Ecosystem Services Markets

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This paper is part of a series of discussion papers written to provide background information on salient issues identified as important by participants at the *Saving Washington's Working Forest Land Base* forum in November 2004.

Abstract

The term “ecosystem services” refers to indirect ecosystem functions such as water purification, flood control, carbon sequestration, climate regulation, and soil and nutrient cycling, as well as recreation or aesthetics-associated tourism. Four types of ecosystem services are of particular relevance for forested ecosystems — carbon sequestration, biodiversity protection, watershed protection or hydrological services, and aesthetics.

Many agencies and concerned citizens are beginning to recognize the role these services play and the need to compensate those who manage the lands that provide them. Reasonable efforts at economic valuation can allow ecosystem services to be considered on a par with marketed ecosystem goods.

There are three types of markets through which ecosystem services can be traded: self-organized private deals that are negotiated business-to-business or business-to-community; trading schemes, in which industries can trade credits below an established cap; and public payment mechanisms through which public agencies purchase services.

This paper reviews examples of existing markets for ecosystem services in the United States and internationally, focusing on forest-lands. It includes a discussion of opportunities for the Pacific Northwest. It also lists databases of international clearinghouses of information on ecosystem services valuation and markets. The paper includes an appendix describing the principles of conservation economics and valuation methodologies for estimating the value of environmental variables.

I. Introduction

This paper examines the recent emergence of valuing benefits or services provided by the natural environment, with particular focus on how they apply to forested areas. The paper reviews several case studies of markets for these ecosystem services and includes a list of databases and information banks. The goal of the paper is not to describe biological issues but to focus on the economic aspects of valuing ecosystem services and to describe market options. A section describing economic methodologies used to derive values for ecosystem services is included as an appendix.

II. What are Ecosystem Services?

Some studies differentiate between goods and services provided by ecosystems. Ecosystem goods might include timber products and non-timber forest products (like harvestable mushrooms, salal, or organisms that might be used for pharmaceuticals, etc.). The term "ecosystem services" refers to indirect ecosystem functions such as water purification, flood control, carbon sequestration, climate regulation, soil and nutrient cycling, groundwater recharge, sediment trapping, pollination by wild species, biodiversity, genetic libraries, pest control, recreation or aesthetics-associated tourism, and many more. For forested ecosystems, four types of environmental services are of particular relevance — carbon sequestration, biodiversity protection, watershed protection or hydrological services, and aesthetics.

III. Why Should Ecosystem Services Be Valued?

Goods extracted from ecosystems have long been traded in markets (i.e., can be bought and sold at established prices). The services provided by ecosystems have been used for just as long but have remained extra-market and largely unpriced. To some extent, the environment and natural resources have been susceptible to an open access problem, whereby resources with poorly defined property rights (including forests, water, or grasslands), if not regulated in their use, can be accessed by all and used until exhaustion. But just as in any market, an emerging scarcity can make them potentially subject to trade (Wunder, 2005). According to the Millennium Ecosystem Assessment, "if current trends continue, ecosystem services that are freely available today will cease to be available or become more costly in the near future. The higher costs that primary users may face will be passed downstream to secondary and tertiary industries and will transform the operating environment of all businesses" (MEA, 2005).

IV. Valuing Ecosystem Services

There are two parts to valuing ecosystem services. The first is fundamentally biological. A biological assessment must not only identify the services, but must also identify units of measurement as well as quantify the number and units of service. The second is economic. An economic assessment must assign a monetary value to the unit of the biological value.

Estimating the value of these services or benefits requires an inter-temporal understanding of the opportunity cost of exhausting resources.

In a study several years ago, Costanza, et al., valued total global services at US $33 trillion (Costanza, et al., 1997). Apart from demonstrating the need for maintaining services because of the synergistic value they have for numerous aspects of our economies, such a large, aggregate number tells us very little about how to develop methods enabling consumers to pay for services at a functional level.

Without attempts at valuation, ecosystem services only enter collective decision-making as public policy issues. Reasonable efforts at economic valuation can allow ecosystem services to also be considered on a par with marketed ecosystem goods. However, unsound attempts at economic valuation may over- or under-represent their significance in economically-grounded decision-making.

V. Developing Payments and Creating Markets

Payments for ecosystem services have been defined as voluntary transactions where a well-defined service is purchased by a buyer from a specific provider. This transaction is dependent on the provider securing its deliverance (this is also referred to as conditionality) (Wunder, 2005). This can be more simply stated as ensuring that the market is stable and enforceable. Ecosystem services suppliers (e.g., landowners) must be able to verify the existence of the service and must have established a baseline against which additional units "produced" can be measured. The proximity of the service in terms of land use settings, human activities, and demography (Boyd and Wainger, 2003) as well as how transferable the service is to market are crucial to the development of a services market.

In general, it may be easier to identify the ecosystem services supplier than to identify the consumer willing to pay for the service; this is not to say that identifying the consumer is difficult, but linking those who want to sell ecosystem services with those who are (or may be in the future) willing to pay will not be possible without significant groundwork. Market creation for ecosystem services requires the following steps 1) generation of demand; 2) definition of unit and supply; 3) definition and establishment of payment mechanism; 4) establishment of supporting institutions; 5) feedback and improvement (Landell-Mills and Porras, 2002). We might also add 6) stability and conditionality of program implementation (Wunder 2005). It is also critical to have well-defined property rights. If these are lacking, it will be impossible to ensure long-term provision of ecosystem services, particularly if there is transference of ownership.

Six Steps to Creating Ecosystem Services Markets

- Generation of demand
- Definition of service unit and supply
- Definition and establishment of payment mechanism
- Establishment of supporting institutions
- Incorporation of feedback and improvement
- Stabilization of program implementation and insurance of conditionality

From Landell-Mills and Porras, (2002) and Wunder (2005).

Along with a well-established property rights system,

conditionality also requires a long-term monitoring system to ensure inter-temporal delivery of services. The inter-temporal aspect is of particular importance to ecosystem services because changes in natural systems generally occur incrementally over long periods of time.

Defining the service and supply require significant study of the spatial scale (including the geographic extent of the source of the service, definition of relevant population and stakeholders) and temporal scale (NRC, 2005). The unit of measurement, such as acre of habitat or ton of carbon, must be defined. This stage must also include the establishment of the rights and responsibilities of the supplier or landowner (Johnson, White, and Perrot-Maitre, 2001). Responsibilities include ability to demonstrate the additionality factor in their service delivery; for example, if a buyer purchases carbon offsets, then the supplier must be able to clearly demonstrate that additional tons of carbon have been sequestered over the established baseline. Supporting institutions must then be able to support the transfer, deliverance and maintenance of the service, and enforce the payment mechanisms.

Three payment mechanisms have been identified by Powell and White (2001) and explored by Johnson, White, and Perrot-Maitre (2001). The first is self-organized private deals. These may include deals negotiated business-to-business or business-to-community and do not generally involve government entities. For example, the Perrier-Vittel Water Company in France has financed reforestation and is working with farmers to develop modern, less polluting facilities in order to ensure clean water sources (The Economist, 2005). Through the Chicago Climate Exchange, companies such as IBM and Dupont are able to purchase or trade carbon credits supplied through an intermediary that sources from privately-owned providers such as forest landowners like MeadWestvaco and Temple Inland (Chicago Climate Exchange, 2005).

The second mechanism is trading schemes, well-established in the United States, in which heavily regulated industries can trade credits below a predetermined cap. A strong regulatory system with enforcement capacity must exist for this system to operate. California is an example: the state has more than 4,000 acres in mitigation banking schemes to restore wetlands and other natural resource areas (Lucas, 2005).

The third is public payment mechanisms that involve public agencies purchasing services. These arrangements can be based on market or quasi-market prices, often using extra-market payment mechanisms such as bonds, tax revenues, or user fees and may be subsidized. Payments generally go directly to the landowner. Examples of this type of financial arrangement include the New York City Watershed, where New York's water utilities invested in watershed protection instead of paying for the construction of a water filtration system (Johnson, White, and Perrot-Maitre, 2001). Seattle Public Utilities has made an exchange or outright purchase of land to protect its interests in the Cedar River and Tolt River watersheds (Seattle Public Utilities, 2005).

In addition to payment mechanisms, Wunder has defined a potential additional need for payment vehicles (Wunder, 2005). Vehicles can be viewed as a way of adding value or creating a product out of the services. Wunder identifies vehicles as either area-based (including concessions, easements, or forest carbon plantations) or product-based (including certified products with premiums for particular attributes).

VI. Examples of Ecosystem Services Markets

Below is a list and short description of some examples of existing or attempted ecosystem services markets that are of particular importance to forestlands.

1. Carbon Sequestration and Offsets Trading Markets

The uncertainty over international participation in the Kyoto Protocol has made faster evolution of the carbon market in the United States difficult. The Climate Trust, based in Portland, Oregon, negotiates trades in carbon offsets. To date, the group has sold offsets for 1.6 million metric tons of carbon dioxide by investing over US $4 million in a diverse portfolio of offset projects such as carbon sequestration, lumber cogeneration, improvements in paper manufacturing efficiency and other innovative solutions targeted at reducing or sequestering carbon emissions. The Climate Trust was responsible for purchasing offsets for Seattle City Light, which has a stated commitment to becoming carbon neutral.

The European Union Emissions Trading Scheme was created in January 2005 in response to the adoption of the Kyoto Protocol. Using a cap and trade model, the EU expects to reduce overall carbon dioxide emissions by 12.5% by 2010. Since adopting the Kyoto Protocol, Europe has experienced a growth in carbon markets. In June, the Times of London reported that the city of London alone saw its daily trading in carbon emissions reach roughly US $71 million, with the price of carbon peaking at US $51 per ton (McCrone, 2005). In 2003, Australia created the New South Wales Greenhouse Gas Abatement Scheme, in which electricity utilities in New South Wales must meet mandatory targets for reducing the emission of greenhouse gases from the production of the electricity they supply or use (NSW GGAS, 2005). This scheme involves concurrent use of a reduction requirement with tradable abatement certificates.

2. Watershed Protection (Public Payment Mechanisms and Trading Schemes)

The New York City watershed example (mentioned above) has been used as a poster child for urban water utilities valuing the contribution of forestlands. The city government has committed to invest more than $1 billion for ecosystem-related projects through its Department of Environmental Protection and watershed management programs; this investment is intended to preempt a future investment of US $6 to $8 billion in water filtration facilities. Another example is the USDA's Conservation Reserve Program, which offers payments to landowners who voluntarily implement conservation practices in lieu of more intensive agricultural practices (Conservation Reserve Program, 2005); these lands often are located in or near watersheds.

In the Pacific Northwest, watershed protection is often associated with salmon habitat protection or enhancement. The Columbia Basin Water Transactions Program employs tools such as water acquisitions, habitat conservation, water banking, etc., to work with nearly a dozen state agencies such as the Washington Department of Ecology and the Idaho Department of Water Resources and non-governmental entities such as the Washington, Oregon and Montana Water Trusts to improve and enhance water quality and fish and wildlife habitat. In Washington, state agencies such as the Departments of Transportation, Fish and Wildlife, and Ecology are exploring options for mitigation banking at the watershed level. Municipal utilities such as those in Seattle and

Portland have either purchased outright or used land exchange programs to secure management over lands within their watersheds. The U.S. Environmental Protection Agency (EPA) has implemented cap and trade systems for water effluent permit trading; areas within this program include the Lower Boise River (Landell-Mills and Porras, 2002).

3. Biodiversity Protection (Self-organized Private Deals)

Conservation easements and land trusts are examples of self-organized private deals between organizations and landowners whereby a conservation or protection arrangement is directly negotiated and purchased. The proposed purchase of the Snoqualmie Tree Farm outside of Seattle by conservation groups represents an attempt at such an arrangement.

4. Certification (Vehicle: Product Based Solution)

"Green" certification of forestland, food, fish, and other resource-derived products provides consumers with a third-party guarantee of a particular management system. Because additional social and policy-based requirements drive the demand for many certification schemes, we can include it as a means of creating additional ecosystem service value. The rapid growth in natural and organic food markets in recent years points to a clear demand for organic foods. The USDA provides a national oversight, third-party guarantee. California has established its own organic program. The Forest Stewardship Council and Sustainable Forestry Initiative have successfully introduced certification of forestlands in North America and abroad. Salmon Safe has emerged as a way for businesses (with particular focus on wineries, farms, and urban parks) to certify themselves according to management principles of importance to guaranteeing healthy salmon habitat (Salmon Safe, 2005).

VII. Creating a Pacific Northwest Market

The regional examples of the Climate Trust, Columbia Basin Water Transactions Program and others described above demonstrate that there is a nascent market for ecosystem services in the Pacific Northwest (PNW). One area in which the PNW demonstrates a relative comparative advantage is in its carbon sequestration capacity. PNW forests, if managed accordingly, have the potential to sequester one and a half times the amount of carbon currently stored; this could lead to a potential increase in storage of up to 338 metric tons more per acre depending on management decisions (Smithwick, et al., 2002). According to Smithwick, et al., Pacific coastal forests sequester nearly six times as much carbon as do their counterparts on the eastside of the Cascades.

Among the Climate Trust's projects are two aimed at sequestration in the PNW, one along the Deschutes River in Oregon and one near Mt. Vernon in Washington. Both of these involve reforestation of previously logged areas. The Environmental Resources Trust, through its EcoLands program, has worked with several landowners, including the Warm Springs Tribe and the Ochoco Lumber Company, to assess their land's capacity for carbon sequestration. More projects such as these would enable landowners to assess their own capacity for sequestration options.

Forestry Practices that Increase Carbon Sequestration on Forestland

- Afforestation of agricultural land
- Reforestation of harvested or burned timberland storage
- Modification of forestry management practices to emphasize carbon storage
- Adoption of low impact harvesting methods to decrease carbon release
- Lengthening forest rotation cycles
- Preservation of forestland from conversion
- Adoption of agroforestry practices
- Establishment of short-rotation woody biomass plantations
- Urban forestry practices

From Stavins (2005).

On the Chicago Climate Exchange, the current per ton trading price is listed in the $2 range; in Europe, the per ton price is currently in the $28 range; in New South Wales, carbon is trading at around $9 per ton. For US forest managers, the cost of annual carbon sequestration ranges from $25 to $75 per ton for a program involving 300 million tons of carbon (Stavins, 2005). Clearly there are significant discrepancies between market prices and production costs.

By lowering entry costs for landowners, short-term instruments such as subsidies (credits or direct payments) targeted at landowners interested in management aimed at increasing carbon uptake could help facilitate the immediate establishment of a trading market (Stavins, 2005). The establishment of a regulatory framework surrounding carbon at a state-wide or regional basis (such as Pacific Coast States), would significantly increase demand for a carbon market at the regional level. Cities like Seattle, Portland and Klamath Falls have already voluntarily committed to mitigating their carbon emissions. More commitments from municipal or private entities along these lines would increase the market and thus create opportunities for small landowners.

A way to connect potential buyers with potential sellers is an additional factor to be considered. One option is to create a database or information clearinghouse similar to the web-based resource www.ecosystemmarketplace.com, but designed explicitly for the PNW. California's Climate Registry (see below) provides an additional example of developing a central resource for information collection on carbon emissions; a state-wide or regional registry might also facilitate the development of a baseline for the PNW or the Pacific Coast States.

VIII. Domestic and International Resources on Ecosystem Services Information Databanks and Clearinghouses

1. Domestic

The Katoomba Group's Ecosystem Marketplace at http://www.ecosystemmarketplace.com has information on markets, prices, and quantities of units exchanged. It updates a list of interested buyers and sellers.

The World Resources Institute has a list of carbon sequestration projects around the world, including four in Oregon and Washington, at http://climate.wri.org/sequestration.cfm.

California's Climate Action Registry provides a resource where large emitters can record their emissions of carbon dioxide against a 1990 baseline in preparation for future greenhouse gas regulatory developments. The database of members with their emissions levels can be found at http://www.climateregistry.org/.

Chicago Climate Exchange allows a trading mechanism for voluntary emissions reduction. It can be found at www.chicagoclimatex.com.

Environmental Valuation Resource Inventory (EVRI) is a joint effort developed by the United States EPA and Environment Canada. It relies on a benefits transfer approach to estimate economic values for changes in environmental goods and services or human health. The EVRI database is available at http://www.evri.ca.

The Millennium Ecosystem Assessment is a United Nations-driven initiative focusing on how changes in ecosystem services affect human wellbeing, how ecosystem changes may affect people in future decades, and response options that might be adopted at local, national, or global scales to improve ecosystem management and thereby contribute to human well-being and poverty alleviation. The MEA is located at: http://www.millenniumassessment.org.

2. International

The Ecosystem Services Project of Australia contains a database of ecosystem services values and ecosystem services markets in that country. It can be found at http://www.ecosystemservicesproject.org/.

The ENVALUE database was developed by the New South Wales Environmental Protection Agency of Australia to maintain environmental values for the purpose of inclusion in cost-benefit analyses, environmental impact statements, project appraisals, and overall valuation of changes in environmental quality. ENVALUE is located at http://www.epa.nsw.gov.au/envalue.

The European Climate Exchange, a subsidiary of the Chicago Climate Exchange, manages sales for companies dealing within the European Emissions Trading Scheme. It can be found at: www.europeanclimateexchange.com.

The New Zealand Non-Market Valuation database enables easy identification of non-market valuation studies undertaken in New Zealand. It is located at http://learn.lincoln.ac.nz/markval.

The Valuation Study Database for Environmental Change in Sweden (ValueBaseSwe) was developed at the Beijer International Institute of Ecological Economics through a project funded by the Swedish Environmental Protection Agency. It is located at http://www.beijer.kva.se/valuebase.htm.

The RED database was developed and funded by the European Commission under the Energy, Environment, and Sustainable Development Program of the Directorate General for Research. RED is intended as a tool to assist policy makers in capturing the effect of externalities produced from new policies which must have sustainable development as their core concern. It can be found at http://www.red-externalities.net.

IX. Conclusion

The emergence of a nascent market for ecosystems services over the past decade indicates an increased demand and willingness to pay for services traditionally left out of the market. If we are going to attempt to either substitute or improve ecosystem services for traditional products such as timber or real estate, it will be important to accurately capture the value of services provided by ecosystems; similarly, ecosystem services must provide a marginal increase in return over alternative uses of the resource.

Given our abundant forested resources in the PNW, we may have the future ability to create significant markets for all of the services listed above: carbon sequestration, biodiversity protection, watershed protection or hydrological services, and aesthetics. But the market is in its infancy and much is still needed in the way of generating demand as well as identifying and connecting buyers to sellers. It will be important to keep in mind that not all services will be available from all ecosystems and not all markets will be feasible everywhere; as a result, not all landowners will benefit from bringing these services to the market.

The Millennium Ecosystem Assessment, one of the most comprehensive collaborative efforts to assess the status of global ecosystem services, acknowledges that information is still inadequate to present a complete and consistent time-series perspective on ecosystem services. If monitoring is not in place, it will be difficult or impossible to ensure deliverance of services (MEA, 2005). In addition to the development of biological data, increased information on the potential size and character of a global ecosystem services market is needed. Ecosystemmarketplace.com estimates the currently *traded* global value of biodiversity, carbon and water markets at US $842 million; this is a good start at providing market data, but more sources are needed to provide up-to-date market information at both the global and regional levels.

This paper has provided a general overview of mechanisms to bring ecosystem services to the market, a description of several projects aimed at creating ecosystem services markets, information sources for data, relevant policies, and market developments. The goal is to inspire discussion about applying these ideas to Washington's working forests during the upcoming forum.

Literature Cited

Boardman, A., 2001, Cost-Benefit Analysis, Prentice Hall, New Jersey.

Boumans, R. et al., 1997, Modeling the Dynamics of the Integrated Earth System and the Value of Global Ecosystem Services Using the Gumbo Model, *Environmental Economics*, 41 (2002) 529–560.

Boyd, J., L. Wainger, April 2003, Measuring Ecosystem Service Benefits: The Use of Landscape Analysis to Evaluate Environmental Trades and Compensation, Discussion Paper 02-63, Resources for the Future, Washington DC.

Brown, Jr., G., R. Mendelsohn, 1984, The Hedonic Travel Cost Method, *The Review of Economics and Statistics*, 66(3): 427-433.

Chicago Climate Exchange, 2005, www.chicagoclimateex.com.

Diamond, P.A. and J. Hausman, 1994, Contingent Valuation: Is Some Number Better Than No Number? *Journal of Economic Perspectives*, 8(4): 45-64.

EPA (US Environmental Protection Agency, 2000, Guidelines for Preparing Economic Analyses, EPA 204-R-00-003, US Environmental Protection Agency, Washington DC.

Freeman, A. M., 2003, The Measurement of Environmental and Resource Values, Resources for the Future, Washington D.C.

Hotelling, H., 1938, The General Welfare in Relation to Problems of Taxation and of Railway and Utility Rates, in Darnell, A. C. (ed.), The Collected Economics Articles of Harold Hotelling, Springer-Verlag, New York.

Johnson, White and Perrot-Maitre, 2001, Developing Markets for the Water Services from Forests: Issues and Lessons for Innovators. Washington DC: Forest Trends.

Landell-Mills, N. and I. Porras, 2002, Silver Bullet or Fools' Gold? International Institute for Environment and Development, London.

Mitchell, R. and R. Carson, 1989, Using Surveys to Value Public Goods: The Contingent Valuation Method, Resources for the Future, Washington D.C.

Nunes, P. and E. Schokkaert, 2003, Identifying the Warm Glow Effect in Contingent Valuation, *Journal of Environmental Economics and Management*, 45(2): 231-245.

McCrone, A., August 7, 2005, Special Report: London leads in carbon market, *The Sunday Times*, London.

MEA (Millennium Ecosystem Assessment), 2005, Ecosystems and Human Wellbeing: Opportunities and Challenges for Business and Industry, World Resources Institute, Washington DC.

Lucas, G., March 29, 2005, "Conservation they can bank on Dove Ridge tries to protect species — and turn a profit." *San Francisco Chronicle, San Francisco*.

NRC (National Research Council), 2005, Valuing Ecosystem Services: Toward Better Environmental Decision-making. Washington DC: National Academies Press.

Powell, I., A. White, 2001, A Conceptual Framework for Developing Markets and Market-Based Instruments for Environmental Services of Forests. Paper prepared for Developing Markets for Environmental Services of Forests, October 4, Vancouver, British Columbia.

Salmon Safe, 2005, www.salmonsafe.net.

Smithwick, E., M. Harmon, S. Remillard, S. Acker, and J. Franklin, 2002, Potential Upper Bounds of Carbon Stores in Forests of the Pacific Northwest, *Ecological Applications*, 12(5): 1303–1317.

Stavins, R., K. Richards, 2005, The Cost of US Forest-Based Carbon Sequestration, Pew Center on Global Climate Change, Arlington, VA.

Thaler, R. and S. Rosen, 1976, The Value of Life Savings, in Terleckyj, N. (ed), Household Production and Consumption, Columbia University Press, New York.

The Economist, April 23, 2005, Are You Being Served? *The Economist*, London.

Wunder, S., 2005, Payments for Environmental Services: Some Nuts and Bolts, CIFOR Occasional Paper No. 42, Center for International Forestry Research, Jakarta.

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Appendix: Methods of Non-Market Valuation

Economics deals with the supply and demand of goods and services. Goods and services are produced and delivered; they are relatively easily measurable and quantifiable. Inputs measured in production functions are those that can be bought and sold. Economists generally study individuals' valuation of goods and services by observing their actual behavior and the prices they are willing to pay for certain items. This enables an estimate of directly revealed preferences, often by using existing price or market data or consumer reports (Boardman, 2001). However, this is not always possible. In traditional economics, environmental attributes (both the benefits provided by and the degradation of) have been considered as externalities outside the scope of evaluation. Over the past few decades, environmental valuation has become a well-established sub-sector of economics (Freeman, 2003) and a number of different ways to quantitatively estimate consumer preferences for environmental benefits have been developed.

Critical to the endeavor of valuing environmental benefits and damages is the concept of Total Economic Value (TEV). TEV implies that inclusion of both existence and use values must be incorporated into the true economic value of a good or service (NRC, 2005). In valuing environmental benefits and damages, standard methods include revealed and stated preference.

Revealed preference methods obtain values by using directly observed competitive market prices and indirectly-obtained market prices by using simulated market prices, household production functions, and general production functions. Production function methods involve using environmental attributes as factor inputs into the production function (Freeman, 1991). This might include the value of fish habitat as it affects catch and the fisheries industries. Household production functions use methods like the travel cost method or the hedonic method, which infer the value of environmental variables by measuring the value of transactions of other goods (Boardman, 2001).

The travel cost method relies on questions surrounding the cost of the consumer's travel to the destination of interest (Hotelling, 1938). This methodology can be used to estimate the value of a park or recreational area, for example. The hedonic method uses the market value of goods and services to derive the value of an environmental good (Brown, 1984). For example, the capitalized value of a house or the price of labor might be used. Property values can be used to estimate the value of air quality in a certain location. The price of labor, using either wage differential or valuation of risk to life, can be used to estimate the value of a project such as an environmental cleanup (Thaler and Rosen, 1976).

	Revealed Preferences	**Stated Preferences**
Direct	Competitive Market Prices	Contingent Valuation, Open-ended response format
Indirect	Simulated Market Prices	Contingent Valuation, discrete-choice and interval response formats
	Household Production Functions models: time allocation, random utility and travel cost, averting behavior, hedonics	Contingent behavior
	Production Function models	Conjoint Analysis
	Referendum Votes	

Adapted from NRC, 2005

Stated preference is a more recently developed estimation methodology that relies on surveys to elicit a willingness to pay (WTP) for an improvement in a particular attribute or a willingness to accept (WTA) a worsening of a particular amenity (Mitchell and Carson, 1989). Stated preference methodologies, if carefully executed, have been endorsed by economists like Kenneth Arrow and Robert Solow (Arrow et al, 1993). They have also been widely criticized as too hypothetical, relying on consumers to state how much they would be "willing" to pay for or to accept something (Diamond and Hausman, 1994). Where the price amount should be based on the marginal rate of substitution, it may in fact be based on a non-economic explanation. In some instances, respondents may have an ideological bias that affects their responses or be experiencing the "warm glow" effect, in which their responses are affected by their feelings that they should be supporting a good cause (Nunes and Schokkaert, 2003).

In all cases, there may be a difficulty in asking individuals to evaluate their real WTP. Another problem is the embedding effect, which refers to the lack of marginal change in an individual's WTP for an environmental good or WTA a worsening of that good (Diamond and Hausman, 1994). For example, an individual may state that he or she is willing to pay the same amount per tree to save 100 trees as to save 200 trees. There may also be a discrepancy between the amounts a respondent is WTA compared to his or her WTP (Hanemann).

Other methods include benefit transfers, which involve using an existing value estimate of one attribute and applying it to an entirely different attribute. Benefit transfers have been criticized as being a "second best" evaluative method generally used to estimate existence and recreation values (NRC, 2005). Replacement cost methods are also a second best approach when no other valuation method is applicable. Replacement cost methods involve estimating the cost of replacement as a proxy (NRC, 2005).