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VALUATION OF ECOSYSTEM SERVICES

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The Need for the Valuation of Ecosystem Services

Valuation of environmental functions is needed to help correct economic decisions that treat the environment as if it were a free input, in turn resulting in its misuse and to track their contribution to national income .

- Presentation covers:
  - Conceptual basis for valuation of ecosystem services.
  - Different ecosystems and the associated ecosystem services (ES), and methods of valuation applied to them
  - Applications of the methods to the full range of ES as prepared by the ecosystem service group (WG3)

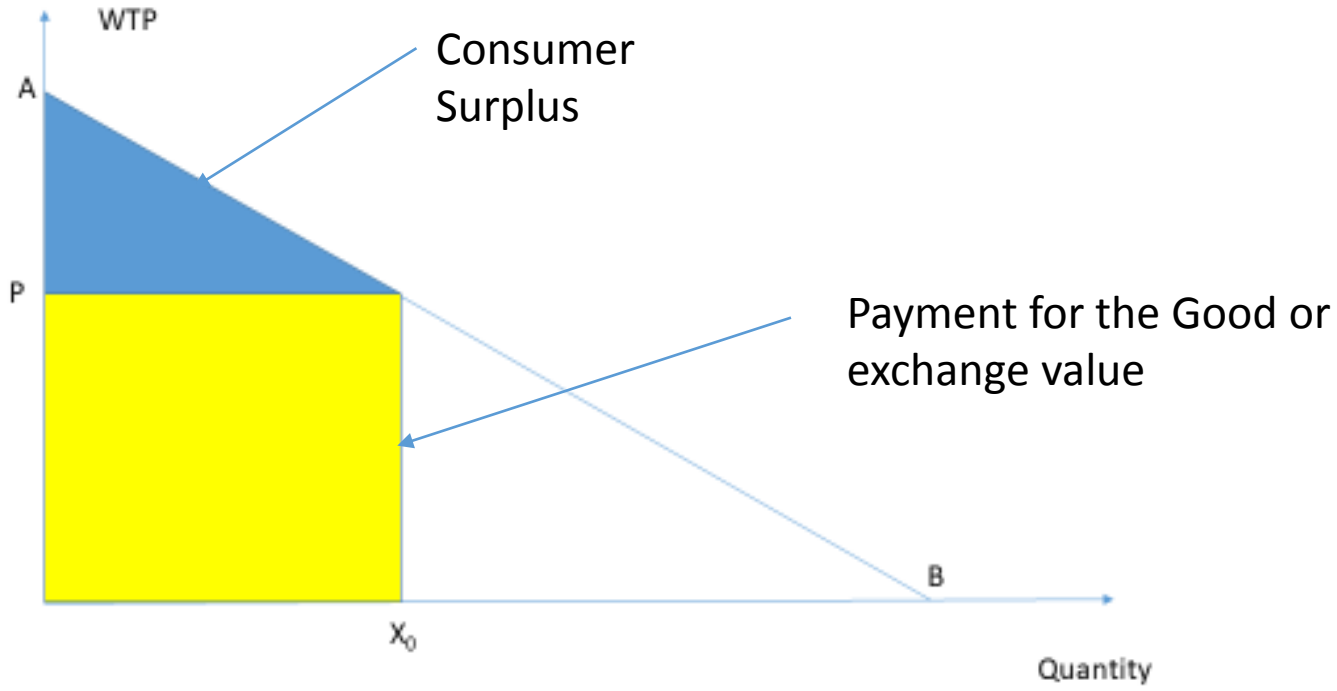
Conceptual Basis for Valuing ES

- Valuation of ES is based on anthropocentric values that are instrumental and quantifiable.
- They can be measured in money values based on the willingness of individuals to pay (WTP) for a given good or service or on their willingness to accept a payment (WTA) for giving up a good or service.
- The WTP and WTA for a good or service can be represented as a ´demand curve´ for a good or service.
- The demand curve obtained from market data assumes that the total income available to the person concerned is constant. As that income changes, so the demand curve will shift, outwards if the good is one where demand rises with income and inwards if it declines.
- Total WTP is made up of actual payment and consumer surplus.

Alternative Value Systems

- A number of value systems argue that some ecosystems have an **intrinsic value,** irrespective of what humans feel about them.
- Quantifying such value systems is more difficult but not impossible. Some parts of an ecosystem may, for example, be regarded as sacrosanct and to be protected under all circumstances. They would lie outside the system of valuation we are proposing here.
- **Relational values,** which aim to bring together both instrumental and intrinsic value systems. Relational values can be defined as the "preferences, principles, and virtues associated with relationships, both interpersonal and as articulated by policies and social norms."
- At present, however, they do not present full alternative that can generate values capable of being integrated in an SNA context.

Payment for a Good and Consumer Surplus



WTP and WTA

- Both WTP and WTP can be represented by demand curves.
- The difference is the assumed level of income of the person whose demand is being represented.
- In the case where the reference point is a loss, WTP < WTA but differences should not be big according to demand theory. They depend how much the loss represents in terms of a reduction in real income.
- In surveys differences between WTP and WTA are much bigger than economic theory would suggest, implying other factors are relevant.
- Where the value of the ES is measured by total WTP or WTA it includes the consumer surplus and not just the exchange value, which is what goes into the SNA.

Common Misconceptions About ES Values

- *Price versus value*: The price of a good is what is paid for it. It is not the full value of the good as there is normally some consumer surplus. The price is the value of the **last** unit purchased, which is also the WTP for that unit. That is also called the **marginal value** of the unit.
- *Cost versus value*: The cost of producing a good or service does not directly relate to its value, although the more expensive it is to produce the higher is its price likely to be, making the marginal value higher. In the SNA a number of goods are valued at cost of production because there is no market for them and hence no price. This is the case with public goods provided by the government and other authorities.

Common Misconceptions About ES Values

- *Exchange values and wellbeing*: The wellbeing derived from a good or service is equal to the WTP for it, which includes the payment made and the consumer surplus. SNA accounts, however, do not take account of the surplus and are based exchange values. How then do these accounts relate to wellbeing?
- The link comes about because the exchange value is also the marginal value of the unit, which is the wellbeing it provides. Thus small variations wellbeing in society are reasonably well represented by the changes in Net Domestic Product (NDP). Thus the change in Gross Domestic Product (GDP) less any additional depreciation, which gives the change in NDP is an approximation for the change in wellbeing generated in society.

Valuation Issues and Methods

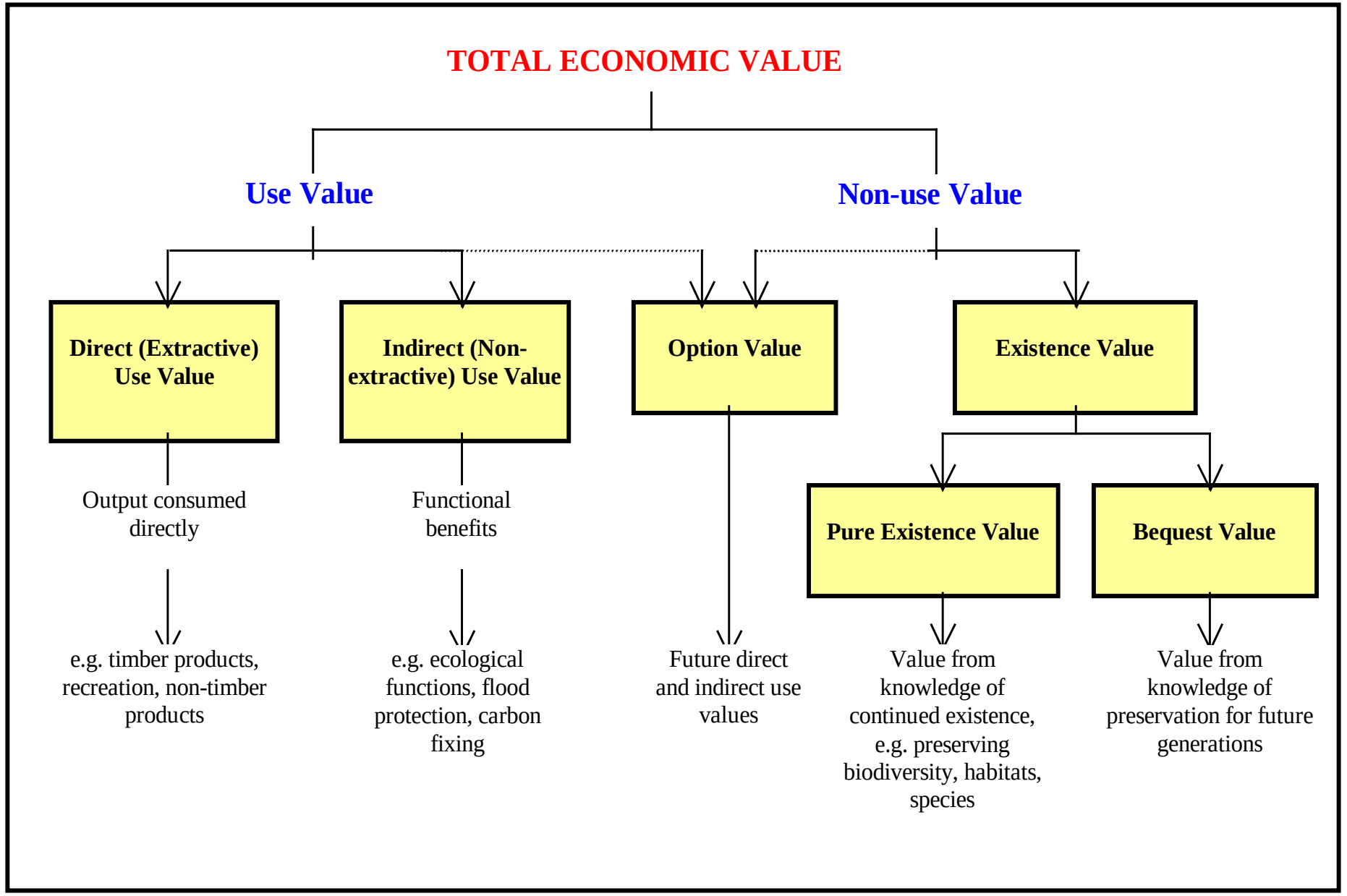
- ES are classified as: **Provisioning**, **Regulation and Maintenance**, and **Cultural**.
- Provisioning services relate to supply of food, energy and materials.
- Regulation and Maintenance services relate to control of wastes, toxics; flows of liquids, solids and gases; and maintenance of physical, chemical, biological conditions.
- Cultural services relate to physical & intellectual interactions with biota/ ecosystems; and to spiritual, symbolic interactions with biota/ ecosystems.

Biomes in Which ES are Derived

Biome (marine/aquatic)	**Biome (terrestrial)**
Marine (Open Oceans)	Freshwater (Rivers/Lakes)
Coral Reefs	Tropical Forests
Coastal Systems	Temperate Forests
Coastal Wetlands	Woodlands
Inland Wetlands	Grasslands

Total Economic Value (TEV)

- TEV is made up of ‘direct use,’ ‘indirect use’ and ‘non-use’ values.
- Direct use can be ‘consumptive’ (e.g. direct harvest of forest products, fish or medicinal plants) or ‘non-consumptive’ (e.g. recreation).
- Indirect use values provide an input into another activity which has economic value, e.g. crop pollination, flood mitigation.
- Non-use values include option, bequest and existence values. Option values are the benefit placed on the potential future ability to use a resource (whether by current or future generations). Bequest value is the value attributed to maintaining something for the benefit of future generations. Existence value is the value obtained from knowing certain things exist for economic, moral, ethical or other reasons.
- TEV has been criticised because it can include double counting and does not separate stock and flow values. It can still provide a useful checklist.



TEV is concerned with the valuation of preferences **held by people**; it does not encompass any value which may intrinsically reside "in" environmental assets.

Estimates of Values of ES in the Literature

- Many ES services have been estimated for selected locations and across all the biomes.
- Estimates of values usually given in USD/ha vary a lot across studies.
- Estimates of different services for a biome cannot be added as regulating services are often the source of provisioning services.
- Also while many ES have been valued there are still gaps. The role of oceans in climate regulation is still being investigated. The same applies to the value of genetic resources and genetic diversity in different biomes and to a number of other categories of services.
- Studies for recreational and cultural services are disproportionately from developed countries

Range of Values for ES (USD/Ha. 2007 Values)

Ecosystem	Mean	Median	Minimum/Mean (%)	Maximum/Mean (%)
Marine	491	135	17%	339%
Coral Reefs	352,915	197,900	10%	603%
Coastal Systems	28,917	26,760	90%	145%
Coastal Wetlands	193,845	12,163	0.2%	458%
Inland Wetlands	25,682	16,534	12%	409%
Rivers and Lakes	4,267	3,938	34%	182%
Tropical Forests	5,264	2,355	30%	396%
Temperate Forests	3,013	1,127	9%	545%
Woodlands	1,588	1,522	86%	138%
Grasslands	2,871	2,698	4%	207%

Methods of Valuation

1. Based on physical linkages between environment and good, services, health.
2. Methods based on revealed preference
   Investigating expenditures made to protect against a bad environment or take advantage of a good one
3. Methods based on stated preference.
   Asking people affected by environmental change how much they value that change.

Methods Based on Physical Linkages

- **Productivity Change Method**. ES is an input into the production function of a marketed good. Changes in the input lead to changes in the output of the marketed good. The value of the change in the ES is therefore estimated as the change in the market value of production consequent upon a change in the ES. *(Care needs to be taken to allow for changes in price of output as a result of the change in input).*
- A special case of this method is the **cost of illness** in terms of loss of output.
- **Replacement Cost method**. Estimates the cost of replacing the ES by something that provides the same benefits but also has with it clearly associated market prices. Validity depends on: i) the substitute providing exactly the same function as the ES; ii) the substitute being the least-cost alternative; and iii) evidence that the producer would demand the substitute.

Methods Based on Physical Linkages

- **Opportunity Cost Approach**. Estimates the value of unpriced goods and services by measuring the forgone benefits of using the same resource for other alternative objectives. For example, preserving forests for a national park rather than harvesting them for timber will be measured by the forgone income from selling timber. *(Assumes the benefits of the preservation are at least equal to the benefits forgone)*
- **Defensive Expenditures.** Individuals spend money on mitigating damages caused by adverse environmental impacts. E.g. double-glazed windows for reducing traffic noise, extra filtration for purifying polluted water, air conditioning for avoiding polluted air. *(Expenditure is a lower bound of the damage as not all impacts are eliminated and people have to change behavior, which has a cost that is not included).*

Revealed Preference and Indirect Proxy

- Based on the assumption that the non-marketed environmental good or service affects the preferences expressed by consumers about other marketed goods or services.
- Their purpose is to identify the relationship between the environmental change and the affected prices of related marketed goods or services.
- The main techniques that fall into this category are the Travel Cost Method (TCM), the Hedonic Price Method (HPM).

Travel Cost Method

- Based on the expenditures incurred by households or individuals to reach a site as a means of measuring WTP for the visit.
- The sum of the cost of travelling (including the opportunity cost of time to travel and visit the site) and any entrance fee gives a proxy for market prices in demand estimation.
- By observing these costs and the number of trips that take place at a range of prices, it is possible to derive a demand curve for the particular environmental good or resource. The area under the demand curve (i.e., the consumer surplus) measures the WTP of consumers for that environmental good or resource.

Travel Cost Method

- TCM is one of the most effective approaches in valuing recreation services.
- Early research using the TCM approach was motivated by estimating the value of visits to recreational sites. In time, the method has been adapted to be able to also value quality changes.
- The last 50 years have witnessed a considerable evolution of travel cost method techniques, from simple aggregate demand models to very sophisticated analysis of individual level choices.
- TCM requires the availability of large data sets on recreational activities, including ideally, GIS analysis of travel cost data and site characteristics. Methods of estimation involve estimation using complex discrete choice econometric methods.

Example of Travel Cost: Change in River Quality in Kruger National Park (KNP)

- A survey was carried out of S. Africans and International visitors to KNP.
- A visitation rate (VR) was calculated for each group, which is the number of visitors from a region (for S. Africa) or country (international) divided by the population of that region/country.
- The cost of a visit to the park was estimated from the entrance fee, costs inside the park plus travel to the park (for international visitors only a share of cost to travel to S. Africa was taken). (TC)
- Two demand curves were estimated: $\ln(VR) = \alpha + \beta TC$. One for S. African and the other for international visitors.

J. Turpie and A. Joubert: (2001) Estimating potential impacts of a change in river quality on the tourism value of KNP: An application of travel cost, contingent and conjoint valuation methods. *Water SA* 27, Nº 3. 2001.

Example of Travel Cost: Change in River Quality in Kruger National Park (KNP)

- The consumer surplus was estimated for each group as area under demand curve multiplied by the population of the sending area.
- To this was added the expenditures inside and outside the park.
- The component benefits were divided into values for visits to Komati Basin and the Crocodile Catchment based on % of time & money spent in these areas.
- The results showed a total value of R384 million for visit to KNP, R236 million for Komati Basin and R85 million for Crocodile Catchment. About 78% was consumer surplus, 10% each was onsite and offsite spending.
- The authors then went on to consider how values would change if Crocodile catchment was degraded if water flows were reduced by using CV methods (discussed next).

Hedonic Pricing

- Estimates the differential premium on property value derived from some environmental attribute. In order to obtain a measure of how the environmental attribute affects the value of houses or other properties, all other variables of the house (number of rooms, central heating, garage space, etc.) and neighborhood need to be included.
- HPM involves collecting large amounts of data on prices and characteristics of properties in an area, and applying statistical techniques to estimate a “hedonic price function”.
- Has been used to estimate the value of ES related to: Water quality; Air quality; Preserved natural areas; Wetlands; Forests; Beaches; Agricultural activities; Nature views; Urban trees; Open spaces.

Hedonic Pricing

- Although widely used, this method has several limits.
- The most important is perhaps the high quality of data required on variables that are seldom recorded in the official statistics even in developed countries.
- Second, to use this method, the housing or property markets must be competitive.
- Third, studies typically focus on a single or a very limited number of environmental attributes, thereby possibly failing to account for the interplay between multiple environmental amenities and housing preferences.
- Lastly, as for the TCM, this method does not capture non-use values.

Example: Water quality

- Leggett and Bockstael (2000) *Journal of Environmental Economics and Management*
- 741 observations
- Effects of Chesapeake Bay water quality on prices of houses located along the bay
- Leggett and Bockstael use the appraised value of houses for size, no of baths etc.
- Water quality is measured using information on the level of pollution of the bay publicly given by the Department of Health of Maryland (fecal coliform concentrations in the water).

Descriptive Statistics

Variable	Description	Media N=741
Price ($1000)	Sale price	335.91
VSTRU	Appraised value of the house	125.84
ACRES	House acreage	0.90
ACSQ	acreage^2	2.42
DISBA	Distance from Baltimore	26.40
DISAN	Distance from Annapolis	13.30
ANBA	DISBA*DISAN	352.50
BDUM	DISBA*(% commuters)	8.04
PLOD	% of land not intensively developed	0.18
PWAT	% of land with water or humid areas	0.32
DBAL	Minimum distance from a polluting source	3.18
F.COL	Median concentration of fecal coliform	109.70

Results

Dependent variable = sale price; Linear model		
	Coefficient	Standard Error
Intercept	238.69	47.44
VSTRU	1.37	0.040
ACRES	116.9	7.62
ACSQ	-7.33	0.79
DISBA	-3.96	1.74
DISAN	-11.80	2.50
ANBA	0.36	0.09
BDUM	-10.2	-0.03
PLOD	71.69	0.27
PWAT	119.97	0.35
DBAL	2.78	2.50
F.COL	-0.052	0.025

‘Welfare’ change

- The presence of fecal coliform is equal to -0.052 dollars per 1,000 dollars of the value of the house

- Suppose fecal coliform increase from 109 (average value) to 159:
- The welfare change is equal to:
- (159-109)*(-0.052) = -2.6

- This means that a person that is buying a house is willing to pay $2,600 more to avoid the increase in the concentration of fecal coliform.

Stated Preference Methods (CV)

- The contingent valuation (CV) method is a survey-based stated preference technique that elicits people´s behaviour through a questionnaire.
- Questionnaire describes a hypothetical market where the good in question can be traded, under a given institutional context and under a given form of payment. Respondents are asked directly for their WTP or WTA for a hypothetical change in the level of provision of the good.
- Major advantage when compared with other methods is that it can be applied to value all goods and services and is the only possible technique for the evaluation of non-use values. Another attraction of this method lies in the fact that in simpler cases it does not require a huge amount of data. Sample size, however, has to more than 500 observations in most cases.

Stated Preference Methods (CV)

- In spite of its widespread use it has been criticized for possible biases:
  - Hypothetical and strategic bias (answers given by respondents are not ´real´ partly because they do not actually make the payments and partly when they have an interest in seeing a higher or lower value)
  - Insensitivity to scope (answers do not vary as one would expect when the scale of what is being covered is increased or decreased significantly)
  - Differences between WTP and WTA
- Over time guidelines for good practice have been developed to limit these biases with some success.
- A comparison of results using CVM methods with those using other methods have found considerable convergence of results. This finding, however, is limited to cases where other revealed preference methods can be applied.

Stated Preference Methods (CV)

- Nevertheless, some problems remain.
- One relates to WTP versus WTA. WTP studies are considered more reliable than WTA. WTA for a loss of ES can be around 7 times greater than WTP. Recent work, however, suggests ways to elicit WTA with less bias.
- Hypothetical bias is still an issue. Comparing CVM studies with cases where actual payment was demanded one finds hypothetical studies exaggerate the payment by about 30 or 40%.
- Insensitivity to scope remains a problem, especially when valuing changes in health risks.

Stated Preference Methods (Discrete Choice)

- Method where an individual is offered a set of alternative goods or services (typically 2 or 3), in which the characteristics vary according to defined dimensions of quality and cost.
- By analyzing preferences across these different bundles it is possible to obtain the value placed by the individuals on each characteristic, as long as the bundles include a cost variable and as long as a baseline option that represents the status quo is included.
- Such models are estimated using maximum likelihood statistical techniques that are now well developed and available as software packages.

Stated Preference Methods (Discrete Choice)

- Similar to CV, choice experiments are based on hypothetical scenarios and non-consequential choices with the caveats that this may imply. Like CV, DCEs are very flexible, and are able to measure future changes as well as non-use values.
- But DCEs have some distinctive characteristics that may differentially affect performance and accuracy.
  - They are particularly suited to situations where ES are multidimensional and where it is useful to know the value attached to different components of a package of services provided by an ecosystem.
  - When valuing multi-attribute programmes, DCE studies can potentially reduce the expense of valuation studies, because of their natural ability to value programme attributes in one questionnaire

Stated Preference Methods (Discrete Choice)

- Weaknesses of DCEs include:
  - The method raises problems of cognitive difficulty in choosing between multiple complex options.
  - It is more difficult for DCE approaches to derive values for a sequences of services delivered over time compared to a CV approach
  - In order to estimate the total value of a good from a DCE, as distinct from that associated with one of its attributes, it is assumed that the value of the whole is equal to the sum of the parts. The “whole” may not be simply additive in this way.
  - There is a bias found for the status quo.

Benefit Transfer Methods

- Studies of the values of ES are location and time specific and do not cover all locations within a country. In these circumstances values that would feed into a set of national accounts would need to draw on data from the limited set to cover the whole country.
- This would involve value or benefit transfer, terms used to refer to using data from given sites and time periods to other sites and time periods.
- Value transfer is now the subject of a large literature dealing with the concerns that the procedures used in such transfer be valid and reliable. The following are 3 common methods used.

Benefit Transfer Methods

- *Unadjusted value transfer.* The procedure here is to "borrow" an estimate of WTP from *S* (the study site) and apply it to *P* (the alternative site). The estimate is usually left unadjusted:
- WTP*S* = WTP*P*.

It fails to capture important differences between the characteristics of an original study site (or sites) and a new site, which arise from socio-economic and demographic characteristics, physical characteristics, market conditions and the difference in time (WTP*S* may be at an earlier time than the WTP*P)*.

Benefit Transfer Methods

- *Adjusted Value Transfer.* Formula for adjusted transfer is:
- WTP*P* = WTP*S* (Y*P*/Y*S*)*e*,
- Where Y is income per capita, WTP is willingness-to-pay, and *e* is the income elasticity of WTP. This last term is an estimate of how the WTP for the (non-market) good in question varies with changes in income).
- According to this expression, if *e* is assumed to be equal to one, then the ratio of WTP at sites *S* and *P* is equivalent to the ratio of per capita incomes at the two sites (i.e. WTP*P*/WTP*S* =Y*P*/Y*S*).
- The factor *e* is used because in meta studies it is often found to be the most important factor determining differences between sites.

Benefit Transfer Methods

- *Value Function Transfer.* If it is known that WTP at the study site is a function of a range of physical features of the site and its use as well as the socio-economic characteristics of the population at the site, then this information itself can be used as part of the transfer. For example a regression estimate may be made to show:
- $WTPS = a_0 + a_1As + a_2Bs + a_3Cs + a_4Ys$,
- Where terms a_i refer to the coefficients which quantify the change in WTP as a result of a (marginal) change in the corresponding variable.
- Then replacing the values of As, Bs, Cs and Ys with those in site P gives the WTP*P.*
- An extension of this is when the WTP function is estimated from data on the WTP in several sites. Such a function is referred to as **meta analysis**.

Benefit Transfer Methods

- Studies show that possible ranges of error in using even sophisticated benefit transfer methods can large. Controlling for extreme outliers, however, the average transfer error is about 40%.
- More sophisticated approaches (based on benefit function transfers) outperformed simpler approaches (based on largely unadjusted value transfers) in terms of reducing the likely error range
- Geographical proximity between policy and study sites reduces transfer error.
- Transfer errors are smaller for policies involving changes in environmental quantities than for those involving changes in environmental quality.

Valuation Methods Applied to Different ES

- SEEA has sought advice on valuing ES for a range of specific ES.
- In each case the question is which method to use and how estimate can be related to values that could be used in an SNA.
- ES covered are:
  - Cultivated biomass from agriculture, forestry and fisheries
  - Uncultivated biomass from agriculture, forestry and fisheries & marine environments
  - Carbon sequestration
  - Air filtration
  - Soil erosion prevention
  - Water purification
  - Water regulation
  - Water supply
  - Recreation enabling services
  - Habitat and biodiversity related services

Cultivated biomass from agriculture

- The contribution of land as an ES is equal to the payment it receives for the production of the crops.
- If there is no market for land, its contribution may be deduced from a production function for the crops; or as a residual from the value of the crops when payments to all other factors have been subtracted but residual value methods can give unstable values when the production chain is complex.
- The same applies in the case of pasture when there is a market for pasture land. When there is no such market, or when the land is not privately owned it may be estimated as for cropland.

Cultivated biomass from forestry

- Timber and other biomass from forests are valued using market prices and the contribution of the forest ecosystem to the final value can be calculated as for cropland if the forest land has a market rental value.
- If there is no explicit rental market, an implicit rental value can be calculated from the price of the land as an asset, given the market rate of discount.
- Not all forest land is privately owned; some is under public ownership and some has unclear, unknown or disputed ownership. If a private firm pays a price for the right to harvest the timber or related product from such forests (i.e. the stumpage value) this can be taken as the basis for calculating contribution of the ecosystem to the final product. Since that will include costs incurred by the state or other agents in managing such land, however, those costs need to be netted out from the stumpage value to get the contribution of the ES.

Cultivated biomass from fisheries

- Cultivated biomass here refers to aquaculture where the ecosystem provides the basis for producing the fisheries. Production function estimates have been made for aquaculture from which the marginal value product of the pond area can be estimated.
- Alternatively, one can start with the value of the final product and subtract the contribution of each paid input, such as labour, capital etc. The residual can then be considered as the contribution of the ES.
- The problem with this approach is that there are often other non-paid inputs into the production process so the residual is not only the return on the pond area. Furthermore, the residual is sensitive to changes in prices of outputs and inputs that vary under market conditions, making the calculation unstable.

Uncultivated Biomass from Agriculture

- For natural pasture a replacement cost approach can been adopted, using the least cost substitute for forage from pasture to value the ES.
- An alternative is to value the forage in terms of its contribution to meat and milk production via a production function but this can only be applied if one is considering a small loss of forage.
- A third possibility is to start with the value of the meat and milk production and subtract the contribution of each paid input, such as labour, capital etc., as was explained for the case of aquaculture. As in that case, however, the residual is not only the return on the natural pasture and residual tends to give an unstable figure.

Other Uncultivated Biomass

- Wild animals provide meat and other products as a positive ES, but they are also responsible for damage to crops and livestock, creating a negative ES.
- Meat and other products from wild animals are sold and thus have market prices, which can be used to value the quantities that are known to be consumed in the home. These prices may include some processing and marketing costs, which need to be netted out to obtain the residual value of the ES.
- Damages caused by wild animals could be estimated using the market value of such damages.

Uncultivated Biomass from forestry

- Timber products are frequently extracted from publicly owned land, in many cases illegally. This makes it difficult to estimate the volumes. Nevertheless, estimates exist of such extraction and its processing through market institutions has been traced.
- Where data on final output are available they can be worked back through the value chain to identify the source of the material. That source can be valued based on data from stumpage values for similar biomass on cultivated land.
- Account needs to be taken, however, of the damages done during the extraction of the biomass to other forest ecosystem services, such as sequestration

Uncultivated biomass: fishery & marine environment

- For fisheries estimates of production functions have been made in a number of studies, in which the catch is regressed on inputs measure the effort made to catch fish (boats, gear, personnel) and the stock of fish available. From this the marginal product of the stock can be estimated but account has to be taken of quality of habitat.
- Seagrasses valuations include direct use of dead seagrass as insulation and formation of dykes; indirect uses to reduce the impact of wave action, thus reducing erosion and reducing sedimentation; and providing a nursery for juveniles of various fish species.
- The productivity method has linked seagrass ES to market values through their contributions to fish catch-per-unit effort but there are some criticisms about the way in which this contribution is measured and there is scope for improving the methods. In principle, productivity methods can capture most of the ES seagrasses provide, with most of them having market prices and others such as organic carbon storage capable of being valued by other methods.

Carbon Sequestration

- There are a number of ecosystems that provide the service of carbon sequestration. Primary among these are forests but this role is also played by grasslands, seagrasses and others.
- Measurement of the amount of carbon sequestered by a given ecosystem is a complex function of the local characteristics of the system and will vary from one location to another.
- Given the amount of carbon stored in any one year, its value per tonne is a global figure that applies in all situations. It has been calculated from models that estimate the damages caused by a small increase in the amount of carbon based greenhouse gases in the atmosphere. Because these gases are present for a long time, the damages they cause will also occur over a number of years.
- Based on a review of the different models the document gives a range of USD14.9-80.5/tonne CO_2 in 2020 rising to USD 19.8-94.1/tonne CO_2 in 2030.
- The other option is to value carbon at the marginal cost of reducing CO_2 per tone. SEEA has recommended this method.

Air Filtration

- Urban plantations of trees indirectly impact human health by improving air quality by dry deposition of air pollutants on the surface of leafs, twigs, branches and trunks.
- However, it is important to take into account that some trees have a greater net effect than others and volatile organic compounds (VOC) from some species can interact with sunlight and nitrogen oxides from fossil fuel emissions to produce ozone and other air pollutants.
- Another indirect health benefit of such trees is the capacity to buffer extreme temperatures.
- The valuation of these services is related to the reduced health costs and gain of wellbeing associated with less exposure to harmful air pollutants. Estimation methods have been developed and applied to value various reductions in concentrations of pollutants.
- Note that filtration will reduce health expenditures, so link to the SNA expenditures will be negative!

Soil Erosion Prevention

- Ecosystems that prevent soil erosion include planting of trees on sloping land and as wind breaks, planting vegetation as ground cover.
- Benefits can be derived from the gain in yields from less erosion, valued using the value-added per unit gain in yield. In addition, erosion causes damages through siltation of water bodies and loss of habitat that has to be included.
- A second approach is to value the erosion in terms of the additional energy, nutrients and water needed to maintain a given level of production, as well as the costs of siltation and damage caused by soil particles entering streams and rivers and harming habitats as a result of the erosion.
- A sophisticated study based on the first approach has modelled the relationship between soil organic matter (SOM) and ecosystem functions (EF) of soil water storage and nitrogen mineralization to ecosystem services (ES) of food and fodder production and carbon sequestration using a soil–plant–atmosphere system dynamic model, which simulates plant growth and soil processes. This can form the basis of a value of the loss of SOM.

Water Purification

- The services of water purification are similar to those of avoided erosion; where an ecosystem, such as a protected forest or wetland provides such services, they can be valued in terms of the costs avoided in treating the water by other means or the costs of maintaining the purification services of the ecosystem.
- A well-known example is New York City, where about 90% of the water never sees the inside of a filtration plant, flowing from huge reservoirs as far as 125 miles away in the rural Catskill Mountains. New York has spent more than $1.7 billion to protect this unfiltered water supply since the early 1990s. The value of the service provided by the mountains is the avoided costs of filtration. If the city did not have this service it would have to spend more than $10 billion to build a massive filtration plant, and at least another $100 million annually on its operation — which would be “the largest capital project that the city has ever taken on.”
- The value of the ES provided each year could be estimated as: (a) avoided filtration costs, or (b) the amortization of the capital expenditures plus the annual operation expenditures. The avoided costs are an upper bound of the value while the actual expenditures are a lower bound.

Water Regulation

- Water regulation services consist of: maintenance of base flow rate for rivers; coastal flood (tidal surge) mitigation; fluvial flood mitigation and pluvial flood mitigation.
- Where water flow rates are maintained at levels that meet minimum requirements for fish and plant and animal life to survive, the value of that maintenance is based on the value of the services provided by the living organisms in the water. For commercial fishery it is the value added; for recreational fishery one of the recreational ES models would have to be used to value the ES.
- The three mitigation services are individually valued on the basis of measurement of the demand for and supply of reduced flood risk.

Water Regulation

- The demand for water flow regulation by ecosystems is defined by the benefits of reduced flood risk made up of reduced damage costs to assets and people in the event of a flood; and mitigation costs including flood protective infrastructure/measures (e.g. levies, dikes, seawalls, beach nourishment), relocation, and avertive/defensive behavior (e.g. growing flood resistant crops).
- The supply of water flow regulation by ecosystems is defined by the capacity to provide the service and the cost of doing so.
- The value of the service, if provided, will lie somewhere between the demand based value (an upper bound) and cost of supply (a lower bound).

Water Supply

- If water as an ES is valued in accounting terms, it will need to draw on data for the price of water (if such exists) and net out the costs of treatment and delivery to get a residual value.
- As noted earlier, however, this method produces unreliable results when the intervening stages are long and complex.
- Alternatively, a production function approach can be used as is done in CGE studies as well as in studies of the contribution of water to the production of different crops. The estimation of the parameters of the production function at the sector level remains problematic, with the functions used in the CGE models drawing on judgments about the right form of the function to use.
- At the micro level there are more data that can give estimates of the marginal value of the input water, and from that a value of the contribution of water to the value added can be obtained.

Recreation Enabling Services

- Ecosystems provide a range of recreational and cultural services in urban and non-urban areas. Places where the activities take place are usually public areas with access that can be free or based on some payment.
- Where a charge is made for access to the location it usually covers some of the costs of maintenance but this is not a ´price´ based on equating the demand for the service to the supply. Such an equilibrium price would lie somewhere between the full cost of provision of the service and the value to the users of the service.
- Supply costs can be estimated based on costs of maintenance plus costs of increasing the level of service to provide recreation for more people.
- Methods for estimating the demand were discussed earlier. The most common are revealed preference methods based on travel cost and hedonic pricing, and stated preference methods based on contingent valuation and discrete choice techniques.
- The ¨market price¨ for the service will lie somewhere between the demand marginal WTP and the marginal cost of supply. Methods to determine where are being researched.

Habitat and Biodiversity-Related Services

- Habitat provision as a means of conservation of valued species is complex as such species may have a link to provisioning services (such as genetic material for drugs), as well as to cultural services to individuals and societies.
- In the case of provisioning services a number of transactions have been made in which commercial interests, particularly in the pharmaceutical industry have made payments for exclusive access to genetic materials. These can be used to value areas with no transactions using benefit transfer methods.
- In the case of sites of cultural interest travel cost and stated preference methods have been used to elicit the values of visits to such sites.
- Where the value of interest is a non-use value, studies have used stated preference methods to obtain estimate of the WTP to preserve threatened, endangered and rare species. As with the previous case of visits to cultural sites such values relate to when there is no market transaction involved.

EXAMPLES OF STUDIES COMBINING SOME THE METHODS DESCRIBED

Valuing Wetland Services: SW Cape in S. Africa

Problem	Wetlands remove pollutants such as nitrogen from the water, which mean less treatment cost for using it for drinking
Method	Removal rates for nitrites+ nitrate nitrogen (NO3+NO2), ammonium nitrogen (NH4-N) at sampling points were regressed against the % area of land that was wetland for each sub catchment. Coefficients for wetland was significant.
Valuation	The removal of N per unit area per year was estimated from the regressions at 1,594 +/- 1,375 kg N per ha per year. This was valued at the cost of removing it using water treatment.
Result	The value of the wetland comes out at USD1,913+/- 1,651 per ha. per year.
Question	It would be nice to know what was the opportunity cost of keeping the wetland – i.e. was it more or less than the value of this service?

See: Turpie, J. et al. Wetland ecosystem services and their valuation: a review of current understanding and practice WRC Report No. TT 440/09 2010.

Valuing Mangrove Services: Gazi in Kenya

Problem	**A mangrove was replanted with r*hizophora mucronata* at Ghazi Bay in Kenya. The question is, what was the value of the plantation?**
Method	Area of 700 ha, with population of 1,000 was assessed for services in 2006 from a planation made in 1994
Valuation	Wood and firewood were valued at market prices less cost of collection. Fisheries were valued at total catch less cost of catch Carbon sequestration was valued at the amount of carbon in the biomass valued at international prices per ton Shoreline protection was valued at replacement cost, which was cost of constructing a sea wall 55km from Gazi Education & research valued at cost of research budget
Result	Values came out USD2,903 /ha/yr. 55% was shoreline protection, education was 29%. Cost of establishing mangrove was USD70/ha.yr.
Questions	Values for education and shoreline may be questioned. Values for wood and fish need to be sustainable.

See: Kairo J, Wanjiru C and Ochiewo J, Net Pay: Economic Analysis of a Replanted Mangrove Plantation in Kenya May 2009 Journal of Sustainable Forestry 28(3-5):395-414

Valuing Floodplain Re-indundation in Cameroon

Problem	The Waza Logone floodplain was degraded as a result of a dam which created a reservoir (Lake Maga). The question was whether engineering work to release water to the floodplain was justified in terms of ESS provided.
Method	Different options for flood release were evaluated in terms of fisheries, dry season pasture, crop production in dry season, transport on water, recovery of wildlife. Also flooding created some losses, which had to be deducted.
Valuation	Techniques for valuation are detailed on the next slides.
Result	Benefits per Km^2 were calculated for 3 engineering flooding options Maximum (X), Middle (Y) and Minimum (Z). The costs of each were compared with the additional benefits from pasture, crops and fisheries. Benefits come over time so a net NPV was calculated showing X to be the best up to 12% discount rate. At higher rates Y and Z may be better.
Questions	Real CBA (rare!). Timing of benefits are uncertain as are costs so sensitivity analysis needed.

See: Emerton L., 2002, The return of the water: Restoring the Waza Logone Floodplain in Cameroon, IUCN Wetlands and Water Resources Programme

Conclusions

- Valuing of ES is a well developed field of research.
- It is based on the theory of value where WTP and WTA are the foundations.
- Values have been obtained for a wide range of services and methods have improved a lot over the last 50 years but there are still gaps.
- In applying these values in an accounting context it will often be necessary to transfer values from studies of specific sites to others where there are studies. This gives rise to some errors but is unavoidable and should be done taking account of differences as much as possible.
- For a number of ES the estimated values are total WTP and include consumer surplus. They cannot then be used directly in an SNA context but can provide a basis for estimating what an exchange value, which could be used would be. Work on this is ongoing.