Market and Nonmarket Values of the Georgia Landscape

MONICA G. TURNER*
EUGENE P. ODUM
Institute of Ecology
University of Georgia
Athens, Georgia 30602, USA

ROBERT COSTANZA
Coastal Ecology Institute
Center for Wetland Resources
Louisiana State University
Baton Rouge, Louisiana 70803, USA

THOMAS M. SPRINGER
College of Business Administration
University of Georgia
Athens, Georgia 30602, USA

ABSTRACT / Natural landscapes produce goods and services, such as fish, wildlife, recreation, climate control, that are not adequately incorporated in their market values. Contingent Valuation (CV) and Energy Analysis (EA) approaches were used to estimate the nonmarket value of forests in Georgia. Both methods yielded similar estimates of approximately \$200 ha^{-1}, which was 31% of the total market and nonmarket value of forests. Energy analysis was also used to estimate the nonmarket value of the major land uses in Georgia. Relative contributions of nonmarket value to total value ranged from 0.1% for urban areas to approximately 100% for wetlands. For the state as a whole, nonmarket production of natural and developed ecosystems was estimated at \$2.6 billion. This value is comparable to annual marketed agricultural (\$2.8 billion) and timber (\$4.5 billion) production, both very important industries in Georgia. Changing land use patterns in Georgia and elsewhere are likely to be accompanied by shifts in the relative importances of market and nonmarket values.

The value of natural lands and waters is not adequately reflected in their market prices. A fundamental reason for this is that the services of natural areas (and to a lesser extent agricultural [Bergstrom and others 1985] and urban areas) are imperfectly owned. The owners of the areas cannot charge others adequately for all the positive services they provide, nor prevent others from benefiting from these services. The nonmarketed values may be quite large, but they must be measured indirectly (Delorme and Wood 1974) and are difficult to determine with any exactness (Westman 1977, Healy 1985). Therefore, environmental services have historically been grossly undervalued (Alig 1983). The lack of precise empirical data for measuring all environmental and wildlife values tends to result in superficial consideration of intangible and qualitative values and greater emphasis on values measurable in monetary terms, even though these may be negligible in comparison (Van Dieren and Hummelinck 1979, Kellert 1984). Valuation of the benefits of nonmarketed resources and services in natural areas has therefore been identified as a major research need (e.g., Odum 1975 and 1977, Westman 1977, Alig 1983, Loomis and Hof 1985, Loomis and Walsh 1986).

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*Present address: Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831-6038, USA.

As the intensity of use of many habitats increases, some types of natural land may become scarce, and resources that should be renewable may sustain damage (Healy 1985). Land use patterns have been changing rapidly in the southeastern United States during the past several decades (cf. Nelson 1957, Brender 1974, Healy 1985, Turner 1987). Changing demands have led to greater competition in allocating increasingly scarce land resources (Alig 1983). However, most land use decisions do not consider impacts on nonmarketed values. Faced with the rapid development occurring in the region, we think it is important to evaluate and compare the nonmarket and market values of habitats.

As part of a landscape-level study of Georgia (southeastern USA) we identified the nonmarket value of forest and other natural lands within the state. In this article, we (1) compile and review previous contingent valuation method estimates of recreation and wilderness values of Georgia forests; (2) estimate the value of forest lands based on energy analysis; and (3) compare these two nonmarket value estimates with each other and with the market value of forest lands and other lands; and (4) estimate the total value of Georgia using energy analysis and compare this value with market values.

Valuation Methods

There are several methods of economic valuation of nonmarket benefits (see for example, Westman 1977, Bernstein 1981, Brookshire and Crocker 1981. Brookshire and others 1982. Kellert 1984, Costanza and Farber 1984, Daly 1984. Loomis and Walsh 1986). Two broad groups include the Contingent Valuation (CV) approach and the Energy Analysis (EA) approach.

The CV method seeks to measure nonmarket values by determining what people would be willing to pay for natural resources and services if a suitable market existed. The US Water Resources Council (1979) approved the CV method as a procedure for estimating the economic value of recreational and environmental resources. Using surveys and questionnaires, pseudomarkets can be constructed to estimate the value of nonmarketed services. Loomis and Walsh (1986) argue that CV is (at least in principle) an adequate means to empirically estimate a consumer's option, existence, bequest, and recreational values of a particular wildlife species or natural area (Weisbrod 1964, Krutilla 1967, Walsh and others 1984). Schulze and others (1981) report that the most readily applicable economic methodologies for evaluating recreation values all yield estimates within one order of magnitude of each other. Even small values per household result in substantial national or regional values (Stoll and Johnson 1984).

The problems with this approach are: (1) it relies on consumers' current preferences and level of knowledge of natural areas (which may be improving but is far from adequate); (2) it must add all the incremental values of the individual services provided by a natural area, and important functions may be omitted or underestimated; (3) it is often difficult to assure honest answers to questions on surveys, since people have a subconscious tendency to tell the questioners what they think they want to hear: and (4) it does not represent an actual transaction.

Energy Analysis (EA) is another approach to the valuation of natural areas that is philosophically more biological and more holistic. It concentrates on the relationships *within* natural systems that lead to the production (supply) of natural services, rather than human demand for natural system products (Costanza and Farber 1984). The method considers the total amount of energy captured by natural ecosystems as an estimate of their potential to do useful work for society. The critical link in using energy analysis for nonmarket valuation is the relationship between the energy embodied in the system and its economic value, and this relationship is still controversial (e.g., Costanza 1980 and 1984, Daly 1981, Huettner 1982, Costanza and Herendeen 1984, Cleveland and others 1984). However, even with this uncertainty, the EA estimate is a useful check on the economic value of natural systems derived from the CV method, which also contains considerable uncertainty.

Contingent Valuation and Energy Analysis methods were compared and evaluated by Costanza and Farber (1984) and have been used jointly to estimate wetland values in Louisiana (Farber and Costanza 1987). The major difference between them is that CV is based on human demand or benefit, whereas EA is based on natural system supply, or cost, including the cost to the natural system for resource production. They represent alternative approaches to incorporating existing information about the environment into nonmarket valuation.

Nonmarketed Natural System Values

Recreation and Wilderness Values

The most extensive studies of nonmarket natural system values have focused on recreation, wildlife, and wilderness-related values. Here we review studies that are applicable to the southeast and Georgia. Outdoor recreation is usually not marketed but is provided as a joint product with other land uses or as a government service (Musser and others 1982). Sorg and Loomis (1982) reviewed a variety of recreation benefits estimated by different methodologies. Their results indicate that recreation values were fairly consistent when the methodological assumptions and dates of the studies were standardized. Differences in value could largely be explained by differences in resource quality and relative location from user populations.

A set of recreation and wilderness value estimates for forests were compiled for the US Forest Service by Loomis and Sorg (1982) as part of the Resource Planning Act (RPA) process. The objective was to derive forest values for each of the nine Forest Service regions. Loomis and Sorg collected data from published and unpublished sources that used either CV or travel cost methods to estimate a variety of forest values (Table 1). Data were adjusted to account for methodological differences and were converted to standard

Table 1. Recreational activity values for national forests in the southern region, and for the Chattahoochee and Oconee National Forests, Georgia.

Activity	Recreational activity value (1982 dollars per recreational visitor day)		
	Southern region[a]	Georgia[b]	Average
Cold water fishing	13.00		
Warm water fishing	24.00		
Fishing, average all types	18.50	29.38	23.94
Big-game hunting	40.00	35.79	
Small-game hunting	28.00	51.31	
Waterfowl hunting	25.00	48.00	
Upland game hunting	40.00		
Hunting, average all types	33.25	46.03	39.64
Motorized travel	11.00		
Camping	16.00		
Picnicking	10.00		
Developed recreation, average all types	12.34	6.21	9.27
Hiking	20.00	11.90	15.95
Wilderness	25.00	28.96	26.98
Average of all types	21.82	24.50	23.16

[a]From Loomis and Sorg 1982.

[b]From USDA 1985 for the Chattahoochee and Oconee National Forests.

units of 1982 dollars per recreational visitor day (RVD). Values for national forests in the southern region, which extends from Virginia to Texas, ranged from a minimum of $10/RVD for picnicking to a maximum of $40/RVD for big-game hunting and upland hunting (Table 1).

The Forest Service then used the regional values to derive estimates for each national forest (e.g., USDA 1985 for Chattahoochee-Oconee National Forests in Georgia). To estimate the present value of each service, the demand for each service was projected 50 yr, multiplied by its value, then discounted to the present at a rate of 4%. For the Chattahoochee and Oconee National Forests in Georgia, value estimates ranged from a low of $6.21/RVD for developed recreation to a high of $51.31/RVD for small-game hunting (Table 1). These values can also be described per unit area (USDA 1985). On the basis of current management directions, present value benefits and costs are calculated for each activity, then costs are subtracted from benefits to determine net present value. By dividing net present value by the national forest area, values per hectare are obtained (Table 2). Recreation, wilderness, and water values total $2770 ha^{-1} ($1121 $acre^{-1}$) in 1982 dollars for the Chattahoochee and Oconee National Forests.

Ziemer and Musser (1978) studied the demand for wildlife recreation in Georgia using a cost approach to estimate a consumer surplus value. Regression models were used to statistically estimate demand, using survey data from wildlife recreation participants. They report that the wildlife resources of Georgia are worth about $0.9 billion to the participants in those activities surveyed (Table 3).

Energy Analysis

The energy analysis methodology can be quite complicated (see for example. Costanza 1980, Costanza and Neill 1984, Costanza and Herendeen 1984). For this study we employed a simplified technique that is readily calculable (we discuss its shortcomings later). This technique uses the Gross Primary Production (GPP) of the whole ecosystem as an index of the energy captured by the system, and converts this energy value into dollars using a single dollar–energy conversion factor (described below).

The procedure can be summarized as follows:

1. Estimate the GPP of the natural area in question.
2. Convert the GPP estimate (usually measured in units of carbon fixed per time unit or the heat equivalent energy content of the carbon) to fossil fuel equivalents (FFE) by considering the fuel efficiency of each source.
3. Convert the FFE value into dollars using an economy-wide ratio of economic value per unit of energy, usually the ratio of GNP to total energy use in the economy (measured in FFE).

All three steps involve uncertainty. Below we discuss the steps in more detail, pointing out the potential sources of error.

Gross Primary Production. GPP is a measure of the solar energy that is used by the plants in the system to fix carbon into organic molecules. which then drives the rest of the ecosystem. The plants and animals in the system also moderate water flow. erosion, sedimentation. and other variables. GPP for an ecosystem can be considered analogous to GNP for an economy: both are crude (but essential) measures of overall system performance that do not consider the internal distribution of production and must therefore be used with caution. GPP measures the value of net inputs of energy going into ecological systems. GNP measures the total value of net outputs from economic systems (including capital accumulation and depletion) which is

Table 2. Valuations of nontimber and timber uses of the Chattahoochee and Oconee National Forests, Georgia.[a]

Use	Present value benefits (range)[b]	Present value costs	Net present value	Value per ha[d]	
	(1978 million dollars · yr^{-1})			1978 dollars	1982 dollars[c]
Nontimber					
Dispersed recreation	651 (622–651)	10	641	2069.91 (838.02)	2815.58 (1139.91)
Wilderness	51 (33–59)	1	50	161.46 (65.37)	219.63 (88.92)
Water	76 (75–77)	n/a	76	245.42 (99.36)	338.82 (135.15)
Developed recreation and all others	35 (19–41)	125	−90	−290.62 (−117.66)	−596.90 (−241.66)
Total nontimber	813 (779–823)	136	677	2186.17 (885.09)	2769.88 (1121.41)
Timber	219 (118–313)	115	104	335.84 (135.97)	456.83 (184.95)
Total	1032 (915–1131)	251	781	2522.02 (1021.06)	3226.71 (1306.36)

[a]Data are from USDA (1985), Management Alternative 3, defined as the current direction.

[b]Range includes minimum and maximum value across seven management alternatives.

[c]Conversion from 1978 to 1982 dollars uses ratio of 1982 GNP price deflator (206.88) to 1978 GNP price deflator (152.09).

[d]Values in parentheses are per acre.

Table 3. Outdoor recreation values for Georgia in 1971.[a]

Activity	Value per occasion (1971 dollars)	Demand (1000/yr)	Total annual value (1971 dollars · 1000/yr)	Total annual value per ha[b]: Forest ($1982 dollars)	All lands ($1982 dollars)
Warm-water fishing	24.53	20,597	505,284	109.72 (44.42)	71.56 (28.97)
Small-game hunting	33.32	4,334	144,419	31.37 (12.70)	20.45 (8.28)
Big-game hunting	71.16	1,405	99,978	21.71 (8.79)	14.15 (5.73)
Wildlife enjoyment	6.24	2,603	162,451	35.27 (14.28)	22.99 (9.31)
Total	N/A	N/A	912,132	198.07 (80.19)	129.16 (52.29)

[a]Data from Ziemer and Musser (1978).

[b]Values in parentheses are per acre.

equivalent for any given year to the total value of net inputs (labor, capital, government services, and natural resources) to the system.

Direct GPP measurements were not available for all the ecosystems of interest. However, we had estimates of Net Primary Production (NPP), which is analogous to the gross capital formation component of GNP. Estimates of NPP (Table 4) range from 0.5 mT $ha^{-1} \cdot yr^{-1}$ for open water systems to 20 mT $ha^{-1} \cdot yr^{-1}$ for wetland systems. The ratios used to convert NPP to GPP ranged from 1.42 to 3.34 times NPP, depending on the type of ecosystem and its successional position (E. O. Box, personal communication). Early successional ecosystems (like pine forest or cropland) allocate more GPP to NPP than do climax ecosystems (Odum 1969), just as rapidly growing

Table 4. Energy analysis estimates of nonmarket values by major land use in Georgia in 1982.

Land use	NPP[a,h] (mT/ha/yr)	GPP[b,h] (mT/ha/yr)	Annual value[c,h] ($/ha/yr)	Present value[d,h] ($/ha)	1982 Area[e,h] (1000)	Total annual value[f] (million $/yr)	Total present value[g] (million $/yr)
Pine	9.39	17.40	232.00	5,795	4.637	1,075	26,865
	(3.80)	(7.04)	(94.00)	(2,346)	(11.453)		
Hardwood	5.03	12.59	168.00	4,199	5.189	872	21,792
	(2.04)	(5.10)	(68.00)	(1,700)	(12.819)		
Wetlands	20.00	66.62	889.00	22,203	260	231	5,781
	(8.09)	(26.97)	(360.00)	(8,989)	(643)		
Open water	0.50	1.65	22.00	548	195	4	107
	(0.20)	(0.67)	(9.00)	(222)	(483)		
Total natural areas					25.398	2,182	54,545
Crops	5.04	7.76	104.00	2,588	2.644	274	6,842
	(2.20)	(3.14)	(42.00)	(1,048)	(6.531)		
Pasture	3.80	7.76	104.00	2,588	889	92	2,299
	(1.57)	(3.14)	(42.00)	(1,047)	(2.196)		
Total agricultural areas					8.727	366	9,141
Urban/other	3.50	7.01	94.00	2,399	861	81	2,014
	(1.42)	(2.84)	(38.00)	(947)	(2.127)		
Grand total					35,253	2,628	65,700

[a]From Turner (1987).

[b]Estimated based on conversions from NPP (from E.O. Box, personal communication).

[c]Based on conversion factors of 4×10^6 Cal plant production/mTon, 0.05 Cal fossil fuel quality/Cal plant production, and 15,000 Cal fossil fuel quality/1982 dollar (from Costanza and Farber 1984).

[d]Based on a stream of constant production into the indefinite future and a discount rate of 4%. This makes the present value simply the annual value divided by 0.04.

[e]From Turner (1987).

[f]Annual value/ha × area, in millions of 1982 dollars/yr.

[g]Present value/ha × area, in millions of 1982 dollars.

[h]Values in parentheses are on a per acre basis.

economies put more of their GNP into new capital formation. The GPP estimates for each ecosystem type are listed in Table 4.

Conversion to Fossil Fuel Equivalents. GPP estimates are frequently stated in units of carbon or Calories of plant biomass per unit area per unit time. The first step in converting this to a measure of equivalent economic value is to convert it to energy units more directly relevant as input to the economy, i.e. fossil fuels. Fossil fuels are a much more concentrated, higher quality form of energy than plant biomass. Consider, for example, the extra energy required to upgrade biomass to fossil fuel, as in a biogas or gasahol process. Another example is to consider the relative number of Calories of biomass that would have to be burned in a power plant to produce the same amount of electricity as a given quantity of oil. Both of these methods have been used to estimate the "energy quality factor" of biomass relative to fossil fuel. An approximate average is 0.05 Cal biomass/Cal fossil fuel (Odum and Odum 1976), indicating that unprocessed biomass, such as that measured by GPP, is about 20 times less concentrated than fossil fuel. This value, however, is imprecise and would likely be improved by additional research.

Conversion to Economic Value. One can consider the overall ratio of the value of economic output to energy input in the economy as a crude way to convert plant production to an equivalent economic value. This step is certainly the most controversial, with critics arguing that energy consumption and economic value are not necessarily related (Huettner 1982). Although economic value and *direct* energy consumption are not, in fact, related, recent studies provide supportive evidence that total *direct and indirect* energy consumption (embodied energy) and dollar values are indeed highly correlated in the US economy (cf. Costanza 1980 and 1984, Costanza and Herendeen 1984, Cleveland and others 1984). We therefore use a conversion factor based on these studies to estimate the economic value of ecosystem production from GPP estimates converted to FFE. This factor is approximately 15,000 Fossil Fuel quality Calories per 1982 dollar.

The nonmarket annual production value of each of the ecosystems based on GPP estimates and the conversion factors discussed above are listed in Table 4. These values (in 1982 dollars) range from \$22 to \$360 $ha^{-1} \cdot yr^{-1}$ (\$9 to \$147 $acre^{-1} \cdot yr^{-1}$). This annual production value is then converted to a present value (assuming a 4% discount rate) and extrapolated to the entire state based on the land area of each ecosystem type.

Habitat Interdependence. The GPP technique outlined above does not account for interdependence between habitats or differences in productivity within the same habitat. For example, all pine forest is assumed to have the same GPP, regardless of the adjacent habitats or any special conditions of the site. In addition, some ecosystems may be much more important for their roles in the landscape other than GPP. For example, open water areas may be more valuable as water supply systems for animals or ecosystems than for primary production, and the value of unique natural features, like the Grand Canyon, would be underestimated by GPP. To incorporate such factors would require a detailed and much more elaborate version of energy analysis based on an ecologic–economic input–output flow accounting model (Costanza and Neill 1981 and 1984).

Comparison of the CV and EA Estimates for Georgia Forests

A summary of nonmarket value estimates for Georgia forests is presented in Table 5. The EA estimate (Table 4) and the CV estimate from Ziemer and Musser (Table 3) are very close. Both are approximately \$200 $ha^{-1} \cdot yr^{-1}$ (\$80 $acre^{-1} \cdot yr^{-1}$) or \$5000 ha^{-1} (\$2000 $acre^{-1}$) in 1982 dollars. The USDA estimate (Table 2) is about half this.

Table 5. Sumary of nonmarket value estimates for Georgia forests.

Method (source)	Annual value (\$1982/ha/yr)[a]	Total value (\$1982/ha)[a]
CV approach		
USDA	110.75	2769
(Table 2)	(44.84)	(1121)
Ziemer and Musser	198.07	4952
(Table 3)	(80.19)	(2005)
EA approach		
This study	200.07	5002
(Table 4)	(81.00)	(2025)

[a]Values in parentheses are per acre.

Total Value of Georgia

Market and nonmarket annual production estimates for the major land uses in Georgia are summarized in Table 6. Our market estimates are based on gross sales per acre. Although this is not the actual market sales price, it should be a good indicator of the gross sales prices of the land. Deriving a statewide market price by observing transaction data would be ideal but difficult, and the gross sales approach is more viable.

For agricultural and forest areas, nonmarket values are a significant portion of the total value (12% for agriculture and 31% for forests). For wetlands, the majority of the total value is nonmarket, and it is equivalent (on a per hecatare basis) to agricultural market plus nonmarket value. For urban areas the nonmarket component is insignificant (0.1% of the total). Thus, as land use changes from natural to developed, value shifts from nonmarket to market.

The total annual value of marketed and nonmarketed production in Georgia was estimated as \$74.4 billion (for 1982 in \$1982). Total marketed production for 1982 was \$71.8 billion and the nonmarket production of natural and developed ecosystems was \$2.6 billion (or 3.5%). The nonmarket value is comparable to the annual marketed agricultural (\$2.8 billion) and timber (\$4.5 billion) production, both very important industries in Georgia. Despite possible errors in the measurement techniques, the nonmarketed natural production is an important component of the state's economic well being.

Energy analysis estimates of nonmarket value are sensitive to the factor used to convert biomass calories to fossil fuel calories. If a 0.10 Cal biomass/Cal fossil fuel value were used instead of the 0.05 Cal biomass Cal fossil fuel value that we used, the nonmarket value estimates would double. The nonmarket component of the state economy would thus increase to \$5.2 billion yr^{-1}. We used conservative values in our calculations, and we believe our overall estimates are conservative.

Discussion

Energy analysis and contingent valuation are sophisticated attempts to unify ecology and economics. Neither succeeds completely (Bernstein 1981; see also Gosselink and others 1974, Shabman and Batie 1978, Odum 1978). One major impediment is that ecological and economic systems are perceived to operate on dif-

Table 6. Market and nonmarket annual production values of major land uses in Georgia.

Land use	Market production	Nonmarket value[a]	Total value	Area[b] (1000 ha)[c]	Total annual value (millions/yr)
	(1982 $/ha/yr)[c]				
Crops/pasture	783[d]	104	887	3.533	3,132
	(317)	(42)	(359)	(8.727)	
Forest	454[e]	200[b]	654	9.827	6,432
	(184)	(81)	(265)	(24.272)	
Wetlands/open water	0[f]	889	889	459	405
	(0)	(360)	(360)	(1.126)	
Urban/other	74,700[g]	94	74,794	861	64,407
	(30,243)	(38)	(30,281)	(2.127)	
Total				14.677	74,377
				(36.253)	

[a]From Table 4, except forest which is from Table 5.

[b]From Table 4.

[c]Values in parentheses are on a per acre basis.

[d]From Ag Census data on Georgia total annual market value of farm products for 1982 ($2768 million, excluding timber) divided by total crop and pasture area (8.727,000 acres).

[e]From Table 2.

[f]Assumed to be negligable.

[g]From Akioka (1984) total 1982 nonagricultural gross state product ($64,329 million) divided by total urban other are (2,127,000 acres from Table 4).

ferent time scales. The long-term detrimental effects of decisions that bring short-term economic gain are thus ignored (Bernstein 1981). As public education on the long-term of nature's services increases, our estimates of nonmarket values will probably also increase (Westman 1977).

Neither market nor nonmarket value estimates account for negative externalities of land use, such as pesticides associated with farming, or the habitat change and erosion associated with intensive forestry. These negative externalities, as well as the habitat interdependencies mentioned previously, must also be considered by decision makers. For natural ecosystems heavily impacted by human activities, replacement values can sometimes be useful (e.g., Gosselink and others 1974, Farnworth and others 1983).

Anticipated land use changes will have major impacts on the South's nonmarket values (Healy 1985). Plausible quality influences associated with land use changes include changes in game populations, harvest success, access to land for recreation, changes in the type and quality of wildlife supported on particular land uses, and aesthetic content (Musser and others 1982). Market and nonmarket values for conversion of forest land to agricultural uses in Georgia were studied by Musser and others (1982). They reported that between 1973 and 1976, such land conversions resulted in a loss of $13.70 acre^{-1} in hunting and fishing value, but a net gain of $82.58 acre^{-1} in overall value. An early study by Helliwell (1969) estimated the value of a 40-ha woodland in an agricultural region using values of four recognizable benefits of wildlife resources: production, potential production, education, and recreation. The estimated value of £5524 was compared to an estimated value of only £631 if the woodland was cleared and planted in a spruce plantation. Thus, the value of the natural woodland was close to nine times the value of the plantation. Leaving land use decisions solely to the market would probably result in foreclosing important long-term options because of short-term gains (Healy 1985). Many of the linkages which could help establish the value of alternative resource policies are not well understood, and economists have too infrequently sought the assistance of biologists and physical scientists (Batie and Shabman 1979).

Imprecision and uncertainty remain in estimates of nonmarket values of natural systems. This uncertainty could be reduced by further research, but given the nature of the problem, it will probably remain relatively large. In natural systems management, a fundamental problem is that those who damage or destroy natural systems are not charged for the true social cost of that damage or destruction. Such situations in which the narrow, short-term incentives are inconsistent with the long-term good of society are termed social traps (Costanza 1987). A trap can be transformed into a tradeoff by charging the responsible parties for the full cost of the environmental damage at the time the damage is done. Knowledge of the economic value of natural systems to society, along with costs of various activities, is necessary. An "environmental assurance bond" might be associated with the conversion of natural systems to other uses, in which the fees would be placed in a trust fund to mitigate environmental damage or to be proportionally returned in the case of minimal damage (Costanza 1987, Perrings 1987). This would effect a sharing of the societal costs among the parties that economically benefit from modifying natural systems, while also making ecologically sound development an attractive option in the short term.

Conclusion

There are many ways to discuss the value of nature (see for example, Van Dieren and Hummelink 1979, Rolston 1986). Some conservationists believe that nonattributable values (Farnworth and others 1981) are priceless and they object to any efforts to place monetary values on them. The Energy Analysis method provides a means for monetary evaluation of at least the life-support good and services of an ecosystem. We believe this is useful because it demonstrates the magnitude and importance of these nonmarket values in units (dollars) that decision makers and the public can readily understand. Markets for ecological goods and services are far from perfect, and we cannot rely on the free market to efficiently allocate these resources. The current system, which misallocates these resources, is better described as a social trap. Implementation of a technique such as the environmental assurance bond may contribute to a truly ecologically sensitive economics. Changing land use patterns in Georgia and elsewhere will be accompanied by shifts in the relative importances of market and nonmarket values. The best estimates of nonmarket values may come from the application and interpretation of both approaches discussed in this article and the development of methods to deal equitably with the remaining uncertainty.

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Literature Cited

Akioka, L. M. (ed.). 1984. Georgia statistical abstract: 1984–85. Division of Research, College of Business Administration, The University of Georgia, Athens, Georgia.

Alig, R. J. 1983. Impacts of forest land conversion: an overview. *Renewable Resources Journal* 1(4) and 2(1):8–13.

Batie, S. S., and L. Shabman. 1979. Valuing nonmarket goods—conceptual and empirical issues: discussion. *American Journal of Agricultural Economics* 51:931–932.

Bergstrom, J. C., B. L. Dillman, and J. R. Stoll. 1985. Public environmental amenity benefits of private land: the case of prime agricultural land. *Southern Journal of Agricultural Economics*, July:139–149.

Bernstein, B. B. 1981. Ecology and economics: complex systems in changing environments. *Annual Review of Ecology and Systematics* 12:309–350.

Brender, E. V. 1974. Impact of past land use on the lower Piedmont forest. *Journal of Forestry* 72:34–36.

Brookshire, D. S., and T. D. Crocker. 1981. The advantages of contingent valuation methods for benefit cost analysis. *Public Choice* 36:235–252.

Brookshire, D. S., M. A. Thayer, W. D. Schulze, and R. D'Arge. 1982. Valuing public goods: a comparison of survey and hedonic approaches. *American Economic Review* 72:165–177.

Cleveland, C. J., R. Costanza, C. A. S. Hall, and R. Kaufmann. 1984. Energy and the United States economy: a biophysical perspective. *Science* 225:890–897.

Costanza, R. 1980. Embodied energy and economic valuation. *Science* 225:890–897.

Costanza, R. 1984. Natural resource valuation and management: toward an ecological economics. Pages 7–18 *in* A. M. Jansson (ed.), Integration of economy and ecology: an outlook for the eighties. University of Stockholm Press, Stockholm, Sweden.

Costanza, R. 1987. Social traps and environmental policy. *BioScience* 37:407–412.

Costanza, R., and S. C. Farber. 1984. Theories and methods of valuation of natural systems: a comparison of willingness-to-pay and energy analysis based approaches. *Man, Environment, Space and Time* 4:1–38.

Costanza, R., and R. A. Herendeen. 1984. Embodied energy and economic value in the United States economy: 1963, 1967, and 1972. *Resources and Energy* 6:129–163.

Costanza, R., and C. Neill. 1984. Energy intensities, interdependence, and value in ecological systems: a linear programming approach. *Journal of Theoretical Biology* 106:41–57.

Costanza, R., and C. Neill. 1981. The energy embodied in products of the biosphere. Pages 745–755 *in* W. J. Mitsch, R. W. Bosserman, and J. M. Klopatek (eds.), Energy and ecological modeling. Elsevier, New York.

Daly, H. E. 1981. Postscript: unresolved problems and issues for further research. Pages 165–186 *in* H. E. Daly and A. F. Umana (eds.), Energy, economics and the environment: conflicting views of an essential interrelationship. Westview, Boulder, Colorado.

Daly, H. E. 1984. Alternative strategies for integrating economics and ecology. Pages 19–29 *in* A. M. Jansson (ed.), Integration of economy and ecology: an outlook for the eighties. University of Stockholm Press, Stockholm, Sweden.

Delorme, C. D., Jr., and N. J. Wood. 1974. Savannah River improvement and environmental preservation. *Land Economics*, August, 284–288.

Farber, S. C., and R. Costanza. 1987. The economic value of wetlands systems. *Journal of Environmental Management* 24:41–51.

Farnworth, E. G., T. H. Tidrick, C. F. Jordan, and W. M. Smathers, Jr. 1981. The value of natural ecosystems: an economic and ecological framework. *Environmental Conservation* 8:275–282.

Farnworth, E. G., T. H. Tidrick, W. M. Smathers, Jr., and C. F. Jordan. 1983. A synthesis of ecological and economic theory toward more complete valuation of tropical moist forests. *International Journal of Environmental Studies* 21:11–28.

Gosselink, J. G., E. P. Odum, and R. M. Pope. 1974. The value of the tidal marsh. Center for Wetland Resources, Louisiana State University, Baton Rouge.

Healy, R. G. 1985. Competition for land in the American south. The Conservation Foundation, Washington, DC.

Helliwell, D. R. 1969. Valuation of wildlife resources. *Regional Studies* 3:41–47.

Huettner, D. A. 1982. Economic values and embodied energy. *Science* 216:1141–1143.

Kellert, S. R. 1984. Assessing wildlife and environmental values in cost–benefit analysis. *Journal of Environmental Management* 18:355–363.

Krutilla, J. V. 1967. Conservation reconsidered. *American Economic Review* 57:777–786.

Loomis, J. B., and J. G. Hof. 1985. Comparability of market and nonmarket valuations of forest and rangeland outputs. USDA Forest Service research note RM-457.

Loomis, J., and C. Sorg. 1982. A critical summary of empirical estimates of the values of wildlife, wilderness and general recreation related to national forest regions. (Unpublished)

Loomis, J. B., and R. G. Walsh. 1986. Assessing wildlife and environmental values in cost–benefit analysis: state of the art. *Journal of Environmental Management* 22:125–131.

Musser, W. N., R. F. Ziemer, and F. C. White. 1982. Tradeoffs between nonmarket and market land use: crop production, forestry, and outdoor recreation. University of Georgia, Agricultural Experiment Station Research Bulletin No. 221.

Nelson, T. C. 1957. The original forests of the Georgia piedmont. *Ecology* 38:390–396.

Odum, E. P. 1969. The strategy of ecosystem development. *Science* 164:262–270.

Odum, E. P. 1975. Pricing the natural environment. Research Reporter, University of Georgia, Athens.

Odum, E. P. 1977. The life-support value of forests. Pages 101–105 *in* Proceedings of the Society of American Foresters 1977 national convention. Society of American Foresters, Washington, D.C.

Odum, E. P. 1978. Rebuttal of "Economic value of natural coastal wetlands: a critique." *Coastal Zone Management Journal* 5:239–241.

Odum, H. T., and E. C. Odum. 1976. Energy basis for man and nature. McGraw-Hill, New York.

Perrings, C. 1987. Economy and the environment: a theoretical essay on the interdependence of economic and environmental systems. Cambridge University Press, London.

Rolston, H., III. 1986. Philosophy gone wild: essays in environmental ethics. Prometheus Books, Buffalo, New York.

Schulze, W. D., R. C. d'Arge, and D. S. Brookshire. 1981. Valuing environmental commodities: some recent experiments. *Land Economics* 57:151–172.

Shabman, L. A., and S. S. Batie. 1978. Economic value of natural coastal wetlands: a critique. *Coastal Zone Management Journal* 4:231–247.

Sorg, C. F., and J. B. Loomis. 1982. Empirical estimates of amenity forest values: a review. USDA Forest Service, general technical report RM-107.

Stoll, J., and L. A. Johnson. 1984. Concepts of value, nonmarket valuation and the case of the whooping crane. Pages 382–393 *in* 49th North American wildlife natural resources conference. Wildlife Management Institute, Washington, D.C.

Turner, M. G. 1987. Land use changes and net primary production in the Georgia, USA, landscape: 1935–1982. *Environmental Management* 11:237–247.

U.S. Department of Agriculture Forest Service. 1985. Proposed land and resource management plan, 1985 revision. Chattahoochee-Oconee National Forests, Washington, D.C.

U.S. Water Resources Council. 1979. Procedures for evaluation of National Economic Development (NED) benefits and costs in water resources planning. *Federal Register* 44:242(Dec. 14):72,950–65.

Van Dieren, W., and M. G. W. Hummelinck. 1979. Nature's price. Marion Boyars, London.

Walsh, R. G., J. B. Loomis, and R. A. Gillman. 1984. Valuing option, existence, and bequest demands for wilderness. *Land Economics* 60:14–29.

Weisbrod, B. 1964. Collective-consumption services of individual consumption goods. *Quarterly Journal of Economics* 78:471–477.

Westman, W. E. 1977. How much are nature's services worth? *Science* 197:960–963.

Ziemer, R. F., and W. N. Musser. 1978. The demand for and the value of wildlife recreation in Georgia. University of Georgia, Agricultural Experiment Station Research Bulletin No. 221. Athens, Georgia.