 (whole area) | PfB 1991 (scenario after 1994–95) |
| Non-timber products: | | |
| *Manilkara quianensis* | 0·15 for 20 fruits | Peters *et al.* (1989) |
| *Brosimum rubescens* | 0·15 for 20 fruits | Peters *et al.* (1989) |
| *Inga* spp. | 1·50 for 100 fruits | Peters *et al.* (1989) |
| Medicinal plants: | | |
| *Agonandra racemosa* | 0·2 * (726/ha) | Balick and Mendelsohn (1992) |
| *Simaruba glauca* | 0·25 * (3327/ha) | Balick and Mendelsohn (1992) |
| *Bursera simaruba* | 0·25 * (3327/ha) | Balick and Mendelsohn (1992) |
| Genetic material | 7/ha | Ruitenbeek (1989) |
| Tourism | 115 000 (whole area) | |
| Carbon storage | 13/ton (of carbon) | Pearce (1990) |
| Soil conservation | 1699/ha | Chopra (1993) |
| Flood control | 23/ha | Ruitenbeek (1989) |
| Existence (CV) | 3·2 billion for the Amazon ($640/km^2$) | Pearce (1990) |
| Existence (PfB) | 50/acre | PfB (1991) (started 1988) |

of ungulates, namely sets of tracks, trails or evidence of feeding (from Fragoso *et al.*, 1990) present in each type. Cells received an ungulate value appropriate to their vegetation type.

The ungulate, monkey and biomass values used in the genetic value calculation (above) were converted to interval data before being weighted and combined to give an existence value for each cell. Biomass was considered to be the most important constituent of existence value and received a 70% weighting. Monkeys and ungulates were considered to be equal in determining existence value, and were each assigned a weighting of 15%.

In the case of existence value, as represented by Programme for Belize donations, no distinction is made by donors between areas of different environmental characteristics. The only criteria for the donation is "presence in the Rio Bravo". Therefore, each cell was assigned a value of 1 because they were all present in the Rio Bravo.

## 8. Mapping the economic value of the environmental assets

Pricing mechanisms for each environmental asset were transferred from existing published sources and work in progress (see Table 2).

The methodologies used in many of these studies are subject to on-going scrutiny and our purpose is not to add to this literature. The economic value of assets for which a market exists may be straightforward (see Godoy *et al.*, 1993; Tobias and Mendelsohn, 1991; Balick and Mendelsohn, 1992 for examples of non-timber products, tourism and medicinal plants, respectively). For other indirect and existence values, no such market behavioural trail is available, and economic values must therefore be determined by production function, replacement or damage cost approaches, or by using surrogate market methods (see Fankhauser, 1995; Dixon *et al.*, 1994 for valuation methods for climate change and other indirect and surrogate methods, respectively).

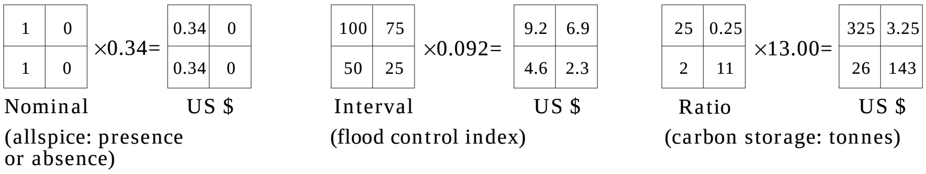



Figure 6. Mapping the economic value of environmental assets.

The way the pricing mechanisms were transferred depended on the nature of their value, which included dollars per quantity (tonnes, number of fruits), dollars per area (ha) and whole area (total income) estimates. Where values were given for quantities of assets (dollars per tonnes, number of fruits), the strength grids were simply multiplied by the pricing mechanism to convert the strength estimates in each cell to dollars, demonstrated in the carbon storage example in Figures 4 and 6.

We assumed that pricing mechanisms given as dollar per area (ha, $km^2$) values represented values for the average strength of assets in their original sites. Therefore, these values were transferred to Rio Bravo cells containing average strength values. Cells with above or below average strength values received a value corresponding to their deviation from average strength value. Before transfer, the pricing mechanisms were converted from dollars per ha (or $km^2$, acre) to dollars per 50 m.

Where benefits estimates were given for the whole area, the total value was divided across the number of productive cells. For tourism value, the total income estimate was first divided equally into visibility and distance value, then sub-divided by allocating value to the different tourist areas for visibility and distance. The visibility and distance values for each tourist area were further divided across the productive cells for that area according to their strength values (see Figure 5).

The transfer of pricing mechanisms produced economic value grids for each environmental asset containing dollar values for each cell. The values of these economic value grids were then adjusted to take account of inflation.

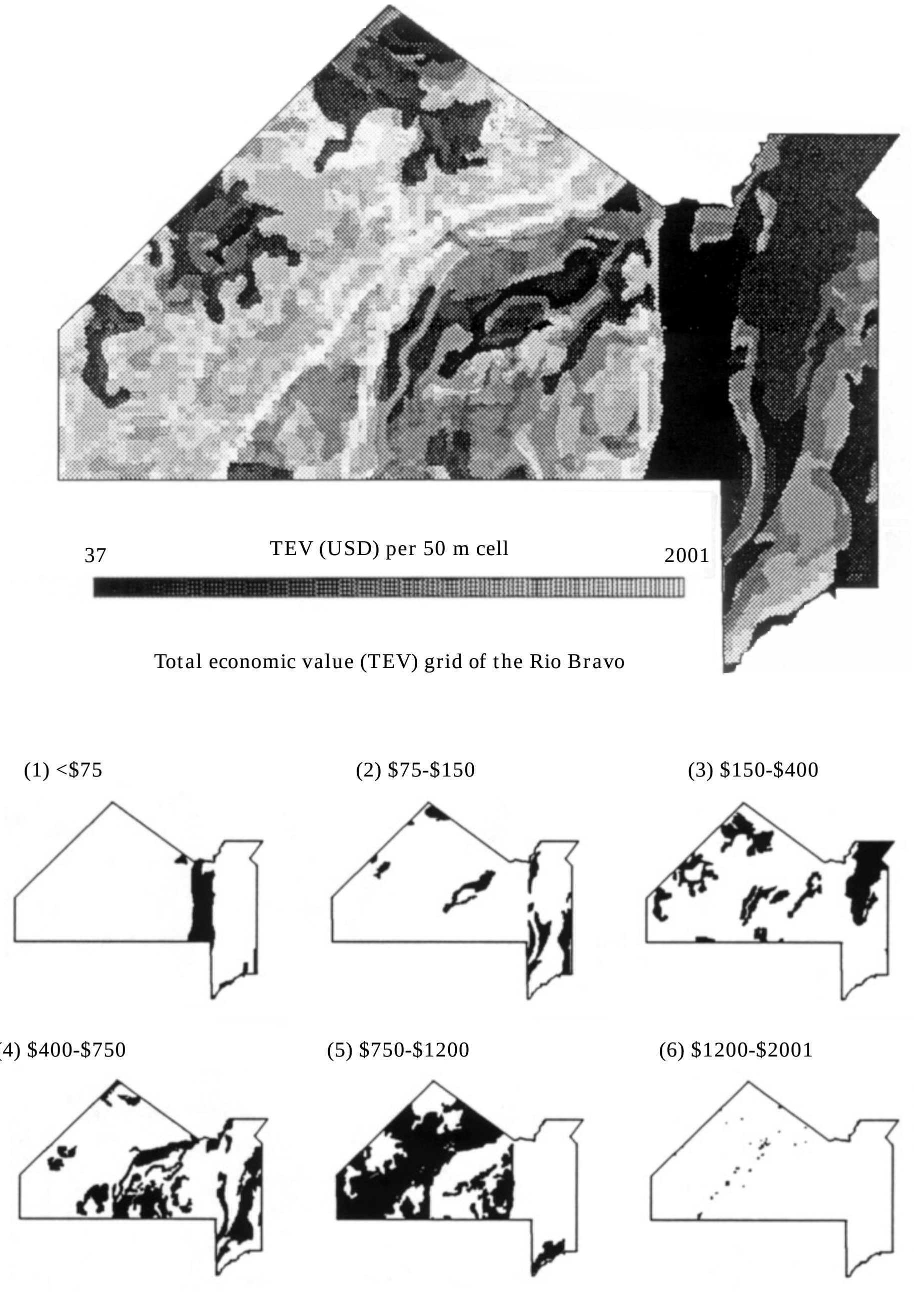
The option value of the assets was calculated by adding together all the direct use and indirect use value grids and multiplying the total by an arbitrary value of 0·16 following Chopra (1993). The inflation-adjusted economic value grids and option value grid were then overlaid arithmetically to produce a grid showing the total economic value of the natural capital of the Rio Bravo (see Figure 7).

## 9. Results

Selected components of natural capital in the Rio Bravo were mapped as data layers in a GIS, with each layer containing monetary values for every 50 m cell. When displayed visually, the cells show the economic value of the environmental assets as a continuous variable across the Rio Bravo area (see Figure 7). The value of the environmental assets ranged from $0·00 to $755·10 per cell (see Table 3). The total economic value grid contained values ranging from $43·36 to $2000·55 per cell.

### 9.1. Sensitivity analysis

A particularly valuable use of economic value maps would be to examine the spatial sensitivity of economic value. The potential of such analyses was demonstrated by




Maps (1) to (6) show values returned by spatial queries on the TEV grid

Figure 7. The total economic value of environmental assets in the Rio Bravo area.

performing simple scenario changes on the Rio Bravo economic value maps. The value of each environmental asset was increased in turn by 10, 50, 100 and 1000% to produce new economic value maps. An AML (Arc Macro Language) program was then used

TABLE 3. Results produced by the natural capital GIS (US$ per cell)

| Natural capital | Minimum | Maximum | Mean |
|---|---|---|---|
| Allspice | 0·00 | 0·34 | 0·036 |
| Chicle | 0·00 | 0·47 | 0·102 |
| Non-timber products | 0·00 | 112·36 | 26·654 |
| Medicine | 0·00 | 446·41 | 244·586 |
| Genetic material | 0·00 | 3·40 | 1·311 |
| Tourism | 0·00 | 755·10 | 0·340 |
| Carbon storage | 3·33 | 360·49 | 249·784 |
| Soil conservation | 0·53 | 444·50 | 4·751 |
| Flood control | 2·65 | 10·60 | 3·303 |
| Existence (CV) | 0·02 | 1·729 | 0·524 |
| Existence (PfB) | 36·83 | 36·83 | 36·830 |
| Total economic value | 43·36 | 2000·55 | 686·742 |

to examine the significance of these changes in economic value to the total economic value of all the environmental assets. The economic change analysis produced maps showing the effect of increasing the economic value of the environmental assets on the total economic value.

### 9.2. OTHER USES

Brazee and Southgate (1993) showed concern that traditional approaches to economic valuation were "lacking a geographic dimension" and failed to appreciate spatial variation. The use of point-specific environmental values as measures of resource depreciation in adjusted national accounts reduces the accuracy of such approaches. GIS can be used to introduce a geographic dimension to the valuation of natural capital through "spatial economic valuation" and economic value maps. However, these maps are not the definitive products of an objective process. Instead, they are in part a consequence of the discreteness of the input data sets, and of the subjective decisions made in the process of manipulating those data sets. Bearing these caveats in mind, there are a number of important potential uses for spatial economic valuation and economic value maps.

First, the ability to present and calibrate economic valuation data in map form offers an additional framework for monitoring environmental progress at various scales. In particular, a natural capital GIS could be used to examine the spatial distribution of sustainability by analysing patterns of saving and capital depreciation for selected cells and producing maps to show how sustainability is manifested in space. This examination would enable issues relevant to sustainability, such as the distribution of asset-related well-being from direct and indirect uses, to be assessed alongside issues such as household incomes and land tenure.

Second, by facilitating direct comparison of economic values, market locations and the temporal occurrence of extractive resources, asset maps could be used to predict where vulnerable areas are likely to occur as a result of disturbance, and to define areas countries might want to conserve for purely extractive purposes. Similarly, asset maps may allow governments in conjunction with outside interests, such as the Global Environmental Facility, to pinpoint areas of highest global (relative to local) value, and areas where project incentives are reduced because of the absence of lucrative alternative uses for land. In other words, different resource use scenarios could be subject to spatial and temporal cost–benefit analyses to decide the most economic use of land from several perspectives and to derive necessary transfer payments as incentives.

Third, GIS offers a systematic method for spatially referencing original estimates and cross-referencing these estimates with conditions at any target site. There is as yet little consensus on the validity of the approach, but while we feel that GIS cannot allow for the cognitive process involved in many evaluation studies, it can make the best allowance for spatial characteristics. As such, GIS represents a potential vehicle for benefits transfer and a cost saving device.

## 10. Conclusions

The spatial dimension to economic valuation has barely been investigated. GIS is probably the most effective instrument for introducing a spatial dimension to economic valuation, through the use of "spatial economic valuation" methodology and production of economic value maps. The adoption of a spatial approach to economic valuation is desirable in terms of producing more accurate economic valuation figures, for use as a repository for benefits estimates, examining spatial sustainability, and facilitating the introduction of natural capital concepts into environmental decision-making processes. The use of GIS to map and model natural capital adds a new dimension to environmental economics and is worthy of further investigation.

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## References

Balick, M. J. and Mendelsohn, R. (1992). Assessing the economic value of traditional medicines from tropical rain forests. *Conservation Biology* **6**, 128–130.

Bergland, O., Magnussen, K. and Navrud, S. (1995). *Benefit Transfer: Testing for Accuracy and Reliability.* Paper presented at the sixth annual conference of the European Association of Environmental and Resource Economists, Umea, Sweden, 17–20 June.

Boyle, K. (1994). *The Practical Implications of Accomplishing an Ideal Benefits Transfer with Limited Data Availability.* Maine: Maine Agricultural and Forestry Experiment Station Publication No. 1826.

Boyle, K. J. and Bergstrom, J. C. (1992). Benefit transfer studies: myths, pragmatism, and idealism. *Water Resources Research* **28**, 657–663.

Brazee, R. J. and Southgate, D. (1993). Development of ethnobiologically diverse tropical forests. *Land Economics* **68**, 454–461.

Brokaw, N. V. L. and Mallory, E. P. (1993). *Vegetation of the Rio Bravo Conservation and Management Area, Belize.* Massachusetts: Manomet Bird Observatory.

Chopra, K. (1993). The value of non-timber forest products: an estimation for tropical deciduous forests in India. *Economic Botany* **47**, 251–257.

Collinson, A. S. (1988). *Introduction to World Vegetation.* 2nd Edn. London: Unwin Hyman Ltd.

Dixon, J., Fallan Scura, L., Carpenter, R. and Sherman, P. (1994). *Economic Analysis of Environmental Impacts.* London: Earthscan.

Eade, J. D. O. (1994). *Natural Capital in Space: Mapping and Modelling the Environmental Assets of the Rio Bravo Conservation Area, Belize.* M.Sc. dissertation, Department of Geography, University of Edinburgh, Drummond Street, Edinburgh, Scotland, U.K.

Fankhauser, S. (1995). *Valuing Climate Change: The Economics of the Greenhouse.* London: Earthscan.

FAO-UNESCO (1977). *Soil Map of the World.* 1:5 000 000. Vols II, III, VI, VII, VIII, IX, X. Paris: UNESCO.

Fragoso, J. M. V., Rumiz, D. I., Hunter, C., Silva-Lopez, G., Grober, C. E. and Jacobson, S. K. (1990). *Wildlife Inventory of the Rio Bravo Conservation and Management Area Part 1: Ungulates and Primates.* Massachusetts: Manomet Bird Observatory.

Fragoso, J. M. V. (1991a). The effect of hunting on tapirs in Belize. In *Neotropical Wildlife Use and*

*Conservation* (J. G. Robinson and K. H. Redford, eds), pp. 154–162. Chicago: University of Chicago Press.

Fragoso, J. M. V. (1991b). The effect of selective logging on Baird's tapir. In *Latin American Mammalogy: History, Biodiversity and Conservation* (M. A. Mares and D. J. Schmidly, eds), pp. 205–304. Oklahoma: University of Oklahoma Press.

Godoy, R., Lubowski, R. and Markandya, A. (1993). A method for the economic valuation of non-timber forest products. *Economic Botany* **47**, 220–233.

Krupnick, A. J. (1993). Benefit transfers and valuation of environmental improvements. *Resources* **110**.

Loomis, J. (1992). The evolution of a more rigorous approach to benefit transfer. *Water Resources Research* **28**, 701–705.

Pearce, D. W. and Atkinson, G. (1995). Measuring sustainable development. In *The Handbook of Environmental Economics* (D. Bromley, ed.). Oxford: Basil Blackwell.

Pearce, D. W. (1990). *An Economic Approach to Saving the Tropical Forests.* LEEC Discussion Paper 90-05. London: London Environmental Economics Centre.

Peters, C. M., Gentry, A. G. and Mendelsohn, R. (1989). Value of an Amazonian rainforest. *Nature* **339**, 655–656.

Programme for Belize (PfB). (1991). *Management Plan for the Rio Bravo Conservation and Management Area.* 2nd Edn. Belize City: Programme for Belize.

Ruitenbeek, H. J. (1989). *Social Cost–Benefit Analysis of the Korup Project, Cameroon.* Paper prepared for the World-Wide Fund for Nature and the Republic of Cameroon.

Sen, A. (1992). *Inequality Re-examined.* Oxford: Clarendon Press.

Smith, V. K. (1992). On separating defensible benefit transfers from smoke and mirrors. *Water Resources Research* **28**, 685–694.

Smith, V. K. and Osborne, L. (1994). *Do Contingent Valuation Studies Pass a Scope Test?: A Preliminary Meta Analysis.* Raleigh, NC: North Carolina State University (mimeo).

Smith, V. K. and Kaoru (1990). Signals or noise: explaining the variation in recreation benefit estimates. *American Journal of Agricultural Economics* **72**, 419–433.

Tobias, D. and Mendelsohn, R. (1991). Valuing ecotourism in a tropical rainforest reserve. *Ambio* **20**, 91–93.

van Tongeren, J., Schweinfest, S., Lutz, E., Gomez Luna, M. and Martin, G. (1993). Integrated environmental and economic accounting: a case study for Mexico. In *Towards Improved Accounting for the Environment* (E. Lutz, ed.). Washington, D.C.: World Bank.

Wolfheim, J. H. (1983). *Primates of the World: Distribution, Abundance and Conservation.* Seattle: University of Washington Press.