Full Cost Accounting for Agriculture

A paper written for

Agriculture and Agri Food Canada

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Contents

1. Introduction and Overview

This paper surveys the key issues involved in full cost accounting for agriculture in Canada. We start the paper with a definition of what full cost accounting is, and why one would want to do it (Section 2). In brief, full cost accounting refers to the overall exercise of valuing the environmental and social costs and benefits of activities that are external to the market. The need for better information for decision making is the key reason to pursue full cost accounting, because agriculture can cause both environmental costs and benefits, and these should be analysed. Both policy makers and farmers themselves can benefit from having the information available.

There are many conceptual issues associated with full cost accounting of agriculture and the key ones are introduced in Section 3. For example, agriculture is an activity that takes place in many ecosystems and with many processes and outputs, necessitating a broad framework of analysis. We therefore discuss frameworks for valuing ecosystem functions and services. Full cost accounting is not just about valuing negative impacts. It also includes benefits from activities that are not captured in the market. On this topic we consider a specific study that focuses on some of the positive externalities that agriculture can bring. This leads to a discussion of the various methods used to value actions that do not pass directly through markets (Section 4). All of the valuation methods discussed have their advantages and disadvantages, which are described in detail. The choice of one method over another will be based on the data and activity being analysed, as well as the strengths and weaknesses of the various methods.

There is then a brief discussion of some of the methodological issues that full cost accounting must address (Section 5). For example, defining the specific impact pathways for both damages and benefits is necessary for full cost accounting and examples of this are briefly discussed. Other methodological issues that are covered include system boundaries, quantification of impacts, and aggregation.

The last section details the approaches and results of valuation studies relevant to agriculture. These studies include an agricultural valuation study in the U.K. and other valuation studies related to the valuation of wetlands and water resources – two of the key ecosystem components for the full cost accounting of agriculture activities.

Finally, we address next steps and outline a plan for the work to be done in 2004-2005.

This paper has been developed under the AAFC agreement with IISD, which was signed in late 2003. The umbrella agreement contemplates several multi-year projects, one of which is the full cost accounting exercise discussed here.

2. Why Do Full Cost Accounting?

In this section we will discuss some definitional issues, and then move on to look at several reasons to conduct full cost accounting exercises.

2.1. Valuation Frameworks

There are a variety of terms and concepts that are commonly used in discussions of the non-market value of an activity. The most common examples relate to negative environmental externalities – if a factory or a farm pollutes a river, but do not pay any cost as a result, there is an externality. The polluter can sell its product at a price that does not include the cost of the pollution. That cost is borne by those downstream of the polluter, who either puts up with dirty water, or pays to clean it up. The costs of this sort of externality can be calculated, if some data and conceptual difficulties can be dealt with.[1]

But there is a broader conceptual framework, into which environmental externalities can be placed. The broad framework or all-encompassing concept can be called "total value", or Total Economic Value" (TEV)[2,3]. Pearce breaks TEV down into use and non-use values, in the following categories:

Use Values:

> Direct use value: The value of the use of the resource, for whatever purpose. Agricultural land can produce crops, but it can also provide biomass for energy generation, perhaps forage for animals, and so on. Some of these values will not be easy to quantify.
>
> Indirect use value: These correspond to "ecological functions", such as protecting watersheds from siltation, or maintaining bio diversity. Carbon sequestration would be an indirect use value, until there is a market for it in a trading system – at which point sequestration will become a direct value.
>
> Option values: These are also direct values, even though they do not require that there be any specific use of the item at this time. Option values are those that individuals are willing to pay for maintaining the availability of something for their future use, even though the individual has not and may never see it. Old growth forests in British Columbia might be an example.

Non-use Values:

> Existence value: This is an indirect value, in contrast to the categories listed above. It is the result of people's willingness to pay for something with no expectation that they themselves will benefit from it. People contribute to organizations to save the Amazonian rain forest or gorillas in Africa, because they feel that these natural wonders should not be destroyed.

The sum of these categories gives TEV. But these are the "economic" values, which is necessarily an anthropocentric calculation. There is a category of non-economic values as well, often called intrinsic values. These values do not depend on human willingness to pay for them, but are intrinsic to the animal, ecosystem, or other part of nature.

A slightly more detailed breakdown of total economic value is given by Bateman *et al*[4]. They add the concept of bequest value, which incorporates the value of an environmental good to include the value to those alive now of leaving the good for future generations. This then shows up as both a use value, and as a non use value, on the basis that the future generations will get both from the asset. The diagram below shows the various components of environmental value.

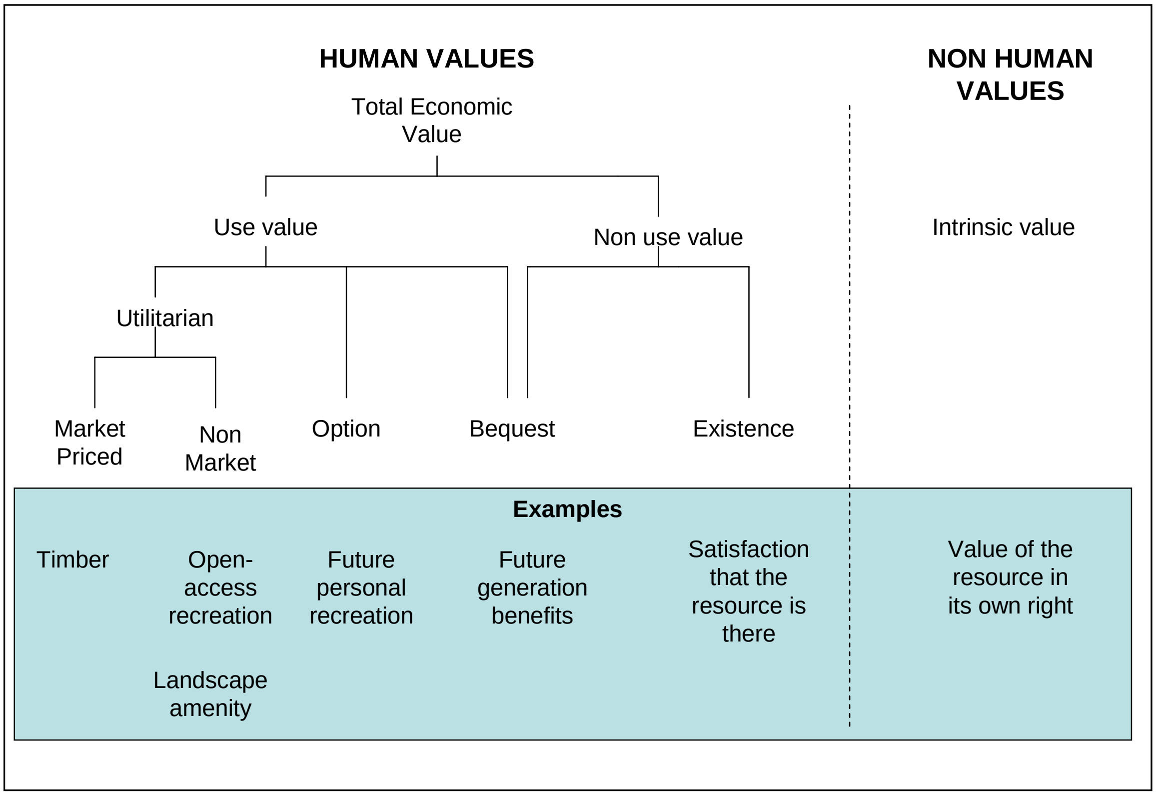


Figure 1. Environmental Value[5]

There is another feature of the natural world that TEV and the above diagram do not capture, according to Pearce[6]. That is the fact that the above listing of economic values does not include the value of the system as a whole. He calls them "system characteristics". The topic is discussed at length by Bocksteel *et al*[7], who point out that the calculation of economic values as outlined by Pearce is done by measuring a change in value from one specified state to another, and that both states have to be feasible and comprehensible to individuals for the valuation calculation to have meaning. (The valuation exercise can be done in a variety of ways, as discussed later in this paper, but most depend on obtaining data from individuals.) The methodology does not produce meaningful results if this condition is breached. Bockstael *et al* say "The economic value of a policy change is defined by the amount (either positive or negative) of compensation that an individual would need in order to be as well off (by his own reckoning of well-being) as he would have been without the policy-induced change. Thus, an economic value estimate is an answer to a carefully defined questioning which two alternatives are being compared." (p. 1385). So consideration of the value of a major part of an ecosystem (or a system characteristic) cannot be conducted for two reasons: we do not understand enough about ecology to fully define what the world would look like if some of the system characteristics were changed; and even if we could describe that world, it might well be so different from the one we inhabit that individuals could not ascribe a value to the difference. In the case where the change would eliminate an essential good (in economic terms, one with infinite value to the individual), then again the valuation exercise is not possible.

In the light of all of this, the term *total economic value* is unfortunate. It implies that the four categories of values listed from Pearce above give an absolute value. However, in actuality they give the value of a marginal change that has been carefully specified, with all other changes held constant. The same problem applies to the terminology *full cost accounting* (FCA) used to describe the broader valuation exercise which also implies the existence of a total cost that is measurable.

To what degree can the results from several valuation studies on specific issues be aggregated together to give an estimate of economic value of a larger, more general environmental change? This question is addressed by Hoehn and Randall[8] who look at the case of a broad public policy agenda that is composed of a large number of specific proposals. The problem that they encounter is that the valuation of each proposal is done independently, and that this leads to a systematic upward bias in the valuations because interactions among the various studies are not taken into account.

Following the above line of argumentation, we can see some of the components of a definition of environmental externalities for agriculture:

> We will be looking at marginal costs and values, based on specific changes in one place, rather than at comprehensive evaluations.
>
> Aggregation of the values from different locations may be difficult.

Nevertheless, techniques exist for calculating the TEV of an activity, as defined in the diagram above. There are many data and aggregation issues, as we will discuss later, but conceptually we are able to build on the work of many earlier studies. However, since methodological choices will need to be made along the way, it is helpful to discuss the reasons for calculating TEV. This will help provide a basis for making some of those choices. The rest of this section of the paper explores briefly some of the reasons for calculating TEV.

2.2. **Highlight issues**

Many environmental problems have complex causes, and thus we are sometimes surprised when they arise. One advantage of a framework like TEV or FCA is that it forces us to look at issues comprehensively. In designing the FCA framework, we try to address all of the issues – and this will highlight issues that a less formal approach might miss.[9]

2.3. **Inform policy makers re priorities**

The results of the FCA exercise will give estimates of the costs of various problems. This can act as a very useful guide in policy making, in that it will provide a fairly objective basis for setting priorities. It is often the case that a problem may have a high media or political profile, and thus get the most policy attention. The FCA results will provide some more information to the policy priority setting process.

2.4. **Improve public discussion**

The existence of specific data on the costs and benefits of various courses of action will help improve public discussion about the options. Sometimes the public debate is based on a series of hypothetical statements about costs and benefits, over which the proponents of various viewpoints can argue but not agree. If there are useful numbers to attach to the discussion, then it can focus more on issues and less on which hypothetical statement is most accurate. Of course, this depends on having a set of reasonably agreed numbers.

2.5. **Inform policy design**

The analysis will give information on both the sources of problems and on those who bear the burden of the costs. This can be very helpful in designing policies that might alleviate the problem, for two reasons:

- The policy responses can be aimed at the most relevant parties
- The information on the amounts of costs or benefits being created can guide the type and rigour of the policy design.

3. Conceptual Issues

3.1. Positive and negative externalities

Both types of externalities – negative and positive – should be considered in full cost accounting for agriculture. These are discussed briefly below in relation to environmental and human health impacts, which are two of the most commonly studied areas, and also in relation to other less studied ecosystem services.

The first and most commonly studied externality is the negative environmental impact. Pollution of soil or water, or damage to other parts of the ecosystem, has been observed in many places. Section 6 of this paper lists some of the studies done on this topic. However, there are also positive environmental externalities arising from agriculture. In particular, certain agricultural practices can improve bio diversity and reduce problems such as soil erosion, green house gas emissions, or water pollution.[10] Furthermore, "The value of agriculture is not just the crops and livestock products it yields. It has other functions, such as maintaining the countryside and rural communities."[11] This quote, from a web site designed to provide information for farmers in the Asia Pacific region, reflects a strong view among some that agriculture produces public goods which benefit society but for which farmers are not remunerated. When agricultural incomes are under pressure, there is an incentive to try to capture some income from the provision of such public goods.

Agriculture may also be positive or negative with respect to human health. Negative externalities may arise because of water pollution or soil contamination, while positive externalities also exist. For example, in a study in Chile, the authors found that "Better labor conditions, cleaner agriculture production and healthier diet were mentioned by 30% of respondents" in a survey regarding likely health externalities.[12]

In general terms, however, any improvement in a negative externality can be considered a positive externality. This results from the fact that the valuation methodology focuses on marginal changes, not absolute amounts. So if the drainage of pesticides into waterways has a negative environmental and health externality, reducing such drainage will create a positive externality.

In addition to food and fibre, agriculture may produce a variety of other useful outputs, such as biodiversity, attractive landscapes, rural economic activity, and also domestic food security. All of these may have positive values, and many have the characteristics of public goods (i.e. their use by one person does not preclude their use by others) and it has been argued by several countries (principally in the EU), that farmers should be paid to provide these goods.[13] This has become a major point of discussion in the WTO negotiations. The Anderson article mentioned above points out that it would be far more efficient, in economic terms, to subsidise specific activities (such as the preservation of hedge rows) than to subsidise all agricultural products. Unfortunately, most of the WTO discussion is not relevant to full cost accounting because the analysis does not focus on producing specific estimates of the values.

There has been some work in Japan on this topic. Table 1 below summarises the results of an interesting paper by Professor Kentaro Yoshido[14], who is on the faculty of the Institute of Policy and Planning Sciences, University of Tsukuba. The paper uses the replacement cost method, calculating what would need to be spent to duplicate the various positive environmental externalities that agriculture brings. For example, flood prevention is enhanced by the existence of terraced paddy fields that act to slow the rate of run off from precipitation. The alternative cost is calculated on the basis of building and maintaining a dam or dams that would have the equivalent effect. This cost is calculated to be 2878.9 billion yen per year for all of Japan, and 1149.6 billion yen per year for just the hilly and mountainous areas. At a current (2004) exchange rate of about 80 yen to the Canadian dollar, these costs amount to $35.1 billion and $14.4 billion respectively, per year.

Table 1. Multifunctional Roles of Agriculture and Rural Areas of Japan

	Valuation (billion yen/year)		Abstract of evaluation
	Nationwide	Hilly and mountainous areas	
Flood prevention	2,878.9	1,149.6	Water retention capacity of paddy fields and upland fields (paddy field: 5.2 billion m^3, upland fields: 0.8 billion m^3) are evaluated based on depreciation costs and annual maintenance costs of a water controlling dam.
Fostering water resources	1,288.7	602.3	Water capability (638 m^3/s) contributing to the stabilization of water flow and the reuse of irrigation water of paddy fields by flowing steadily back to rivers is evaluated based on depreciation costs and annual maintenance costs of an irrigating dam. Also, the volume of ground water supply from paddy fields and upland fields (3.7 billion m^3) is evaluated by the difference in prices between ground water and tap water.
Soil erosion prevention.	285.1	174.5	The estimated volume of eroded soil (53 million tons) prevented by cultivation of farmland is evaluated based on the construction costs of a sand arrestation dam
Landslide prevention	142.8	83.9	The estimated number of landslides (1,700 cases) prevented by cultivation of paddy fields is evaluated based on average losses incurred.
Organic waste disposal	6.4	2.6	The reduced amount of organic wastes to farmland (municipal waste: 60,000 tons, human waste: 860,000 kl, sewage sludge: 230,000 tons) is evaluated based on the final disposal costs.
Air purification	9.9	4.2	The estimated volume of exhausts (SO_2: 49,000 tons, NO_2: 69,000 tons) absorbed by paddy fields and fields is evaluated based on depreciation costs and annual maintenance costs of de-SOx equipment and de-NOx equipment.
Climate mitigation	10.5	2.0	Capability of paddy fields to drop the temperature in summertime (1.3 C on average) is evaluated based on costs required for air conditioning.
Recreation and relaxation	2,256.5	1,012.8	Functions of recreation and relaxation, which agriculture and rural areas have, are evaluated by traveling costs for tourists and homecoming people to rural areas.
Total	6,878.8	3,031.9	

Source: Kenato Yoshida, *An Economic Evaluation of Multifunctional Roles of Agriculture and Rural Areas in Japan*, Food & Fertilizer Technology Center, Technical Bulletin 154, August 2001:1-9

3.2. **Ecosystem frameworks**

The components of TEV from Figure 1 provide a framework for the economic aspect of full cost accounting of environmental externalities through the different types of use and non-use values. But additional resolution is required pertaining to precisely what kinds of environmental "use" could be valued. Review of the valuation literature shows that the notion of ecosystem functions or services is typically used to provide an organizing framework for what can potentially be valued. We introduce two similar ecosystem frameworks used in the economic valuation of ecosystems: ecosystem functions as introduced by de Groot *et al*.; and ecosystem services as used in the Millennium Assessment. The vocabulary used in these frameworks is not consistent, so we take special note of this were needed.

An ecosystem framework will help create a bridge between changes in agri-environmental indicators and valuation. For example, economic value is not attached to the risk of water contamination by phosphorous (one of the agri-environmental indicators), but rather, value is estimated for the ecosystem function or service that is changed by phosphorous contamination. Therefore, it will be important to select early on in the AAFC Full Cost Accounting project, a particular ecosystem framework and then use the terminology in a consistent manner throughout the life of the project.

Ecosystem framework of the National Center for Ecological Analysis and Synthesis

A conceptual framework for valuing the world's ecosystem services and natural capital was developed by a working group supported by the National Center for Ecological Analysis and Synthesis at the University of California, Santa Barbara. This ecosystem framework put forth by de Groot *et al*.[15] was born out of the recognition that an increasing amount of information was being compiled on economic valuation of ecosystems and that in order to facilitate comparative ecological economic analysis, a comprehensive standardized framework for describing, classifying and valuing ecosystem functions, goods, and services in a clear and consistent manner was needed.

The framework put forth by de Groot *et al*. is presented in Figure 2. This framework recognizes that ecosystem structure and processes can be translated into four ecosystem functions:

- *Regulation* – the capacity of natural and semi-natural ecosystems to regulate essential ecological processes and life support systems through bio-geochemical cycles and other biospheric processes. Additionally, regulation provides direct and indirect services to people such as air, water, and soil;
- *Habitat* – refuge and reproduction habitat to wild plants and animals contributing to biological and genetic diversity;
- *Production* – conversion of water, carbon dioxide and nutrients by ecosystems into carbohydrate structures and a variety of living biomass, many of which provide people with food, raw materials, energy and genetic material

- *Information Functions* – a reference function for people by contributing to the maintenance of human health, opportunities for reflection, spiritual enrichment, cognitive development, recreation, and aesthetic experience.

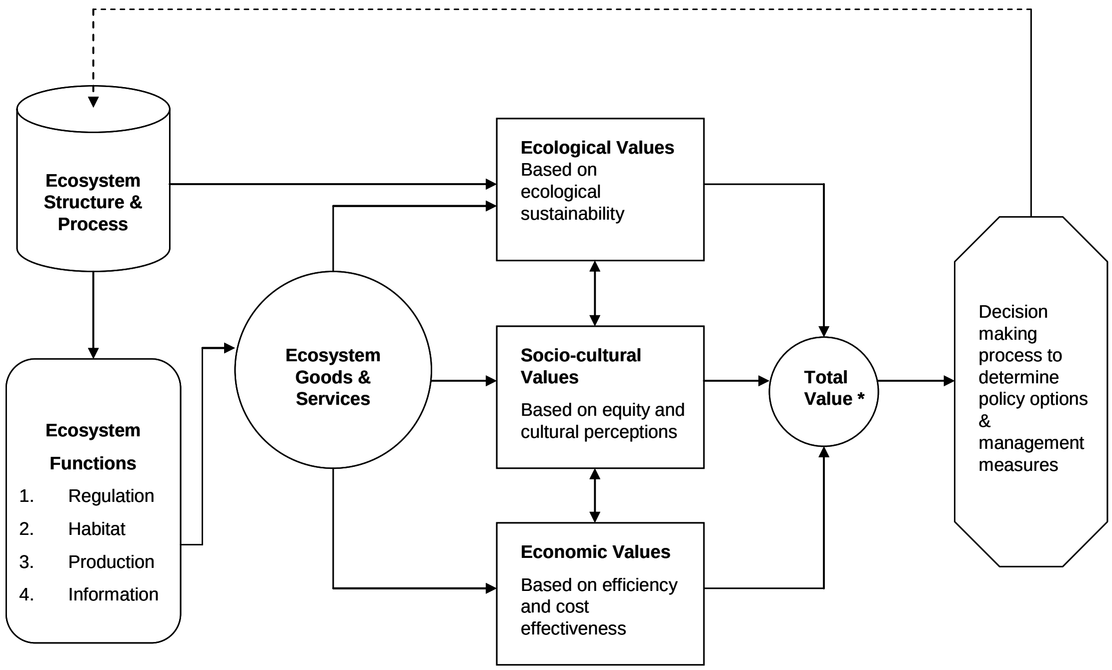


Figure 2. Framework for integrated assessment and valuation of ecosystem functions, goods and services.[16]

These four functions provide the goods and services valued by humans. A classification of these goods and services are provided in Table 2 linking specific ecosystem functions to specific economic functions referred to as goods and services.

In this framework, the total value of these goods and services is captured in a sustainable development framework of ecological, socio-cultural, and economic values. It is then this total value that should be used to help guide the decision making process. The authors note that ecological value is the importance of a given ecosystem which is determined by the regulating and habitat functions, but also by complexity, diversity and rarity.

Socio-cultural value pertains largely to the information function of ecosystem services. More specifically, it relates to aspects of equity and emphasizing the benefit of ecosystem functions in physical and mental health, education, cultural diversity and identify, freedom and spiritual values. Economic value was categorized into direct market valuation, indirect market valuation (e.g., avoided cost, replacement cost, factor income, travel cost, hedonic pricing), contingent valuation, and group valuation. A useful characterization of ecosystem functions and economic valuation methods (described in detail in Section 4) is provided in Table 3.

This type of ecosystem framework was used in a 1997 global ecosystem valuation project and in a 2004 global synthesis on wetland valuation prepared by WWF. Costanza *et al*.[17]

presented the results of a global ecosystem valuation exercise. For 17 ecosystem services in 16 different biomes, a lower bound estimate of the marginal value of the world's ecosystems was estimated at between US $16-56 trillion per year, approximately 1.8 times global GNP of approximately US $18 trillion per year. The estimates were based largely on willingness-to-pay data for individuals for ecosystem services. Global valuations from other sources using different methods showed similar ranges. A detailed breakdown of the average global value for some of the ecosystem services determined from the Costanza *et al*. (1997) analysis is shown in Table 4. The methodology used was based on a partial equilibrium approach which ignored the complex interdependencies between ecosystem services. The authors note that a general equilibrium approach would be far superior to their static snapshot, and that this would be the next logical step for such estimates. Estimates from a 1972 study using static general equilibrium analysis yielded similar values to this study – US $34 trillion per year when converted to 1997 dollars.

A global wetland valuation synthesis was conducted by the WWF[18] which used the de Groot *et al*. framework to identify ecosystem functions and make links to ecosystem goods and services to be valued. For purposes of the WWF study, the following ecosystem functions were identified:

- Regulation functions:
    - storage and recycling of nutrients
    - storage and recycling of human waste
    - storage and recycling of organic waste
    - groundwater recharge
    - groundwater discharge
    - natural flood control and flow regulation
    - erosion control
    - salinity control
    - water treatment
    - climate stabilization
    - carbon sequestration
    - maintenance of migration and nursery habitats
    - maintenance of ecosystem stability
    - maintenance of integrity of other ecosystems
    - maintenance of biological and genetic diversity
- Carrier functions:
    - Agriculture, irrigation
    - Stock farming (grazing)
    - Wildlife cropping/recources
    - Transport
    - Energy production
    - Tourism and recreation
    - Human habitation and settlements
    - Habitat and nursery for plan and animal species
- Production functions:

  - Water
  - Food
  - Fuel wood
  - Medicinal resources
  - Genetic resources
  - Raw materials for building, construction and industrial use
- Information functions:
  - Research, education and monitoring
  - Uniqueness, rarity or naturalness and role in cultural heritage

The results of this wetland valuation are discussed in more detail later in Section 6.

Table 2 Functions, goods and services of natural and semi-natural ecosystems[19]

Functions	Ecosystems processes and components	Goods and Services (examples)
Regulation Functions	***Maintenance of essential ecological processes and life support systems***	
1. Gas regulation	Role of ecosystems in bio-geochemical cycles (e.g. CO_2/O_2 balance, ozone layer, etc.)	1.1 UVb-protection by O_3 (preventing disease). 1.2 Maintenance of (good) air quality. 1.3 Influence on climate (see also function 2.)
2. Climate regulation	Influence of land cover and boil. Mediated processes (e.g. DMS-production) on climate	Maintenance of a favourable climate (temp., precipitation, etc) for, for example, human habitation, health, cultivation
3. Disturbance prevention	Influence of ecosystem structure on dampening env. disturbances	3.1 Storm protection (e.g. by coral reefs). 3.2 Flood prevention (e.g. by wetlands and forests)
4. Water regulation	Role of land cover in regulating runoff & river discharge	4.1 Drainage and natural irrigation. 4.2 Medium for transport
5. Water supply	Filtering, retention and storage of fresh water (e.g. in aquifers)	Provision of water for consumptive use (e.g. drinking, irrigation and industrial use)
6. Soil retention	Role of vegetation root matrix and soil biota in soil retention	6.1 Maintenance of arable land. 6.2 Prevention of damage from erosion/siltation
7. Soil formation	Weathering of rock, accumulation of organic matter	7.1 Maintenance of productivity on arable land. 7.2 Maintenance of natural productive soils
8. Nutrient regulation	Role of biota in storage and re-cycling of nutrients (eg. N,P&S)	Maintenance of healthy soils and productive ecosystems
9. Waste treatment	Role of vegetation & biota in removal or breakdown of xenic nutrients and compounds	9.1 Pollution control/detoxification. 9.2 Filtering of dust particles. 9.3 Abatement of noise pollution
10. Pollination	Role of biota in movement of floral gametes	10.1 Pollination of wild plant species. 10.2 Pollination of crops
11. Biological control	Population control through trophic-dynamic	11.1 Control of pests and diseases. 11.2 Reduction of herbivory (crop damage)
Habitat Functions	***Providing habitat (suitable living space) for wild plant and animal species***	***Maintenance of biological & genetic diversity (and thus the basis for most other functions)***
12. Refugium function	Suitable living space for wild plants and animals	Maintenance of commercially harvested species
13. Nursery function	Suitable reproduction habitat	13.1 Hunting, gathering of fish, game, fruits, etc.
Production Functions	***Provision of natural resources***	
14. Food	Conservation of solar energy into edible plants and animals	14.1 Building & Manufacturing (e.g. lumber, skins)

		14.2 Fuel and energy (e.g. fuel wood, organic matter) 14.3 Fodder and fertilizer (e.g krill, leaves. Litter)
15. Raw materials	Conversion of solar energy into biomass for human construction and other uses	15.1 Improve crop resistance to pathogens & pests. 15.2 Other applications (e.g. health care)
16. Genetic resources	Genetic material and evolution in wild plants and animals	16.1 Drugs and pharmaceuticals. 16.2 Chemical models & tools. 16.3 Test- and essay organisms
17. Medicinal resources	Variety in (bio)chemical substances in, and other medicinal uses of, natural biota	Resources for fashion, handicraft, jewellery, pets, worship, decoration & souvenirs (e.g. furs, feathers, ivory, orchids, butterflies, aquarium fish, shells, etc.)
18. Ornamental resources	Variety of biota in natural ecosystems with (potential)ornamental use	
Information Functions	***Providing opportunities for cognitive development***	
19. Aesthetic information	Attractive landscape features	Enjoyment of scenery (scenic roads, housing, etc.)
20. Recreation	Variety in landscapes with (potential) recreational uses	Travel to natural ecosystems for eco-tourism, outdoor sports, etc.
21. Cultural and artistic information	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, painting, folklore, national symbols, architect, advertising, etc.
22. Spiritual and historic information	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (i.e. heritage value of natural ecosystems and features)
23. Science and education	Variety in nature with scientific and educational value	Use of natural systems for school excursions, etc. Use of nature for scientific research

Table 3. Relationship between ecosystem functions and monetary valuation techniques[20]

Ecosystem functions (and associated goods and services) (see Table 1)	Range of monetary values in US$/ha year[a]	Direct market pricing[b]	Indirect market pricing					Contingent valuation	Group validation
			Avoided cost	Replacement cost	Factor income	Travel cost	Hedonic pricing		
Regulation functions									
1. Gas regulation	7-265		+++	0	0			0	0
2. Climate regulation	88-223		+++	0	0			0	0
3. Disturbance regulation	2-7240		+++	++	0		0	+	0
4. Water regulation	2-5445	+	+++	0	+++		0	0	0
5. Water supply	3-7600	+++	0	++	0	0	0	0	0
6. Soil retention	29-245		+++	++	0		0	0	0
7. Soil formation	1-10		+++	0	0			0	0
8. Nutrient cycling	87-21 100		0	+++	0			0	0
9. Waste treatment	58-6696		0	+++	0		0	++	0
10. Pollination	14-25	0	+	+++	++			0	0
11. Biological control	2-78	+	0	+++	++			0	0
Habitat functions									
12. Refugium function	3-1523	+++		0	0		0	++	0
13. Nursery function	142-195	+++	0	0	0		0	0	0
Production functions									
14. Food	6-2761	+++		0	++			+	0
15. Raw materials	6-1014	+++		0	++			+	0
16. Genetic resources	6-112	+++		0	++			0	0
17. Medicinal resources		+++	0	0	++			0	0

18. Ornamental resources	3-145	+++	0	++		0	0	0
Information functions								
19. Aesthetic information	7-1760		0		0	+++	0	0
20. Recreation and tourism	2-6000	+++	0	++	++	+	+++	
21. Cultural and artistic insp.		0		0	0	0	+++	0
22. Spiritual and historic inf.	1-25				0	0	+++	0
23. Science and education		+++		0	0		0	0

[A] Dollar values are based on Costanza *et al*. (1997) and apply to different ecosystems (e.g. waste treatment is mainly provided by wetlands and recreational benefits are, on a per hectare basis, highest in coral reefs). In the columns, the most used method on which the calculation was based is indicated with +++, the second most with ++, etc.; open circles indicate that the method was not used in the Costanza study but could potentially also be applied to that function.

[B] Based on added value only (i.e. market price minus capital and labor costs (typically about 80%).

Table 4 Summary of average global value of annual ecosystem services[21]

		Ecosystem services (1994 US$ ha^{-1} yr^{-1})									
Biome	Area (ha x 10^6)	1 Gas regulation	2 Climate regulation	3 Disturbance regulation	4 Water regulation	5 Water supply	6 Erosion control	7 Soil formation	8 Nutrient cycling	9 Waste treatment	10 Pollination
Marine	36,302										
Open ocean	33,200	38							118		
Coastal	3,102			88					3,677		
Estuaries	180			567					21,100		
Seagrass/ Algae beds	200								19,002		
Coral reefs	62			2,750						58	
Shelf	2,660								1,431		
Terrestrial	15,323										
Forest	4,855		141	2	2	3	96	10	361	87	
Tropical	1,900		223	5	6	8	245	10	922	87	
emperate/boreal	2,955		88		0			10		87	
Grass/rangelands	3,898	7	0		3		29	1		87	25
Wetlands	330	133		4,539	15	3,800				4,177	
Tidal marsh/ Mangroves	165			1,839						6,696	
Swamps/ Floodplains	165	265		7,240	30	7,600				1,659	
Lakes/rivers	200				5,445	2,117				665	
Desert	1,925										
Tundra	743										
Ice/rock	1,640										
Cropland	1,400										14
Urban	332										
Total	51,625	1,341	684	1,779	1,115	1,692	576	53	17,075	2,277	117

Table 4 Summary of average global value of annual ecosystem services – Continued

		Ecosystem services (1994 US$ ha^{-1} yr^{-1})								
Biome	Area (ha x 10^6)	11 Biological control	12 Habitat/ refugia	13 Food production	14 Raw materials	15 Genetic resources	16 Recreation	17 Cultural	Total value per ha ($ ha^{-1} yr^{-1})	Total global flow value ($ yr^{-1} x 10^9)
Marine	36,302								577	20,949
Open ocean	33,200	5		15	0			76	252	8,381
Coastal	3,102	38	8	93	4		82	62	4,052	12,568
Estuaries	180	78	131	521	25		381	29	22,832	4,110
Seagrass/ Algae beds	200				2				19,004	3,801
Coral reefs	62	5	7	220	27		3,008	1	6,075	375
Shelf	2,660	39		68	2			70	1,610	4,283
Terrestrial	15,323								804	12,319
Forest	4,855	2		43	138	16	66	2	969	4,706
Tropical	1,900			32	315	41	112	2	2,007	3,813
Temperate/boreal	2,955	4		50	25		36	2	302	894
Grass/rangelands	3,898	23		67		0	2		232	906
Wetlands	330		304	256	106		574	881	17,785	4,879
Tidal marsh/ Mangroves	165		169	466	162		658		9,990	1,648
Swamps/ Floodplains	165		439	47	49		491	1,761	19,580	3.231
Lakes/rivers	200			41			230		8.498	1,700
Desert	1,925									
Tundra	743									
Ice/rock	1,640									
Cropland	1,400	24		54					92	128
Urban	332									
Total	51,625	417	124	1,386	721	79	815	3,015		33,268

Numbers in the body of the table are in $ ha^{-1} yr^{-1}. Row and column totals are in $ yr^{-1} x 10^9, column totals are the sum of the products of the per ha services in the table and the area of each biome, not the sum of the per ha services themselves. Shaded cells indicate services that do not occur or are known to be negligible. Open cells indicate lack of available information.

Ecosystem framework of the Millennium Assessment

The Millennium Ecosystem Assessment (MA) – a current global scientific assessment of the world's ecosystems – also employs an ecosystem framework and in addition, describes linkages with human wellbeing.[22] The framework, presented in Figure 3, resembles the de Groot *et al*. (2002) ecosystem framework. The most notable difference is terminology and groupings. For example, the MA uses the term ecosystem services instead of ecosystem functions. Additionally, the MA framework is grouped differently and describes ecosystem services not in terms of regulation, habitat, production, and information functions, but rather in terms of provisioning, regulating, and cultural services, and all built upon the supporting services for production of other ecosystem services.

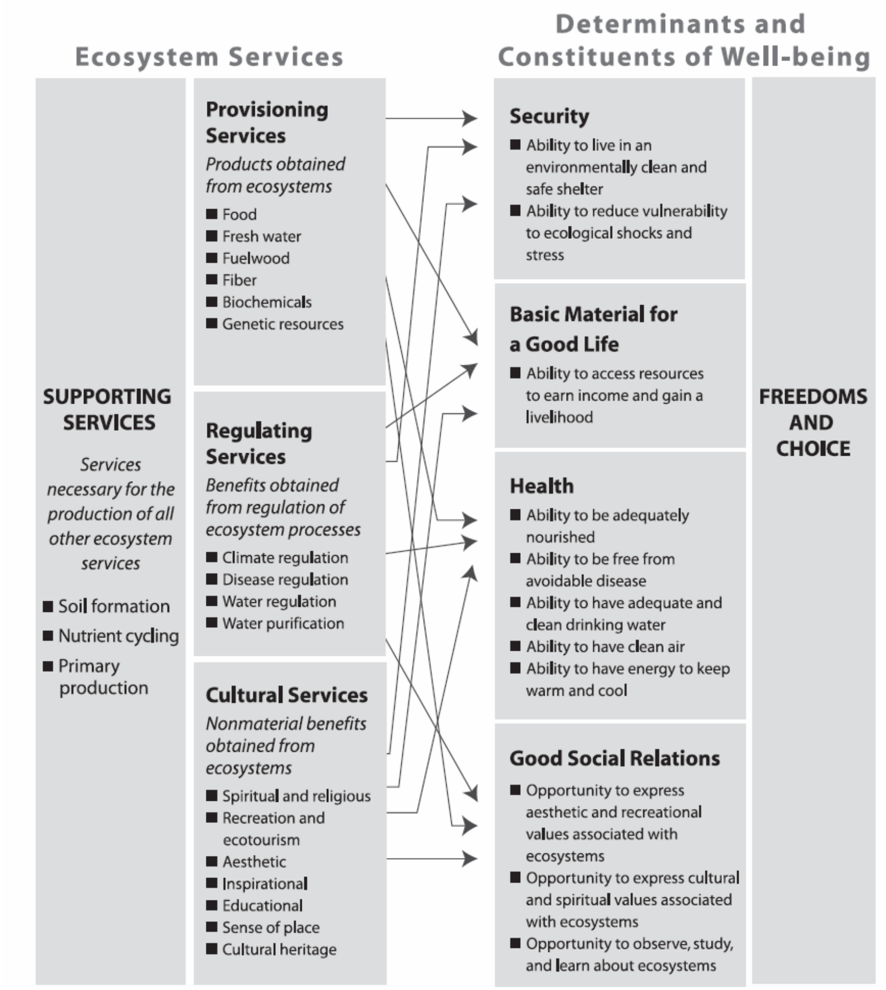


Figure 3. Linkages between ecosystem services and human well-being used in the Millennium Ecosystem Assessment (from MA 2003[23]).

The Millennium Assessment notes that provisioning and cultural services can be broadly categorized as direct use values; whereas, regulating and supporting services correspond more with indirect use values. Option values are noted to include provisioning, regulating, and cultural services.

The MA is proposing to use valuation as a "tool that enhances the ability of decision-makers to evaluate trade-offs between alternative ecosystem management regimes and courses of social action that alter the use of ecosystems and the multiple services they provide."[24] Their proposed conceptual valuation methodology will be based on the TEV framework described earlier, but also placing significant emphasis and research on the intrinsic aspects of ecosystem value particularly in relation to socio-cultural values.[25] Their methodology, summarized in Figure 4 will involve "estimating the change in the physical flow of benefits (quantifying biophysical relations) and tracing through and quantifying a chain of causality between changes in ecosystem condition and human welfare." They identify that a common problem in this methodology is that "data is only available on some of the links of the chain and in incompatible units."

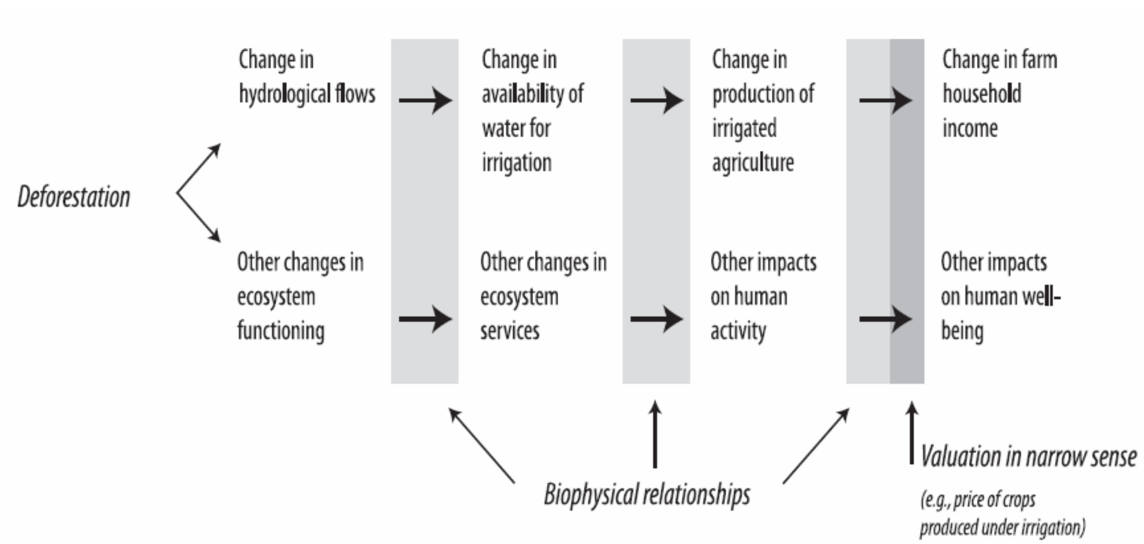


Figure 4. The MA methodology for valuing the impact of ecosystem change (from MA 2003[26]).

4. Valuation methods

When a good or service is sold in a market, good information is provided about its price, and therefore an aspect of its value. Even if the data needs to be corrected for market failures, there is a firm base to work with. However, as is usually the case with externalities, there is no market transaction from which to gather information. The methods that have been developed by economists to deal with this issue are reviewed in this section. Detailed examples of applications of some of these methods relevant to agriculture are featured in Section 6.

4.1. The problem with "Value"

Economic valuation approaches assume that goods and services are substitutable, and thus that it is reasonable to ask someone how much income they would be willing to give up in order to preserve some aspect of the environment. However, this assumption is not always valid.[27] There are many reported cases where someone is not willing to accept a substitution and insists that the value of something to them is essentially infinite.[28] This is termed a *lexicographic preference*, because it is ordered as in a dictionary – you cannot start one until you have finished the previous one - and is thus discontinuous.

There is an equivalent ecological discontinuity. Many ecosystems are non-linear and discontinuous, where changes can be irreversible. Farber, Costanza and Wilson cite "the recent wildfire in Los Alamos, New Mexico, in the summer of 2000, [which] provides a dramatic tragic example of the catastrophes and irreversibilities associated with being near critical thresholds. The fire was started as a controlled burn of several hundred acres by the U. S. National Park Service. Years of improper forest management, such as natural fire suppression and grazing of under story vegetation created a circumstance in which a minor change, the small controlled burn, had disastrous consequences, destroying 300 homes and temporarily displacing 30,000 people. To make matters worse, the destruction of groundcover over nearly 50,000 acres will likely permanently alter soil conditions as soil erosion will be very severe. The former forest system may never be replicated."[29]

The implication of this discussion is the same as the discussion in section 1.1 – that we will need to deal with marginal changes in well defined situations if we are to develop numbers that are meaningful.

Using the typology of King and Mazotta.[30], the following sections outline the various approaches to valuation that have been used to date, for circumstances where markets do not directly capture social value. They divide valuation methods into three broad categories, each of which is explored further below:

- Market prices and revealed willingness to pay, which include prices directly set in markets, as well as prices that can be inferred from market prices
- Circumstantial evidence and imputed willingness to pay, for example the amount that people are willing to pay to avoid floods can suggest the value of wetlands that will perform this service

Surveys, which capture people's statements of their willingness to pay.

4.2. **Market price and revealed willingness to pay**

Four specific methods are included in this category of valuation. They include:
- Direct estimation of producer and consumer surplus.
- Productivity method.
- Hedonic pricing method.
- Travel cost method.

The first of these is the *direct estimation of producer and consumer surplus*, which can be done for markets where there is a reasonable amount of data and supply and demand curves can be calculated. For example, in a commercial fishery, the value of extra productivity resulting from reduced pollution can be calculated and measured against the cost of reducing the pollution. The main advantages and disadvantages of this approach as summarized by King and Mazzotta[31] include:

Advantages:
- Reflects an individual's willingness to pay for costs and benefits of goods that are bought and sold in markets, such as fish, timber, or fuel wood. Thus, people's values are likely to be well-defined.
- Price, quantity and cost data are relatively easy to obtain for established markets.
- The method uses observed data of actual consumer preferences.
- The method uses standard, accepted economic techniques.

Issues and Limitations:
- Market data may only be available for a limited number of goods and services provided by an ecological resource and may not reflect the value of all productive uses of a resource.
- The true economic value of goods or services may not be fully reflected in market transactions, due to market imperfections and/or policy failures.
- Seasonal variations and other effects on price must be considered.
- The method cannot be easily used to measure the value of larger scale changes that are likely to affect the supply of or demand for a good or service.
- Usually, the market price method does not deduct the market value of other resources used to bring ecosystem products to market, and thus may overstate benefits.

The second method in this category is variously called the *productivity* method, the *derived value* method, or the *net factor income* method. Here, the ecosystem value being calculated is one input to a marketed product, so it is necessary to estimate the value of the input as a portion of the value of the marketed product. For example, an increase in the quality of water in a river will decrease the costs of treatment at a municipal treatment plant, thus contributing to an overall cost savings for drinking water users. So, where the technical links between the factor input and the improvements in the output are well understood, and the supply and demand curves of the output can be calculated, the value of the input improvement can also be calculated. Among the advantages and disadvantages of this approach are[32]:

Advantages
- In general, the methodology is straightforward.
- Data requirements are limited, and the relevant data may be readily available, so the method can be relatively inexpensive to apply.

Issues and Limitations
- The method is limited to valuing those resources that can be used as inputs in production of marketed goods.
- When valuing an ecosystem, not all services will be related to the production of marketed goods. Thus, the inferred value of that ecosystem may understate its true value to society.
- Information is needed on the scientific relationships between actions to improve quality or quantity of the resource and the actual outcomes of those actions. In some cases, these relationships may not be well known or understood.
- If the changes in the natural resource affect the market price of the final good, or the prices of any other production inputs, the method becomes much more complicated and difficult to apply.

The third method is called the *hedonic pricing* method, and it can be used to estimate the values of changes in the characteristics of a good. For example, the value that people derive from a nice view from their house can be estimated from data on the cost of houses both with and without a view. The same methodology can be used to value (or derive costs for) such things as air pollution or noise. Some of the advantages, issues and limitations of this approach include[33]:

Advantages
- The method's main strength is that it can be used to estimate values based on actual choices.
- Property markets are relatively efficient in responding to information, so can be good indications of value.
- Property records are typically very reliable.
- Data on property sales and characteristics are readily available through many sources, and can be related to other secondary data sources to obtain descriptive variables for the analysis.
- The method is versatile, and can be adapted to consider several possible interactions between market goods and environmental quality.

Issues and Limitations
- The scope of environmental benefits that can be measured is limited to things that are related to housing prices.
- The method will only capture people's willingness to pay for perceived differences in environmental attributes, and their direct consequences. Thus, if

people aren't aware of the linkages between the environmental attribute and benefits to them or their property, the value will not be reflected in home prices.
- The method assumes that people have the opportunity to select the combination of features they prefer, given their income. However, the housing market may be affected by outside influences, like taxes, interest rates, or other factors.
- The method is relatively complex to implement and interpret, requiring a high degree of statistical expertise.
- The results depend heavily on model specification.
- Large amounts of data must be gathered and manipulated.
- The time and expense to carry out an application depends on the availability and accessibility of data.

Finally, the fourth method in this category is the *travel cost* method. It is best suited to valuing ecosystems or sites that are used for recreation. Basically, the approach uses the costs that people incur in visiting a place as an indicator of its value. With appropriate data, the demand curve and the consumer surplus can be calculated, thus giving the value of the site. The advantages and disadvantages of the travel cost method include[34]:

Advantages
- The travel cost method closely mimics the more conventional empirical techniques used by economists to estimate economic values based on market prices.
- The method is based on actual behavior—what people actually do—rather than stated willingness to pay—what people say they would do in a hypothetical situation.
- The method is relatively inexpensive to apply.
- On-site surveys provide opportunities for large sample sizes, as visitors tend to be interested in participating.
- The results are relatively easy to interpret and explain.

Issues and Limitations
- The travel cost method assumes that people perceive and respond to changes in travel costs the same way that they would respond to changes in admission price.
- The simplest models assume that individuals take a trip for a single purpose – to visit a specific recreational site. Thus, if a trip has more than one purpose, the value of the site may be overestimated. It can be difficult to apportion the travel costs among the various purposes.
- Defining and measuring the opportunity cost of time, or the value of time spent traveling, can be problematic. Because the time spent traveling could have been used in other ways, it has an "opportunity cost." This should be added to the travel cost, or the value of the site will be underestimated. However, there is no strong consensus on the appropriate measure—the person's wage rate, or some fraction of the wage rate—and the value chosen can have a large effect on benefit estimates. In addition, if people enjoy the travel itself, then travel time becomes a benefit, not a cost, and the value of the site will be overestimated

- The availability of substitute sites will affect values. For example, if two people travel the same distance, they are assumed to have the same value. However, if one person has several substitutes available but travels to this site because it is preferred, this person's value is actually higher. Some of the more complicated models account for the availability of substitutes.
- Those who value certain sites may choose to live nearby. If this is the case, they will have low travel costs, but high values for the site that are not captured by the method.
- Interviewing visitors on site can introduce sampling biases to the analysis.
- Measuring recreational quality, and relating recreational quality to environmental quality can be difficult.
- Standard travel cost approaches provides information about current conditions, but not about gains or losses from anticipated changes in resource conditions.
- In order to estimate the demand function, there needs to be enough difference between distances traveled to affect travel costs and for differences in travel costs to affect the number of trips made. Thus, it is not well suited for sites near major population centers where many visitations may be from "origin zones" that are quite close to one another.
- The travel cost method is limited in its scope of application because it requires user participation. It cannot be used to assign values to on-site environmental features and functions that users of the site do not find valuable. It cannot be used to value off-site values supported by the site. Most importantly, it cannot be used to measure non-use values. Thus, sites that have unique qualities that are valued by non-users will be undervalued.
- As in all statistical methods, certain statistical problems can affect the results. These include choice of the functional form used to estimate the demand curve, choice of the estimating method, and choice of variables included in the model.

4.3. **Circumstantial evidence and imputed willingness to pay**

There are three variations on valuation under this heading, all of which are based on indirect estimates of costs. They are the *damage cost avoided, replacement cost and substitute cost* methods. These methods estimate ecosystem costs by estimating the cost of damages due to lost services, the cost of replacing services, or the cost of substituting for such services. For example, the damage that might be caused by flooding after the removal of a wetland can be estimated by looking at the area or property that might be flooded, and the cost of replacing the flood control capacity of the wetland can be estimated from engineering estimates of other sorts of control systems.

The advantages of these methods include[35]:

- The methods may provide a rough indicator of economic value, subject to data constraints and the degree of similarity or substitutability between related goods.
- It is easier to measure the costs of producing benefits than the benefits themselves, when goods, services, and benefits are non-marketed. Thus, these approaches are less data and resource intensive.

- Data or resource limitations may rule out valuation methods that estimate willingness to pay.
- The methods provide surrogate measures of value that are as consistent as possible with the economic concept of use value, for services which may be difficult to value by other means.

Some of the issues and limitations associated with this method include[36]:

- These approaches assume that expenditures to repair damages or to replace ecosystem services are valid measures of the benefits provided. However, costs are usually not an accurate measure of benefits.
- These methods do not consider social preferences for ecosystem services, or individuals' behaviour in the absence of those services. Thus, they should be used as a last resort to value ecosystem services.
- The methods may be inconsistent because few environmental actions and regulations are based solely on benefit-cost comparisons, particularly at the national level. Therefore, the cost of a protective action may actually exceed the benefits to society. It is also likely that the cost of actions already taken to protect an ecological resource will underestimate the benefits of a new action to improve or protect the resource.
- The replacement cost method requires information on the degree of substitution between the market good and the natural resource. Few environmental resources have such direct or indirect substitutes. Substitute goods are unlikely to provide the same types of benefits as the natural resource, e.g., stocked salmon may not be valued as highly by anglers as wild salmon.
- The goods or services being replaced probably represent only a portion of the full range of services provided by the natural resource. Thus, the benefits of an action to protect or restore the ecological resource would be understated.
- These approaches should be used only after a project has been implemented or if society has demonstrated their willingness-to-pay for the project in some other way (e.g., approved spending for the project). Otherwise there is no indication that the value of the good or service provided by the ecological resource to the affected community greater than the estimated cost of the project.
- Just because an ecosystem service is eliminated is no guarantee that the public would be willing to pay for the identified least cost alternative merely because it would supply the same benefit level as that service. Without evidence that the public would demand the alternative, this methodology is not an economically appropriate estimator of ecosystem service value.

4.4. **Survey based methods**

There are three methods under this heading:

- Contingent valuation method.
- Contingent choice method.
- Benefit transfer method.

The first is the *contingent valuation* method, often shortened to *CVM* or *CV*. The method involves direct surveys of individuals, asking them what they would be willing to pay for certain specific environmental services. The word "contingent" refers to the fact that people are asked how much they would pay for something like an environmental service, contingent on a specific scenario and description of the service. While the methods discussed above try to derive values from market behaviour and engineering cost calculations, CV depends on what people say they would pay for something. The results are controversial, because it is easy to argue that what people say, and what they might actually do, are different. However, such studies are the only way to get some sort of estimates of non use values. The value of such studies can be to help demonstrate that people do value non-use ecosystem services, and divert the debate from an environment-vs-people path to one that tries to optimize both use and non-use values. Some of the specific advantages and disadvantages of CVM have been cited as[37]:

Advantages

- Contingent valuation is enormously flexible in that it can be used to estimate the economic value of virtually anything. However, it is best able to estimate values for goods and services that are easily identified and understood by users and that are consumed in discrete units (e.g., user days of recreation), even if there is no observable behaviour available to deduce values through other means.
- CV is the most widely accepted method for estimating total economic value , including all types of non-use, or "passive use," values. CV can estimate use values, as well as existence values, option values, and bequest values .
- Though the technique requires competent survey analysts to achieve defensible estimates, the nature of CV studies and the results of CV studies are not difficult to analyze and describe. Dollar values can be presented in terms of a mean or median value per capita or per household, or as an aggregate value for the affected population.
- CV has been widely used, and a great deal of research is being conducted to improve the methodology, make results more valid and reliable, and better understand its strengths and limitations.

Issues and limitations

- Although the contingent valuation method has been widely used for the past two decades, there is considerable controversy over whether it adequately measures people's willingness to pay for environmental quality.
- People have practice making choices with market goods, so their purchasing decisions in markets are likely to reflect their true willingness to pay. CV assumes that people understand the good in question and will reveal their preferences in the contingent market just as they would in a real market. However, most people are unfamiliar with placing dollar values on environmental goods and services. Therefore, they may not have an adequate basis for stating their true value.
- The expressed answers to a willingness to pay question in a contingent valuation format may be biased because the respondent is actually answering a different question than the surveyor had intended. Rather than expressing value for the good, the respondent might actually be expressing their feelings about the

scenario or the valuation exercise itself. For example, respondents may express a positive willingness to pay because they feel good about the act of giving for a social good (referred to as the "warm glow" effect), although they believe that the good itself is unimportant. Respondents may state a positive willingness to pay in order to signal that they place importance on improved environmental quality in general. Alternatively, some respondents may value the good, but state that they are not willing to pay for it, because they are protesting some aspect of the scenario, such as increased taxes or the means of providing the good.

- Respondents may make associations among environmental goods that the researcher had not intended. For example, if asked for willingness to pay for improved visibility (through reduced pollution), the respondent may actually answer based on the health risks that he or she associates with dirty air.
- Some researchers argue that there is a fundamental difference in the way that people make hypothetical decisions relative to the way they make actual decisions. For example, respondents may fail to take questions seriously because they will not actually be required to pay the stated amount. Responses may be unrealistically high if respondents believe they will not have to pay for the good or service and that their answer may influence the resulting supply of the good. Conversely, responses may be unrealistically low if respondents believe they will have to pay.
- The payment question can either be phrased as the conventional 'What are you willing to pay (WTP) to receive this environmental asset?', or in the less usual form, 'What are you willing to accept (WTA) in compensation for giving up this environmental asset?' In theory, the results should be very close. However, when the two formats have been compared, WTA very significantly exceeds WTP. Critics have claimed that this result invalidates the CVM approach, showing responses to be expressions of what individuals would like to have happen rather than true valuations.
- If people are first asked for their willingness to pay for one part of an environmental asset (e.g. one lake in an entire system of lakes) and then asked to value the whole asset (e.g. the whole lake system), the amounts stated may be similar. This is referred to as the "embedding effect."
- In some cases, people's expressed willingness to pay for something has been found to depend on where it is placed on a list of things being valued. This is referred to as the "ordering problem."
- Respondents may give different willingness to pay amounts, depending on the specific payment vehicle chosen. For example, some payment vehicles, such as taxes, may lead to protest responses from people who do not want increased taxes. Others, such as a contribution or donation, may lead people to answer in terms of how much they think their "fair share" contribution is, rather than expressing their actual value for the good.
- Many early studies attempted to prompt respondents by suggesting a starting bid and then increasing or decreasing this bid based upon whether the respondent agreed or refused to pay a such sum. However, it has been shown that the choice of starting bid affects respondents' final willingness to pay response.

- Strategic bias arises when the respondent provides a biased answer in order to influence a particular outcome. If a decision to preserve a stretch of river for fishing, for example, depends on whether or not the survey produces a sufficiently large value for fishing, the respondents who enjoy fishing may be tempted to provide an answer that ensures a high value, rather than a lower value that reflects their true valuation.
- Information bias may arise whenever respondents are forced to value attributes with which they have little or no experience. In such cases, the amount and type of information presented to respondents may affect their answers
- Non-response bias is a concern when sampling respondents, since individuals who do not respond are likely to have, on average, different values than individuals who do respond.
- Estimates of non-use values are difficult to validate externally.
- When conducted to the exacting standards of the profession, contingent valuation methods can be very expensive and time-consuming, because of the extensive pre-testing and survey work.
- Many people, including jurists policy-makers, economists, and others, do not believe the results of CV.

The second survey based method is the *contingent choice* method. In this case, the survey does not ask for specific values, but inquires about the choices or tradeoffs that people might make, and infers value figures from this information. The survey will define two or more outcomes including their costs and benefits, and ask the respondents to rank the outcomes. This approach has the advantage of allowing several policy options to be ranked, but it suffers from the basic weaknesses of the survey approach. A summary of specific advantages and disadvantages of this method is provided below[38].

Advantages

- The contingent choice method can be used to value the outcomes of an action as a whole, as well as the various attributes or effects of the action.
- The method allows respondents to think in terms of tradeoffs, which may be easier than directly expressing dollar values. The trade-off process may encourage respondent introspection and make it easier to check for consistency of responses. In addition, respondents may be able to give more meaningful answers to questions about their behaviour (i.e. they prefer one alternative over another), than to questions that ask them directly about the dollar value of a good or service or the value of changes in environmental quality. Thus, an advantage of this method over the contingent valuation method is that it does not ask the respondent to make a trade-off directly between environmental quality and money.
- Respondents are generally more comfortable providing qualitative rankings or ratings of attribute bundles that include prices, rather than dollar valuation of the same bundles without prices, by de-emphasizing price as simply another attribute.
- Survey methods may be better at estimating relative values than absolute values. Thus, even if the absolute dollar values estimated are not precise, the relative values or priorities elicited by a contingent choice survey are likely to be valid and useful for policy decisions.

- The method minimizes many of the biases that can arise in open-ended contingent valuation studies where respondents are presented with the unfamiliar and often unrealistic task of putting prices on non-market amenities.
- The method has the potential to reduce problems such as expressions of symbolic values, protest bids, and some of the other sources of potential bias associated with contingent valuation.

Issues and Limitations

- Respondents may find some tradeoffs difficult to evaluate, because they are unfamiliar.
- The respondents' behaviour underlying the results of a contingent choice study is not well understood. Respondents may resort to simplified decision rules if the choices are too complicated, which can bias the results of the statistical analysis.
- If the number of attributes or levels of attributes is increased, the sample size and/or number of comparisons each respondent makes must be increased.
- When presented with a large number of trade-off questions, respondents may lose interest or become frustrated.
- Contingent choice may extract preferences in the form of attitudes instead of behaviour intentions.
- By only providing a limited number of options, it may force respondents to make choices that they would not voluntarily make.
- Contingent ranking requires more sophisticated statistical techniques to estimate willingness to pay.
- Translating the answers into dollar values, may lead to greater uncertainty in the actual value that is placed on the good or service of interest.
- Although contingent choice has been widely used in the field of market research, its validity and reliability for valuing non-market commodities is largely untested.

The final survey based valuation method is the *benefit transfer method.* This provides a methodology by which valuations obtained in one study can be used elsewhere, in situations shown to be similar enough that such a transfer is reasonable. This depends on whether the services being valued are comparable to the services in the existing study, in terms of the features and qualities of sites and ecosystems, and in terms of the existence of substitutes. The populations in the two areas must also be comparable, in demographic profile and preferences. The transfer of the study may require adjusting the data in the original study to better reflect the situation in the new area – for example the demographic profile may need to be corrected. Some of the specific advantages and disadvantages include the following[39].

Advantages

- Benefit transfer is typically less costly than conducting an original valuation study.
- Economic benefits can be estimated more quickly than when undertaking an original valuation study.
- The method can be used as a screening technique to determine if a more detailed, original valuation study should be conducted.

- The method can easily and quickly be applied for making gross estimates of recreational values. The more similar the sites and the recreational experiences, the fewer biases will result.

Issues and Limitations

- Benefit transfer may not be accurate, except for making gross estimates of recreational values, unless the sites share all of the site, location, and user specific characteristics.
- Good studies for the policy or issue in question may not be available.
- It may be difficult to track down appropriate studies, since many are not published.
- Reporting of existing studies may be inadequate to make the needed adjustments.
- Adequacy of existing studies may be difficult to assess.
- Extrapolation beyond the range of characteristics of the initial study is not recommended.
- Benefit transfers can only be as accurate as the initial value estimate.
- Unit value estimates can quickly become dated.

One particular form of benefit transfer is called meta-analysis. Meta-Analysis considers a set of valuation studies to yield a number of values of the dependent variable – a dollar valuation per unit of what is being valued. The independent variables represent the characteristics of the particular valuation study. Most importantly it allows the evaluation of the effect of changes in the underlying characteristics on the valuation – an analysis that is typically not possible given just a single valuation study[40]. Meta-analysis can be performed using bivariate or multi-variate econometric regression techniques, although multi-variate regression is able to account for the interaction among the independent variables.

Meta-analysis was first used to place value on outdoor recreation in the early 90s and has since been used to study economic valuation for air pollution, recreational fishing, visibility, health risks, endangered species, and perhaps most recently, for wetland studies[41]. Meta-analysis provides a useful tool for understanding what characteristics of a valuation study and the study site have the most influence on the economic valuation. For example, this type of analysis can help to prioritize data collection activities and therefore help make full-cost accounting efforts more efficient and economical. However, the researchers and practitioners using meta-analysis for value transfer note that it is an "imprecise science…and the need for site-specific studies remains"[42] and some urge caution "particularly for policy sites for which their characteristics are not well represented in the underlying valuation studies."[43]

5. Methodological Issues for Full Cost Accounting

5.1. The goal will help define the study

The valuation methods discussed above all have their advantages and disadvantages, as discussed in the previous section. These relate both to the environmental valuation being undertaken, and to the time and budget available for conducting the study. Choice of a specific methodology depends on the specific goals.

5.2. Defining the impact pathways

In arriving at the externality cost for an activity, one must define how the activity affects the environment. This requires defining the impact pathways – the routes by which the actual damage and benefit takes place. For example, recent work in both the United States and the European Union on calculating the externalities of electricity production developed the following conceptual diagram.

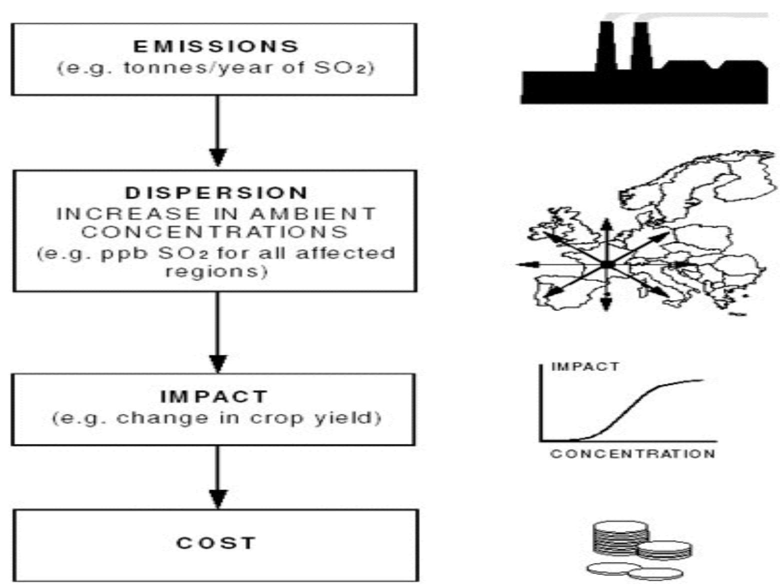


Figure 5 Impact-pathway methodology[44]

The stages in the impact pathway are defined as:

1. Emissions: the specification of power generation technologies and the magnitude of their associated pollutant release (e.g., tonnes of SO_X emitted).
2. Dispersion: the geographically-referenced calculation of incremental pollutant concentration (e.g., through the use of pollutant transport models which simulate the effects of atmospheric dispersion and photo-chemical reactions of the emissions).

3. Impacts: the estimation of the damage caused by exposure to the elevated incremental pollution level (e.g., the increased incidence of asthma due to elevated ozone levels).
4. Costs: the economic valuation of these impacts, (e.g., by multiplying the number of asthma cases induced by the willingness-to-pay (WTP) to avoid those cases).

This methodology is applicable to all sorts of full cost accounting exercises.

5.3. Boundaries of the analysis

An important question in calculating the externalities of an activity is to define the boundaries – to define in detail the specific activities for which cost will be determined. This requires a *life cycle approach*, meaning that the activities that take place because of the primary activity for which cost is determined must also be included in the calculation. For example, if the cost of pesticide use on farms is to be calculated, the external costs of manufacturing, transporting and applying those pesticides should also be considered, because they would not have taken place if the farm use were not taking place. Of course, following all of the impact pathways to calculate all of the costs in the life cycle of an on-farm activity will not be possible because of data availability. It is also often the case that the indirect impacts may be much smaller than the direct ones. The environmental externalities involved in the transportation of the pesticide, for example, may well be very small compared to the other impacts. Ideally this issue would be examined for each case, to try to ensure that only items that really are negligible are ignored.

5.4. Quantifying the impacts

For a pollutant, this involves calculating the dispersion of the pollutant, then calculating the incremental damage done by it, and finally calculating the economic cost of that damage. This requires the definition of a damage function – a statement of the relationship between a change in pollution levels and a cost. For air pollution, where public health effects have been extensively studied, there is the *Air Quality Valuation Model* (AQVM), a computer model co-developed by Environment Canada and Health Canada to estimate human health and material damage costs from air pollution within individual Census divisions. AQVM uses 1996 Canadian Census data to calculate costs within each Census division as a function of the number of exposed persons and the increase in level of concentration.[45]

5.5. Aggregating the impacts by geographic area

All of the externalities that will be considered with respect to agriculture will need to be dealt with on a geographic basis. Not only will the positive or negative impacts of agriculture vary with crop type, farming practice, and so on, but also the sensitivity of the environment to impacts will vary from place to place. In this sense, the challenge of valuing agricultural impacts is greater then that faced by AQVM in valuing costs to human health, because humans can be assumed to be reasonably homogeneous, especially if an age profile is included in the analysis. This cannot be assumed for the environments across Canada.

6. Application to Agriculture

This section reviews studies that employ many of the valuation methodologies and ecosystem frameworks described earlier in the paper. The first study reviewed below relates directly to agriculture while the other examples highlighted provide valuation information on two of the most commonly studied ecosystem components (wetlands and water) – components that will require value estimates in order to quantify the cost or benefit associated with changes in agri-environmental indicators.

6.1. Agriculture specific studies

Pretty *et al*[46] reviewed a wide range of data sets to arrive at an estimate of the environmental externalities for UK agriculture. They point out that: "The type of externalities encountered in the agriculture sector have five features: (1) their costs are often neglected; (2) they often occur with a time lag; (3) they often damage groups whose interests are not represented; (4) the identity of the producer is not always known; and (5) they result in sub-optimal economic and policy solutions."[47]

Their estimates cover two sorts of costs: the cost of preventing or treating damages in order to comply with health and environmental legislation or return the ecosystem to an undamaged state, and the cost of public agencies which administer and monitor the relevant programs. They only estimate externalities which give rise to financial costs, so none of the values used come from contingent valuation studies. Using these costs will result in an underestimate of the totals, but has the advantage of reducing the subjective component of the estimates. They do not attempt to estimate positive externalities. Table 5 gives the summary of their results.

The article organizes the externalities into seven categories:

Damage to natural capital – water: These costs are estimated from the actual treatment costs incurred by water utilities in providing potable water to their customers. Thus the estimate is of the cost to meet legal standards, rather than elimination, and the estimate does not include the damage that might be done by the various pollutants in other ways.

Damage to natural capital – air: Climate change costs due to CO_2, methane and other emissions, as well as the health impacts of ammonia emissions are included.

Damage to natural capital – soil: This includes the damage caused off the farm by soil erosion, and damage from carbon dioxide losses.

Damage to natural capital – biodiversity and landscape: The cost of restoring some of lost habitat and thus strengthening biodiversity, as well as the restoration of hedgerows and dry stone walls, and the replacement of some of lost bee colonies are included in this category.

Damage to human health – pesticides: Workers who manufacture, transport and dispose of pesticides, as well as those who apply them and the general public are all affected.

Damage to human health – nitrate: The study reviews available data and makes the assumption that there is no external human health costs due to nitrates in the UK.

Damage to human health – micro organisms and other disease agents: This is a complex category that includes damage caused by food poisoning and related diseases, by antibiotic resistance (due to lack of data, included as a zero cost), and the cost of BSE (bovine spongiform encephalopathy) and Creutzfeldt-Jakob disease (CJD).

The aggregate of the costs is £2,343 million, which is about 89% of UK average farm income in 1996, and amounts to about £208 per hectare per year, averaged across the 11.28 million ha of arable land and permanent grassland. As noted earlier, these are likely to be very conservative estimates of total environmental externalities.

Table 5. The annual total external costs of UK agriculture, 1996
(range values for 1990-1996)[a]

Cost category	UK (£ million)	Range [b] (£ million)
1. Damage to natural capital – water		
1a. Pesticides in sources of drinking water	120	18-129
1b. Nitrate in sources of drinking water	16	8-33
1c. Phosphate and soil in sources of drinking water	55	22-90
1d. Zoonoses (esp. Cryptosporidium) in sources of drinking water	23	15-30
1e. Eutrophication and pollution incidents (fertilisers, animal wastes, sheep dips)	6	4-7
1f. Monitoring and advice on pesticides and nutrients	11	8-11
2. Damage to natural capital – air		
2a. Emissions of methane	280	248-376
2b. Emissions of ammonia	48	23-72
2c. Emissions of nitrous oxide	738	418-1700
2d. Emissions of carbon dioxide	47	35-85
3. Damage to natural capital – soil		
3a. Off-site damage caused by erosion	14	8-30
3b. Organic matter and carbon dioxide losses from soils	82	59-140
4. Damage to natural capital-biodiversity and landscape		
4.a. Biodiversity/wildlife losses (habitats and species)	25	10-35
4c. Bee colony losses	2	1-2
4d. Agricultural biodiversity	+[d]	+
5. Damage to human health - pesticides		
5a. Acute effects	1	0.4-1.6
5b. Chronic effects	+	+
6. Damage to human health –nitrate	**0**	**0**
7. Damage to human health: micro organisms and other disease agents		
7a. Bacterial and viral outbreaks in food	169	100-243
7b. Antibiotic resistance	+	+
7c. BSE[e] and nvCJD	607	33-800
Total	2343	1149-3907

[a] This table does not include private costs borne by farmers themselves.
[b] The ranges for costs do not represent formal standard deviations of the data as this is impossible given the huge variation in types of data and contexts. The ranges represent best estimates for higher and lower quartiles for costs incurred annually during the 1990s. The range values for the external costs of each of these gases, rather than the variation of emissions during the 1990.
[c] The offsite damage caused by erosion I category 3a does not include the costs of removing soils/sediments from drinking water (these are in cost category 1c).
[d] +, Not yet able to calculate costs.
[e] BSE costs are an average for 1996 and 1997.

Source: J.N. Pretty et al./ Agricultural Systems 65 (2000)

6.2. Wetlands valuation using meta-analysis

Meta-analysis of economic valuation studies for wetlands has been the focus of much research in recent years in part due to the Ramsar Convention on Wetlands. Perhaps one of the most comprehensive wetlands meta-analysis studies was conducted by Brander *et al*.[48] who reported on a comprehensive summary and meta-analysis of the wetlands valuation literature. These results were also used in a 2004 global synthesis on wetland valuation prepared by WWF.[49]

The Brander *et al.* [50] study included190 wetland valuation studies with 250 observations, including 25 countries and all continents. Approximately half of observations were from sites in the United States and Canada. The purpose was to obtain marginal effects given the interference of potentially relevant intervening characteristics. Multi-variate regression was performed with wetland value in US$ per hectare (1995 prices) as the dependent variable. Explanatory variables included three categories: study characteristics (valuation method, marginal value); physical and geographic characteristics (e.g., wetland type, functions, area, urban, continent, latitude, Ramsar proportion); and socio-economic characteristics (e.g., GDP per capita, population density). Logarithm forms for the dependent variable, GDP, population density, and wetland size helped to reduce heteroskedasticity. A summary of the data set is provided in Table 6. Global summaries of this data from the WWF report are presented in Tables 7 through 10.

Results of the meta-analysis revealed that GDP per capita and population density variables were the most important explanatory variables and were positively correlated with wetland value. Additionally, CVM studies tended to produce higher values than other valuation methods. Freshwater marshes were valued less than other wetland types with no clear relationship between wetland size and value. It was observed that the meta-analysis systematically over-predicted for very low wetland values and systematically under-predicted for very high valuations.

Woodward and Wui reported on a much smaller scale wetland meta-analysis that considered 39 studies containing sufficient data to allow inter-study comparisons. This analysis used both bivariate and multivariate regression to determine wetland values as a function of the number and type of wetland service provided (e.g., bird watching only, or also fishing, etc.), the valuation methodology used, the size of the wetland, year of the study, and site location. The analysis did find some evidence that CVM methods tend to find lower wetland values compared to other methods.[1] Additionally, the analysis found that the size of the wetland did not affect the wetland value.

[1] However, no conclusions could be made relative to the travel cost or net factor methods.

Table 6 Meta-regression results[51]

Category	Variable	Coefficient	Standard Error
	Constant	-6.98	4.67
Socio-economic	GDP per capita (log)	1.16**	0.46
	Population density (log)	0.47***	0.12
Geographic characteristics	Wetland size (log)	-0.11**	0.05
	Latitude (absolute value)	0.03	0.07
	Latitude squared	-0.0007	0.0010
	South America	0.23	1.19
	Europe	0.84	0.92
	Asia	2.01	1.34
	Africa	3.51**	1.52
	Australasia	1.75*	0.94
	Urban	1.11**	0.48
Valuation methods	CVM	1.49**	0.73
	Hedonic pricing	-0.71	1.54
	TCM	0.01	0.65
	Replacement cost	0.63	0.81
	Net factor income	0.19	0.61
	Production function	-1.00	0.75
	Market prices	-0.04	0.53
	Opportunity Cost	-0.03	0.72
Type value	Marginal	0.95	0.48
Wetland type	Mangrove	-0.56	0.82
	Unvegetated sediment	0.22	1.09
	Salt/brackish marsh	-0.31	0.42
	Fresh marsh	-1.46**	0.59
	Woodland	0.86	0.42
Wetland function	Flood control	0.14	0.55
	Water supply	-0.95	0.71
	Water quality	0.63	0.74
	Habitat and nursery	-0.03	0.35
	Hunting	-1.10**	0.43
	Fishing	0.06	0.36
	Material	-0.83	0.42
	Fuelwood	-1.24***	0.45
	Amenity	0.06	0.39
	Biodiversity	0.06	0.81
RAMSAR	RAMSAR proportion	-1.32*	0.70
	N	202	
	R^2-adjusted	0.45	
	F	5.50***	
	Breusch-Pagan	51.46***	

[A] OLS results with White-adjusted standard errors. The Breusch-Pagan test concerns heteroskedasticity and is $_x{}^2$ distributed with 36 degrees of freedom. Significance is indicated with ***, **, and * for the 1,5, and 10 percent level, respectively.

The authors of this study are even more hesitant to advise transferring the results of their meta-analysis to other projects and go as far as concluding that the need for site-specific studies remains. They note that from their analysis that the prediction of wetland value is at best an imprecise science due to the lack of uniformity across the studies included in the meta-analysis. For example, in analyzing whether the number of different ecosystem services effects wetland value, the analysis found that bird watching and commercial fishing were among the highest services valued, while amenity services were the least valued. But most noteworthy in this regard, is that the confidence intervals "extraordinary" and spanned thousands of dollars. They concluded that it "would be highly speculative to use a single point from this distribution in a benefits transfer exercise."[52]

Table 7 Median Wetland Economic Values by Wetland Type[53]

Wetland Type	Median Wetland Economic Value (US$ per hectare per year, 2000)
Unvegetated Sediment	374
Freshwater Wood	206
Salt/Brackish Marsh	165
Freshwater Marsh	145
Mangrove	120

Table 8 Medium Wetland economic Values by Wetland Function[54]

Wetland Function	Median Wetland Economic Value (US$ per hectare per year, 2000)
Flood Control	464
Recreational Fishing	374
Amenity/Recreation	492
Water Filtering	288
Biodiversity	214
Habitat Nursery	201
Recreational Hunting	123
Water Supply	45
Materials	45
Fuel Wood	14

Table 9 Total Area of Wetlands by Continent and Wetland Type (1000 ha)[55]

	Mangrove	Unvegetated. Sediment	Salt/Brackish Marsh	Freshwater Marsh	Freshwater Woodland	**TOTAL**
N America	510	16,906	2,575	192	3,258	**22,931**
Latin America	4,224	9,223	1,707	289	1,010	**12,230**
Europe	0	2,374	500	66	330	**3,271**
Asia	1,439	8,011	1,027	2	657	**9,697**

Africa	3,686	4,632	487	48	310	**5,477**
Australasia	2,253	4,641	461	167	4,090	**9,361**
TOTAL	**12,112**	**45,788**	**6,758**	**765**	**9,657**	**62,967**

Table 10 Total Economic Value of Global Wetlands by Continent and Wetland Type
(thousands of US$ per year, 2000)[56]

	Mangrove	Unvegetated. Sediment	Salt/Brackish Marsh	Freshwater Marsh	Freshwater Woodland	TOTAL
N America	30,014	550,980	29,810	1,728	64,315	**676,846**
Latin America	8,445	104,782	3,129	531	6,125	**123,012**
Europe	0	268,333	12,051	253	19,503	**300,141**
Asia	27,519	1,617,518	23,806	29	149,597	**1,818,534**
Africa	84,994	159,118	2,466	334	9,775	**256,687**
Australasia	34,696	147,779	2,120	960	83,907	**269,462**
TOTAL	**185,667**	**2,848,575**	**73,382**	**3,836**	**333,223**	**3,444,682**

6.3. **Water-related valuation case studies**

We reviewed a number of valuation case studies from the recent literature to gain an appreciation for the state of developments in this arena. The case studies include:

- Concepts and policy applications of agricultural water valuation - Rio Grande Basin
- UK water resource planning
- Bangladesh water development – integrated assessment modelling
- Valuing the indirect watershed benefits of a tropical forest through integrated assessment methods
- Valuing groundwater through integrated quantity and quality modelling
- An iterative choice approach to valuing clean lakes, rivers and streams
- Non-use attributes of wetlands in Greece
- Groundwater valuation using meta-analysis

Concepts and Policy Applications of Agricultural Water Valuation - Rio Grande Basin

Ward and Michelsen[57] conducted a drought policy analysis of the Rio Grande Basin and illustrated water values for agriculture use. Their review identified several issues that should be taken into account in deriving accurate estimates of water value including: establishing common denominators for water values in quantity, time, location and quality; identifying the point of view from which the values are measured; distinguishing the period of adjustment over which values are estimated' and accounting for the differences between total, average, and incremental water value.[58]

The study highlighted that water has economic value only when supply is scarce relative to demand, and additionally, water is different than other scarce resources – it has re-use potential. Water used for one purpose at a given time and location does not necessarily prevent its use elsewhere, or at a later time for a similar or dissimilar purpose. Additionally, the policy review identified that measures of consumption in terms of net stream depletion may be misleading – for example, return flows from irrigation through saline soils may degrade the water quality so that it is not re-useable in any practical planning period.

The study highlights some of the obvious, yet very important differences between total, average and marginal value of water. The marginal value of water is the most useful for policy making because it represents the economic contribution of an incremental unit of water to whatever objective is under consideration. The average value is the total value divided by the total quantity of water supplied and is typically of less interest to policy makers. However, the authors note that its ease of calculation often leads to its use to approximate marginal value – and this is a problem since average value is most often significantly greater than marginal values. Average value is simply not as useful as they are backward looking, value only existing use, and are unable to evaluate plans that would augment current use.[59]

UK Water Resource Planning

McMahon and Postle[60] report on the introduction of Average Incremental Social Cost (AISC) for water resource schemes in the UK and Wales. AISC is based on the calculation of the net present value of the capital and expenditure cost stream. These costs are summed with the net present value of the environmental and social cost streams. This total cost is then divided by the discounted total volume of water from the total water management option that reduces the supply/demand imbalance.

A preliminary methodology was developed with the underlying principle that the value of a unit of water should be maximized it in its use, whether it be for drinking, industry, or ecosystem protection.[61] To distinguish between different water resource management options, the valuation methodology included five sub-components: river abstractions, groundwater abstractions, reservoir construction/usage, intra- and inter-basin transfers, leakage reduction and demand management. Both use and non-use values were estimated and guidelines were developed for valuations in each of the sub-components. The method employed the value transfer method from other studies which had generated per unit estimates of WTP or market-based measures of economic value. The value transfers were adjusted to site-specific conditions to account for the fact that most of the valuation studies available were for low-flow valuation schemes only. Other adjustments include site location and accessibility, and site quality in terms of environmental and aesthetic conditions. One of the *sticky* aspects of this value transfer was how to adjust the low-flow values. The preliminary solution was to assume that there was a link between ecological quality and river flows and that change in ecological quality was an indicator of the relative impacts on recreation, angling and non-use values.[62]

The valuation methodology developed was guided by pragmatism – it was strongly felt that for the method to see any use it had to be straightforward and not overly burdensome in terms of resources needed to conduct the valuation. It was for these reasons that the end unit of economic measurement was aggregated to the extent possible. For example, impacts on recreation were valued in terms of kilometer of river that would be affected by a change in river flow due to abstraction; and wetlands were measured in terms of the general recreation and conservation value of the area.

Bangladesh Water Development – Integrated Assessment Modelling

A modified cost-benefit analysis was conducted by Wattage and Soussan[63] to evaluate development scenarios for water development tin Bangladesh. Net present value was calculated by discounting and summing the annual stream of net benefits over the lifetime of the project. A continuous time calculation was carried out using a spreadsheet model in which environmental benefits and dis-benefits were added to the net development benefit (benefit less cost). The environmental benefits and dis-benefits were determined using the contingent valuation method in site-specific surveys to give insights into non-market aspects such as flood protection, biodiversity, and declining environmental utility.

$$NPV = \int_0^T \{NDB_t - DBP_t + ENB_t\} e^{-rt}\, dt \qquad [1]$$

where
NDB = net development benefits (B_{dt}-C_{dt})
DBP = disbenfits as result of the project
ENB = environmental benefits (CV method).

A scenario analysis was then conducted using the modified cost-benefit analysis based on CV survey results to assess the likely effects on the livelihoods of the residents of 26 different sub-projects of the System Rehabilitation Project (SRP) started in 1982. In their analysis, 10 of 26 projects did not exhibit a net social welfare gain (e.g., a positive NPV), compared to 7 projects as determined using traditional cost benefit analysis.

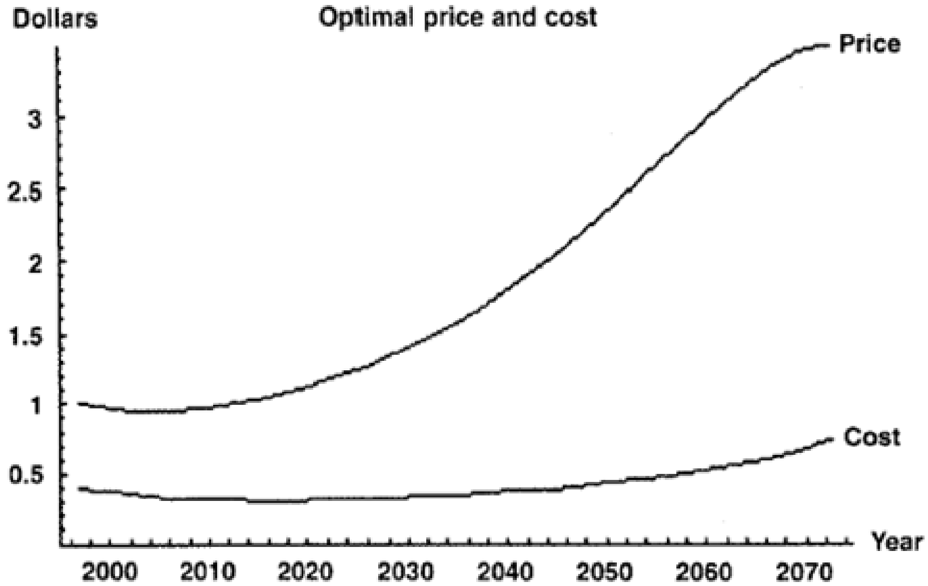
Valuing the Indirect Watershed Benefits of a Tropical Forest through Integrated Assessment Methods

Kaiser and Roumasset[64] illustrate a method for valuing the indirect watershed benefits of a tropical forest without resorting to survey techniques such as CV. The method is a rather sophisticated integrated assessment model that couples the physical processes of groundwater recharge with a dynamic optimal control micro-economic model to determine the value of foregone groundwater recharge – that in the absence of conservation, would be apportioned to runoff. The present value of the water saved through conservation is valued at the shadow prices obtained from the optimal control model. It is recognized that this can only be a lower bound to the value of the forest as groundwater recharge is not the only positive externality of a tropical forest. The method developed was applied to the Ko'olau watershed on the island of Oahu.

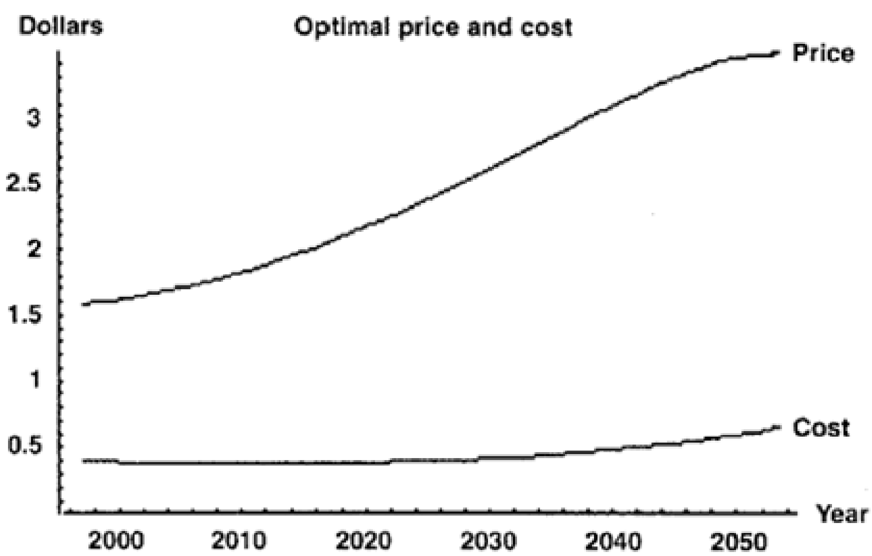
The methodology is based on the rationale that a conservation project that retards depreciation of a watershed's ability to recharge groundwater is analogous to an irrigation project with its present value determined according to the appropriate shadow prices of water in different time periods. The benefit is quantified by calculating the optimal withdrawal pattern from the aquifer with and without conservation, with the benefit represented by the difference in present value between the two scenarios. In other words, the model optimizes social welfare derived from the use of the resource using a demand function for the resource over time. This type of dynamic optimal control and integrated assessment modelling is similar to what is being advanced in green national income accounting for natural resources.[65, 66]

The dynamic optimal control model describes the choice quantities for the consumption of groundwater and desalinized water and forest management expenditures to maximize the consumer surplus associated with water consumption over time. The results of the optimal control problem reveal a net present value of the forests contribution to groundwater recharge at $1.42-$2.63 billion corresponding to 3 percent and 1 percent social discount rates, respectively. The dynamic model results are summarized in Figure 6 which trace the optimal price and cost for a representative gallon of water over time. The area between the optimal price and the extraction cost (i.e., the scarcity rent) is smaller in Figure 6 b which represents deteriorated forest watershed quality. Additionally, the peak in price occurs earlier in Figure 6 b indicating that a switch to desalinated water must occur earlier. In other words, for the conserved forest quality, larger quantities of water can be extracted for a longer time before the island must meet its growth potential through desalinated water.

The authors urge that attempts such as this at integrating the scientific relationships of ecosystem services and the natural resources that we consume with economic valuation should be considered as a viable and valuable approach to measuring economic value for non-market ecosystem services.



a) Current forest quality



b) Deteriorated forest quality

Figure 6. Optimal price and cost for Pearl Harbour Aquifer
(from Kaiser and Roumasset 2002)

Valuing Groundwater through Integrated Quantity and Quality Modelling

A Portuguese policy researcher observed that economic literature on groundwater management has typically focused on either valuation pertaining to pumping costs (quantity focus) or valuations that consider contamination (quality focus). Situations where both quantity- and quantity-like externalities were of concern were few. To study this integrated quantity and quality situation for groundwater, Roseta-Palma[67] used a physical groundwater flow and contaminant transport model as the basis for a dynamic optimal control analysis to determine which extraction paths maximize the net present value. One of the goals of the analysis was to estimate appropriate taxation levels that maximize social welfare.

The methodology used did not involve the estimation of WTP or environmental health damage functions. Instead the method imposed water quality constraints on the management problem – available typically through regulated values. It was also noted in the study that an alternative could be to determine a cost function for treating the water. It is noteworthy that production and pollution functions for this Portuguese study drew heavily from the agricultural contamination literature.

The results of the analysis revealed that for cases involving water quantity management or water quality management separately, existing analytic methods are adequate. However, for the integrated case where water quantity and quality are interacting, existing methods are inadequate and the proposed integrated physical-economic assessment model provides a robust alternative.

An Iterative Choice Approach to Valuing Clean Lakes, Rivers and Streams

The *iterative choice approach* estimates for individuals, the dollar value of changing the percent of lakes in a given region that are rated "good."[68] The information is useful for estimating the value of a given policy or project by assessing the impact on the percent of good water in the region. The innovation in method is that the valuation is specifically conditioned on the characteristics of the respondent and the characteristics of the change in water quality; and therefore, it is proposed by the authors that it is straightforward to adjust for sampling biases or to project expected valuation to any affected population.

This method is a specific improvement to the EPA's water quality ladder approach which values changes in water quality by assuming a particular hierarchy of values (e.g., water that is satisfactory for swimming is also satisfactory for fishing), and it is the author's thesis that this hierarchical simplification is not an accurate reflection of our current scientific knowledge of water quality.[69]

In the *iterative choice approach* individual interviews are used as in traditional CVM; however, this approach is designed to determine the individual preferences based on the valuation of underlying attributes. The approach then considers moves to hypothetical locations for which the different components of the choice are varied – contrasting with traditional CVM and allowing the results to be more generally applied. Finally, and perhaps most central to this approach, is the iterative choices involved. Individuals make a choice between two hypothetical locations that differ in terms of water quality and cost of living. The computer survey then frames subsequent choices until the individual is indifferent to the next choice.

Groundwater Valuation Using Meta-Analysis

Poe *et al*.[70] conducted a preliminary meta-analysis of contingent values for groundwater quality. This analysis suggests that WTP values systematically vary with the explanatory variables which included the following:

- Whether the program focused on values associated with drinking water protection or broad environmental and non-use values associated with aquifer protection;
- Whether the program was for general quality change or specific quality change;
- Whether the program related to quantity or a supply;
- Price of substitution;
- Whether an alarm word was used in study (e.g., cancer);
- Whether or not locality was emphasized;
- Percent of respondents connected to municipal supplies; and
- Survey technique including open-ended survey technique, paycard, or dichotomous choice methods.

The results of the meta-analysis results are provided in Table 11. The authors summarize the analysis by noting that "perhaps the results could be used to provide value estimates for policy decisions"; however, they are extremely cautious noting that amalgamation of a number of studies and theoretical constructs may lead to misleading magnitudes of coefficients.

Table 11 Estimated meta-analysis for ground water willingness-to-pay functions[71a]

Variable	Type of Variable	Expected Sign	Core Economic	Full Complete	Short Complete
Constant			-437.8871	-491.1078	-606.1551
			(122.8006)[b]	(121.8075)[b]	(114.2564)[b]
D(USE)	Binary	-	-525.3888	-440.3059	-378.9782
			(244.1817)[c]	(240.8310)[d]	(175.1660)[c]
D(△PROB)	Binary	?	-150.7279	-174.1401	-214.1035
			(233.1261)	(228.7353)	(220.7103)
△PROB	Continuous	+	1116.1780	1085.1610	1106.0240
			(342.3272)	(348.6740)[b]	(348.0058)[b]
D(△SUPPLY)	Binary	?	401.4944	235.4335	206.1893
			(342.3272)	(221.0381)	(192.1265)
△SUPPLY	Continuous	+	289.1667	289.1667	289.1667
			(0.0000)[bc]	(0.0000)[bc]	(0.0000)[bc]
D($SUBS)	Binary	-	-164.9097	-83.0452	-55.7698
			(193.641)	(128.9884)	(102.5404)
I (thous.)	Continuous	+	12.3259	8.4125	8.5054
			(2.4500)[b]	(2.1409)[b]	(2.2663)[b]
D(CANC)	Binary	+		186.8805	153.8043
				(111.6271)[d]	(90.0627)[d]
D(LOCAL)	Binary	+		-121.1955	
				(146.8399)	
PUBLIC %	Continuous	?		210.4727	212.3484
				(121.8724)[d]	(128.0199)
D(OEaftDC)	Binary	+		73.8525	133.9757
				(52.2359)	(87.3535)
D(PCARD)	Binary	?		-93.5884	
				(86.8525)	
D(DC)	Binary	+		185.2280	214.1465
				(50.1987)[b]	(79.5873)[b]
D(DC-CAM)	Binary	-		-181.0027	-192.8408
				(25.7664)[b]	(33.0719)[b]
D(DC-UTIL)	Binary	?		227.4003	220.0108
				(101.3476)[c]	(97.8578)[c]
N			105	105	105
R^2			0.74	0.83	0.82

Notes

[a]Numbers in () are asymptotic standard errors. The small standard error on the co-efficient for △s is due to the new linearity of the limit number of WTP observations in this sample.

[b]significant at 1% level.

[c]significant at 5% level.

[d]significant at 10% level.

7. Next Steps

The next steps for the 2004-2005 year can be introduced best by referring to AAFC's integrated economic/environmental analysis approach (Figure 7). IISD's focus will be to use the information provided in this paper as the basis for recommending how AAFC might develop the feedback loop that extends from environmental to economic analysis.

This feedback loop is both formal and informal. The formal feedback loop is valuing the changes in agri-environmental indicators to be used as input into the CRAM model for economic analysis. The other feedback loop is more informal as the valuation information for changes in agri-environmental indicators is used not within the models, but more as supporting information for decisions. In both instances however, the information can be used for quantitative trade-off analysis. This articulation of feedback mechanisms will involve several steps over the year. These steps will form the basis for the 2004-2005 work plan that will be submitted to AAFC under separate cover.

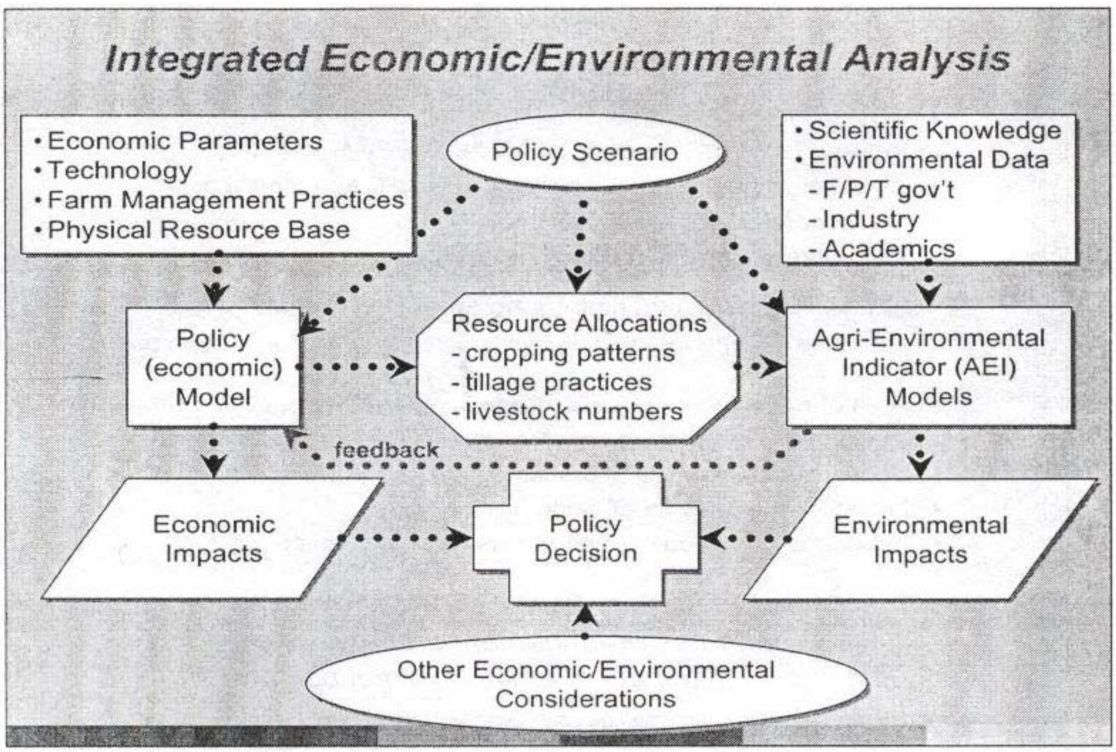


Figure 7. AAFC's integrated economic/environmental analysis approach.

First, we will develop an understanding of the existing models that AAFC uses – the CRAM model and the agri-environmental indicator models of biophysical processes. An important aspect of this understanding is determining how well the input and output from the environmental indicator models can communicate with the associated economic valuations that can potentially be generated or transferred from other areas, and with the CRAM model. This can be done by mentally mapping the spatial scales of the input and outputs for each of these three components. AAFC has already recognized the spatial differences of CRAM (crop production regions based on political boundaries) and the agri-environmental indicator models (SLC polygons of which there are over 3,000 containing significant agricultural land). At a first glance, the economic valuation information is likely to be available at the watershed level or other regional spatial unit.

Another step is for IISD to review the Canadian data sources for economic valuation information related to the agri-environmental indicators, as well as mine the literature for transferable economic valuation information.

This type of integrated systems analysis is inherently complex, and for such systems, a learn-by-doing approach is an effective way to proceed. In the 2004-2005 period, we will identify a location to ground the development and testing of the methods and mechanisms used to close the feedback loop from environmental to economic models. This location would be determined in consultation with AAFC and its regional partners and would be based on data availability and other criteria.

Using available economic valuation data, we will run the models (or work with AAFC to run them) to clarify both data needs and possible modelling modification needs. This will be done for the specific location. The result will be a set of recommendations regarding two issues: priorities for new data gathering possibilities, and steps necessary to extend the modelling exercise from the single location to the provincial (the most influential decision making level) and the national basis. These recommendations can form the basis of the work plan for the following year. These recommendations and the work plan will provide a further articulation of the feedback loop between the CRAM and agri-environmental indicator modelling systems, in order to provide more integrated analysis for decision making.

As an additional step to begin exploring longer-term notions of integrated analysis, IISD will begin to explore the linkages between the economic and agri-environmental modelling work, and the social indicators that IISD is also working on for AAFC. Potentially, this could allow AAFC to add a social dimension to its integrated economic and environmental analysis and therefore, create an integrated sustainability analysis for the APF.

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