24 Economic valuation of marine ecosystem services: Methodological issues and challenges

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The environment and the economy

The economy has a complex relationship with the environment. The environment not only provides the raw materials and energy for the production of goods and services that support people's lifestyles, but also sustains damage through the activities of households and businesses. Environmental economics, being a sub-field of economics, is concerned with environmental issues. According to the quoting from the National Bureau of Economic Research Environmental Economics program, "Environmental Economics undertakes theoretical or empirical studies of the economic effects of national or local environmental policies around the world. Particular issues include the costs and benefits of alternative environmental policies to deal with air pollution, water quality, toxic substances, solid waste, and global warming''. Environmental economics seeks to assess various losses due to the economic activities and to fix upon the most competent way to reduce them, as well as to compare the cost of environmental damage to the cost of mitigation.

The processes by which the resources such as clean water, timber, habitat for fisheries, pollination of native and agricultural plants, etc produced by the environment is known as ''Ecosystem services''. An ecosystem is a community of animals and plants interacting one another along with the physical and chemical components, such as soils, water, and nutrients that support organisms living within them. While it is often impossible to place an accurate monetary amount on ecosystem services, we can calculate some of the financial values. Many of these services are performed seemingly for "free," yet are worth many trillions of dollars, for example: 80% of the world's population relies upon natural medicinal products. Of the top 150 prescription drugs used in the U.S., 118 originate from natural sources: 74% from plants, 18% from fungi, 5% from bacteria, and 3% from one vertebrate (snake species). Nine of the top ten drugs originate from natural plant products. Hence, it is very important to be aware of the relevance of ecosystem services in human life. The choices we make today in how we use ecosystem services will have enormous consequences on the future sustainability of earth's ecosystems and the services they provide.

The marine ecosystem

Marine and coastal wetlands encompass the enormous variety of marine and coastal species and open sea habitats and ecosystems, and the wealth of ecological processes that support all of these. Considering marine ecosystems, they are among the largest of Earth's aquatic ecosystems including oceans, salt marsh and intertidal ecology, estuaries and lagoons, mangroves and coral reefs, the deep sea and the sea floor. Marine ecosystems are very important for the overall health of both marine and terrestrial environments. According to the World Resource Center, coastal habitats alone account for approximately 1/3 of all marine biological productivity, and estuarine ecosystems (i.e., salt marshes, sea grasses, mangrove forests) are among the most productive regions on the planet. In addition, other marine ecosystems such as coral reefs provide food and shelter to the highest levels of marine diversity in the world. Marine ecosystems usually have a large biodiversity and are therefore thought to have a good resistance against invasive species.

Coastal zone has high biological potential as it serves as feeding, nursery and spawning grounds with rich biodiversity and as an intermediary biotope between marine and freshwater environments.

The marine fauna of India is rich and varied. The coastline encompasses almost all types of intertidal habitat, from hyper saline and brackish lagoons, estuaries, and coastal marsh and mudflats, to sandy and rocky shores with every degree of exposure and widely varying profile. Tropical marine ecosystem of Indian coast includes lagoons, mangrove swamps, sandy and rocky shores and opens sea front.

Marine ecosystem services

Below given are the brief description of the different biomes of the coastal and marine ecosystem and their corresponding ecosystem services (Fig 1.)

a) Coastal systems and subtypes

i. Estuaries, marshes, salt ponds, and lagoons

Estuaries are defined as partially enclosed coastal body of water which is either permanently or periodically open to the sea and within which there is a measurable variation of salinity due to the mixture of sea water with freshwater derived from land drainage. Coastal marshes and lagoons are also included within the estuaries. Estuaries, marshes and lagoons play a key role in maintaining hydrological balance, filtering water of pollutants, and providing habitat for birds, fish, and mollusks, crustaceans, and other kinds of ecologically and commercially important organisms. The estuaries are important nursery areas for fisheries and other species and form one of the strongest linkages between coastal, marine, and freshwater systems and the ecosystem services they provide. The main threats facing estuarine systems include coastal development, pollution, changes to hydrology, as well as upstream threats.

ii. Mangroves

Mangroves are trees and shrubs that grow in intertidal zones and estuarine margins that have adapted to living in saline water, either continually or during high tides. Mangroves grow under various salinity levels ranging from fresh water to 2.5 times seawater strength (66 ppm). Mangroves are classified into three major zones based on dominant physical processes and geomorphological characters: tide dominated fringing mangroves, river-dominated riverine mangroves, and interior basin mangroves. Mangroves are also a vital source for carbon sequestration. The main ecosystem services provided by the mangroves include land stabilization, nutrient cycling, processing pollutants (including adsorption of heavy metals), supporting nursery habitats for marine organisms, and providing fuel wood, timber, fisheries resources, and serve as buffer zones from storms. The main threats facing mangrove forests include removal, aquaculture, forest use, and freshwater diversion.

iii. Intertidal habitats, deltas, beaches, dunes

Intertidal habitats provide ecosystem services such as food, shoreline stabilization, maintenance of biodiversity, and recreation. Mudflats are critical habitat for migrating shorebirds and many marine organisms, including commercially important species like the horseshoe crab and a variety of clam species. Coastal deltas are important microcosms where many dynamic processes and human activity converge. Beaches and sandy shores also provide ecological services and are being altered worldwide. Sandy shores have undergone massive alterations due to coastal development, pollution, erosion, storms, alteration of freshwater hydrology, sand mining, groundwater use, and harvesting of organisms. Beaches provide feeding grounds for migratory birds, provide nesting habitat, deliver land-based nutrients to the near shore coastal system, and provide both food and recreational space to humans. Removal of beach wrack near urban centers and tourism resorts also alters habitat and services.

iv. Coral reefs and atolls

Reef formations occur as barrier reefs, atolls, fringing reefs, or patch reefs, or a combination of these formations mainly in relatively nutrient poor waters of the tropics, and are known to provide a variety of provisioning, regulating, and cultural services. Among the provisioning services is their contribution to fisheries products (e.g., nutrition and livelihoods to coastal communities) as well as to pharmaceutical compounds and bio-prospecting; they also provide regulating services such as the formation of beaches (important to tourism), and buffering of coastal area again the impact of waves and storm surges. As the most diverse ecosystems in the ocean, if not the planet, they act as absorbers of biological carbon, thereby coral reefs play an important regulatory role in nutrient and carbon cycling. However, the most well known services of this ecosystem are the cultural services with respect to tourism related activities. Although coral reefs are also a source of construction material for coastal communities, and of curios and ornamentals for the aquarium industry, these are not environmentally sustainable activities. Human induced stress on reefs, such as coastal construction, pollution, destructive land use practices, as well as warming seawater and climate change lead directly or indirectly to coral reef degradation and have placed coral reefs on an accelerated path to ecosystem collapse in many parts of the world.

v. Seagrass beds or meadows

Seagrass is a generic term for the flowering plants that usually colonize soft-bottom areas of the oceans from the tropics to the temperate zones, and tropical Seagrass beds can occur in association with coral reefs as well as in their absence. Seagrass provides a range of ecosystem services including habitat and food services for coral reef fish and invertebrates including species that are used in traditional medicine, seafood, fodder, agar, carageenan, paper, and flour, as well as stabilizing coastal sediments and shorelines, and filtering sediment from coastal waters that might otherwise smother coral reefs. Seagrass beds are threatened by human activities in coastal areas such as construction and dredging, anchoring, habitat conversion, pollution, and are also affected by climate change .

vi. Kelp forests

Kelp forests are temperate ecosystems that have a complex biological structure organized around large brown algae, supporting a high diversity of species interactions. Kelp forests provide provisioning and regulating services as they support invertebrate and finfish fisheries and are themselves harvested for food and additives; protection against wave and storm impacts; and are nursery habits for some species. Most of the kelp forests worldwide have been degraded and there is no kelp forest in its natural condition. One of the main threats to kelp forests is the removal of predators like sea otters; this causes the proliferation of sea urchins, which in turn graze on the kelp.

vii. Other benthic communities: Rock and shell reefs, mud flats, coastal surmounts, and rises.

Other rock communities provide a variety of ecosystem services: rock reefs provide rich nursery habitat for fisheries; mud flats are productive habitats that exhibit high species diversity; hard-bottom habitats below the photic zone are dominated by sponges, corals, bryozoans, and compound ascidians. Most of these temperate, non-reef-building corals are found in deeper waters beyond the coastal limit, although their ecosystem dynamics and the threats facing them are similar to many coastal systems. Human induced disturbances can cause major ecological damage and compromise biodiversity, regardless of whether these communities occur more inshore of offshore. Bottom trawling and other fishing methods that rake the benthos have destroyed many of these communities already.

viii. Semi enclosed seas

The semi enclosed seas are defined as a gulf, basin or sea surrounded by two or more states and connected to another sea or the ocean by a narrow outlet or consisting entirely or primarily of the territorial seas and exclusive economic zones of two of more coastal states such as, Mediterranean Sea, Red Sea, Black Sea, and Baltic Sea. The Millennium Ecosystem Assessment report notes the high productivity of these ecosystems and high species diversity and endemism. At the same time semi enclosed seas are adversely affected by pollution and the heavy extractive use of surrounding communities and countries.

b) Marine system

The marine system is defined as the sea that is deeper than 50 m below sea level, and is the main source of fishing. The Millennium Ecosystem Assessment classifies the marine system into four biomes: the coastal boundary zone, trade-winds, westerlies, and polar. The coastal boundary zone that surrounds the continents is the most productive part of the world ocean, yielding about 90% of marine fisheries catches, while the other three biomes are less productive, and their deep waters are exploited mainly for their large pelagic fish.

For purposes of classifying the valuation studies, those studies that provide valuation for fisheries within an identified coastal zone ecosystem, have been classified as provisioning service of that ecosystem. While those valuation studies that refer to open seas fisheries were classified under general marine provisioning service.

Ecosystem services may be divided into four categories: provisioning, regulating, cultural, and supporting services . Below is a brief description of each of these services:

(a) Provisioning services are defined as those that result in products obtained from ecosystems (in some cases referred to as production services). These include:

i. Food: Marine ecosystems provide ample provisioning services including fish from marine and capture fisheries, marine products, and aquaculture products. Both total and per capita fish consumption have grown over the past four decades leading to over fishing and over exploitation of marine fishery resources, which in turn reflected in increases in real prices of fish products. While traditional aquaculture is generally sustainable, an increasing share of aquaculture uses carnivorous species, and this puts increased pressure on other fisheries to provide fishmeal as feed and also exacerbates waste problems. Shrimp farming often results in severe damage to mangrove ecosystems, although some countries have taken steps to reduce these harmful impacts.

ii. Fiber, timbres, and fuel: Even though marine ecosystems are not usually associated with fiber, timbres and fuel, nevertheless mangroves are an important source of these. Coastal communities rely on mangroves for mangroves for building, manufacturing, fuel, and other needs.

iii. Medicines and other resources: A wide variety of species—microbial, plant, and animal— and their genes contribute to commercial products in such industries as pharmaceuticals, botanical medicines, crop protection, cosmetics, horticulture, agricultural seeds, environmental monitoring and a variety of manufacturing and construction sectors. Several marine ecosystems provide habitat or are direct resource for medicinal resources. For example, several species of fin fishes are used in Nigeria in traditional medicinal recipes, other species such as algae are researched for use in Alzheimer's disease. Shrimp and crabs are two important sources of chitin and chitosan (one of chitin deliverables) that has high value-added applications in medicine and cosmetics; coral (which has a similar chemical composition to human bone) is used as a bone supplement; sponges and tunicates have been used to cure certain forms of cancer , and omega 3 fatty acids, derived from fish oil, are widely used as nutritional supplements.

(b) Regulating services are defined as those that regulate ecosystem processes:

i. Biological regulation: which includes regulating interactions between different trophic levels thus preserving functional diversity and interactions. An important example are the urchin barrens which used to be kelp forests that have been reduced to mostly urchin species due to the over-fishing that reduces natural predators of urchins. Almost no kelp forest exists in its natural state today.

ii. Freshwater storage and retention: storage and retention of water; provision of water for irrigation and for drinking. This ecosystem service is most relevant to freshwater estuaries and wetlands.

iii. Hydrological balance: even though this mostly concerns groundwater recharge / discharge in terrestrial ecosystems, some features of marine ecosystem also exhibit this service. For example, the coral reef carst material acts as regulator of groundwater discharge and mineral leaching.

iv. Atmospheric and climate regulation: marine ecosystems affect and are affected by atmospheric and climate conditions. For example, while marine plants fix atmospheric CO_2, they return it via respiration; moreover, dead organisms, particles, and dissolved organic carbon form carbon sinks in the deep ocean, some of which remains sequestered in the sediment while the remaining is respired at depth and eventually re-circulated to the surface (the biological pump). At present, several sources are proposing the restoration of mangroves as use for carbon sinks. Moreover, the reduction in number of ocean vertebrate species hinders the functioning of marine ecosystems and leads to significant reduction in the ocean's carbon sink ability.

v. Human disease control: The marine ecosystems contribute to regulating conditions that affect public health. An example of such is the red tide phenomenon, which results from the proliferation of certain type of algae (K. brevis) which produce powerful toxins called brevetoxins that not only result in death of millions of fish and other marine species, but also could accumulate in tissue of shellfish, which, if ingested leads to severe gastrointestinal and neurological symptoms.

vi. Waste processing: marine ecosystems vary in their ability to absorb wastes and to detoxify, process, and sequester them, depending on the type of wastes, concentration, loading rates, and type of ecosystem. An example of marine ecosystem waste processing is the mangroves' ability to adsorb heavy metals and other pollutants, thus reducing their concentrations in marine environment. In addition, the bioturbation activity of faunal organisms within the seabed can bury, sequester, and process waste material through assimilation and chemical alteration.

vii. Flood/storm protection: This function relates to the ability of ecosystems to ameliorate natural hazards and disruptive natural events. For example, vegetative structure can alter potentially catastrophic effects of storms, floods and droughts through its storage capacity and surface resistance; coral reefs buffer waves and protect adjacent coastlines from storm damage. The services provided by this function relate to providing safety of human life and human constructions.

viii. Erosion control: The soil retention function mainly depends on the structural aspects of ecosystems, especially vegetation cover and root system. Tree roots stabilize the soil and foliage intercepts rainfall thus preventing compaction and erosion of bare soil. Plants growing along shorelines and (submerged) vegetation in near-coastal areas contribute greatly to controlling erosion and facilitating sedimentation. The services provided by this function are very important to maintain agricultural productivity and prevent damage due to soil erosion (both from land slides and dust bowls).

(c) Cultural services are the nonmaterial benefits people obtain from ecosystems

Human cultures, knowledge systems, religions, social interactions, and amenity services have been influenced and shaped by the nature of ecosystems. At the same time, humankind has influenced and shaped its environment to enhance the availability of certain valued services. There are six main types of cultural and amenity services provided by ecosystems: cultural diversity and identity; cultural landscapes and heritage values; spiritual services; inspiration (such as for arts and folklore); aesthetics; and recreation and tourism, because global aggregated information on the condition of cultural services was limited (with the partial exception of recreational and tourism benefits).

i. Cultural and amenity: communities impact their surrounding ecosystems, and at the same time are affected by the nature that surrounds them. Nature shapes the traditions and beliefs of the communities, and maintains the cultural value of these ecosystems in spite of advances in lifestyle. Marine ecosystems also stand out in the cultures of many people such as those of the aboriginal groups in Australia lived along the Great Barrier Reef region for over 40,000 years, which resulted in the reef permeating their culture and shaping many of their traditions such as traditional hunting.

ii. Recreational: perhaps recreational value of ecosystem forms the vast share of valuation studies, which is not surprising given the growing magnitude of the tourism industry. According to Millennium Ecosystem Assessment report nature travel increased at an estimated rate of 10–30% annually in the early 1990s, and in 1997 nature tourism accounted for approximately 20% of total international travel. A number of developing countries depend on tourism as the largest contributor to their economy.

iii. Aesthetics: Many people enjoy the scenery of natural areas and landscapes. This is clearly reflected in peoples' preference to live and visit aesthetically pleasant environments. Aesthetic information has considerable economic importance, which is reflected in such sectors as the real estate where housing with ocean / sea view are usually considerably higher priced than similar housing in other areas.

iv. Education and research: marine ecosystems provide numerous opportunities for education and research, through excursions, field studies, and reference areas for monitoring environmental change.

(d) Supporting services are those services that are necessary for the production of all other ecosystem services, but do not yield direct benefits to humans:

i. Resilience and resistance (life support): it is the extent to which ecosystems can absorb recurrent natural and human perturbations and continue to regenerate without slowly degrading or unexpectedly flipping to alternate states. Healthier ecosystems are expected to have higher resilience than are ecosystems that are weakened by external factors such as overfishing, pollution, and other human pressures.

ii. Biologically mediated habitat: is defined as habitat which is provided by living marine organisms. Examples of such habitat are coral reefs, seagrass beds, and kelp forests which provide a habitat for numerous other marine species the survival of which depends on the health of their habitat forming species.

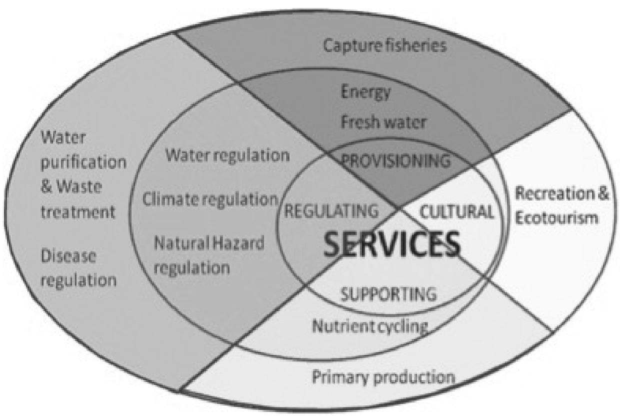

Fig.1 Ecosystem Services. Source: unep.org

iii. Nutrient cycling and fertility: Ecosystems regulate the flows and concentrations of nutrients through a number of complex processes that allow these elements to be extracted from their mineral sources (atmosphere, hydrosphere, or lithosphere) or recycled from dead organisms. This service is supported by a diversity of different species.

Valuation of ecosystem

The Ecosystem services contribute to economic welfare in two ways – through contributions to the generation of income and wellbeing and through the prevention of damages that inflict costs on society. Both types of benefits should be accounted for in policy appraisal. With a broader focus on valuing the benefits provided by ecosystems, policy options that enhance the natural environment are also more likely to be considered that demonstrate that investing in natural capital can make economic sense. The popular way of valuing ecosystem services is an impact pathway approach, which is presented below (Figure 2.)

In an impact pathway approach, the impacts on an ecosystem due to the change in policy are observed. Following this there may be changes in ecosystem services which impacts on human welfare and by observing this the overall economic value of changes in ecosystem can be done.

In brief, the key steps involve;

- Establishing the environmental baseline.
- Identifying and providing qualitative assessment of the potential impacts of policy options on ecosystem services.
- Quantifying the impacts of policy options on specific ecosystem services.
- Assessing the effects on human welfare.
- Valuing the changes in ecosystem services.

All these steps ensure a more systematic approach to accounting for impacts on ecosystems. Even though, there is considerable complexity in understanding and assessing the causal links between a policy, its effects on ecosystems and related services and then valuing the effects in economic

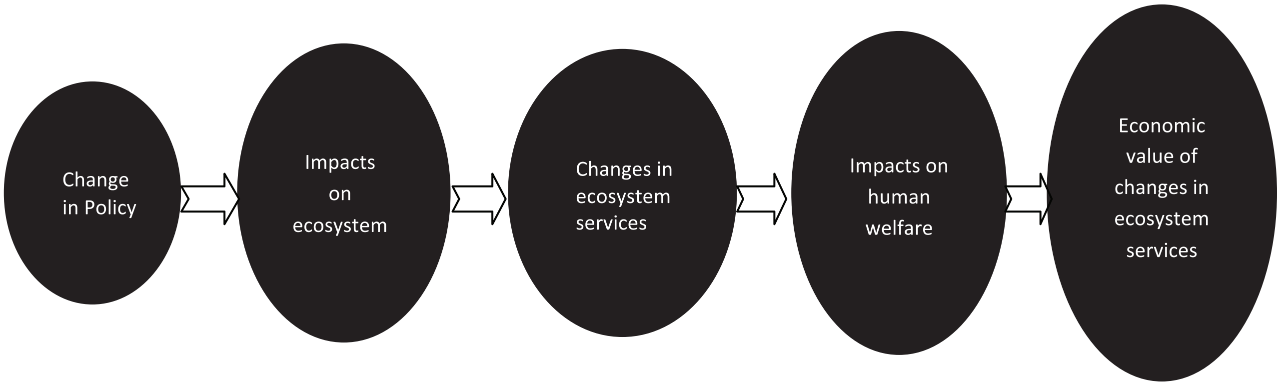

Fig.2 Impact pathway approach

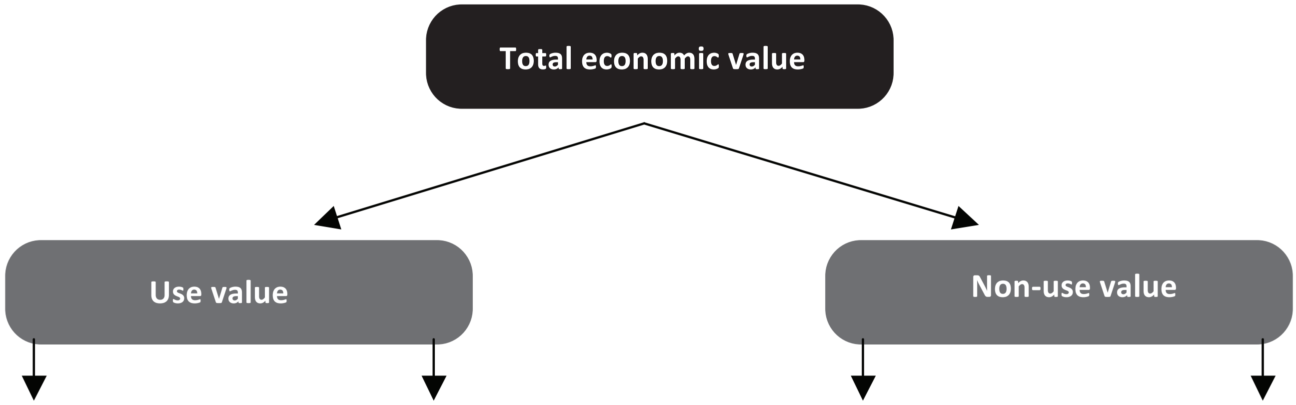

Fig.3 Total economic value framework

terms. Integrated working with policy, science and economics disciplines will be essential in implementing this approach in practice.

A range of methodologies are available to value changes in ecosystem services which are considered in a Total Economic Value framework that takes into account both the use and non-use values. The total economic value framework (Figure 3.) is presented below;

The Total Economic Value (TEV) comprises use and non-use values. TEV refers to the total gain in wellbeing from a policy measured by the net sum of the willingness to pay (WTP) or willingness to accept (WTA). The value that we are trying to capture for the purposes of appraisal is the total value of a marginal change in the underlying ecosystem services. Use value includes direct use, indirect use and option value. Direct use value is in which individuals make actual or planned use of an ecosystem service. This can be in the form of consumptive use which refers to the use of resources extracted from the ecosystem (e.g. food, timber) and non-consumptive use, which is the use of the services without extracting any elements from the ecosystem (e.g. recreation, landscape amenity). Indirect use value is in which individuals benefit from ecosystem services supported by a resource rather than directly using it. These ecosystem services are often not noticed by people until they are damaged or lost, yet they are very important. These services include key global life-support functions, such as the regulation of the chemical composition of the atmosphere and oceans, and climate regulation, water regulation, pollution filtering, waste decomposition and pollination. Option value is that in which people place on having the option to use a resource in the future even if they are not current users. Non-use value (also known as passive use) is derived simply from the knowledge that the natural environment is maintained. There are three main components:

a)Bequest value: where individuals attach value from the fact that the ecosystem resource will be passed on to future generations.

b) Altruistic value: where individuals attach values to the availability of the ecosystem resource to others in the current generation.

c) Existence value: derived from the existence of an ecosystem resource, even though an individual has no actual or planned use of it.

Economic valuation methods

The type of valuation technique chosen will depend on the type of ecosystem service to be valued, as well as the quantity and quality of data available. Some valuation methods may be more suited to capturing the values of particular ecosystem services than others. The choice of valuation methods for different ecosystem services (Figure 4.) can be picturised as follows;

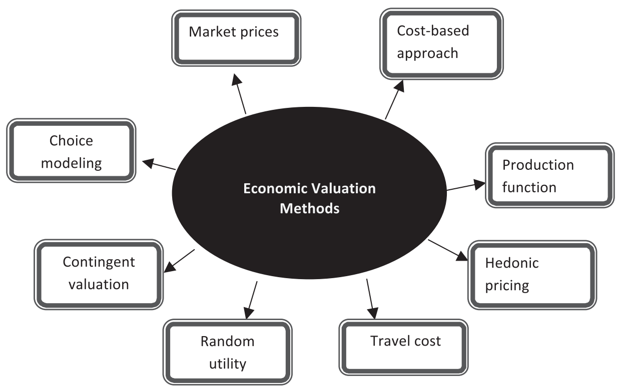

Fig 4. Economic valuation methods

The details of the various economic valuation methods are as follows;

1. Market prices: This method is used for valuing items like timber, fish, genetic information etc which contributes to marketed products. The readily available market data can be pointed out as the benefit of this method. But the method is limited to those ecosystem services for which a market exists.

2. Cost-based approach: The usage of this method depends on the existence of relevant markets for the ecosystem service in question. The benefit of the method is the readily available market data whereas there is a possibility of the overestimation of the actual value too.

3. Production function approach: The environmental services that serve as input to market products are valued under these methods. For eg, effects of air or water quality on agricultural products. The easily available market data can be taken as a benefit. The intensive data and data changes in services and missing of the impact on production can be considered as the limitation of the approach.

4. Hedonic pricing: Ecosystem services that contribute to air quality, visual amenity, landscape, quiet i.e. attributes that can be appreciated by potential buyers can be valued under this method. It is based on market data, so relatively robust figures. Even though, the method is very data-intensive and is limited mainly to services related to property.

5. Travel cost: All ecosystem services that contribute to recreational activities are valued under this method. The method is based on observed behavior. The method is generally limited to recreational benefits. Difficulties in valuation arise when trips are made to multiple destinations.

6. Random utility: All ecosystem services that contribute to recreational activities are valued under this method. The method is based on observed behavior. The method is generally limited to use values.

7. Contingent valuation: All ecosystem services are valued by this method. The benefits of the approach are that it is able to capture use and non-use values. The limitation of the method is that there may be bias in responses. Moreover it is a resources-intensive method and also the market is of a hypothetical nature.

8. Choice modeling: All ecosystem services are valued by this method and it is able to capture use and non-use values. The limitation of the method is that there may be bias in responses. Moreover it is a resources-intensive method and also the market is of a hypothetical nature.

The steps involved in an economic valuation are depicted in the flow chart below (Figure 5.)

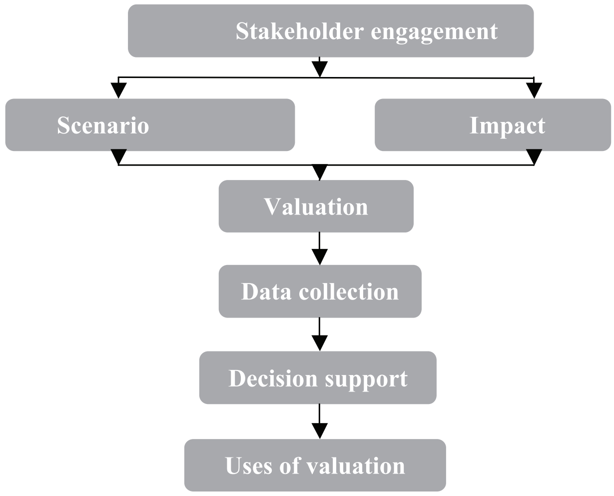

Fig.5 Economic valuation flowchart

Hypothetical case study : Mangrove ecosystem

This study attempts at projecting the ecosystem value by employing economic tools. Since the mangroves offer multiple ecosystem services, it is impossible to evaluate all the services with one single tool. Thus identifying the appropriate tool for individual services is necessary. The major ecosystem services include disaster risk reduction, carbon sequestration, biodiversity conservation, livelihood sustenance and food security, and recreation.

Of the very many unique features of the coastal ecosystem, the mangroves play a significant role. Mangroves are salt-tolerant plants of tropical and subtropical intertidal regions of the world. The specific regions where these plants occur are termed as 'mangrove ecosystem'. These are highly productive but extremely sensitive and fragile. Besides mangroves, the ecosystem also harbours other plant and animal species. The distribution of mangrove ecosystem on Indian coastlines indicates that the Sundarban mangroves occupy very large area followed by Andaman-Nicobar Islands and Gulf of Kachh in Gujarat. Rest of the mangrove ecosystems is comparatively smaller. Over 1600 plant and 3700 animal species have been identified from these areas.

Mangroves act as a barrier against cyclonic storms, protecting the land behind. They also act as a buffer against floods, preventing soil erosion. Mangroves trap fine sediments that are carried into the coastal zone by floodwaters, and there is a significant net export of nutrients from the mangroves into the coastal zone, which acts as a source of enrichment for the marine environment. Mangroves prevent inorganic nutrients being sunk in the sea through swift flowing terrestrial runoff and synthesise organic matter absorbing the inorganic nutrients. Hence various inorganic nutrients from the terrestrial runoff are recycled within the mangrove environment. They are breeding, feeding and nursery grounds for many estuarine and marine organisms. Hence, these areas are used for captive and culture fisheries. The ecosystem has a very large unexplored potential for natural products useful for medicinal purposes and also for salt production, apiculture, fuel and fodder, etc.

Leaf litter production by mangrove plants contributes largely to the organic matter available to the ecosystem. Thus the terrestrial and aquatic components of mangrove ecosystem contribute to each other enabling high productivity of the ecosystem. Due to their productive nature, they serve as nurseries for prawns, crabs, lobsters, and various fishes such as mullet. Mangroves also shelter a number of endangered animals such as crocodile, turtle and pelican. Mangroves offer a variety of commercial utilities in the form of wood for timber and fuel, fodder for cattle and with substances of commercial value such as lignin, tannin, etc. It is scenic and an excellent place for pleasure boating and thus contributes to the tourism industry.

Disaster risk reduction

In order to evaluate the Disaster risk reduction service of mangroves such as flood control, storm buffering and sediment retention replacement coast method (RCM) is used. The replacement cost method uses the cost of replacing an ecosystem or its services as an estimate of the value of the ecosystem or its services. Studies show that where mangroves are intact they work as an effective buffer against tsunami and that 30 trees per 100m2 in a 100m wide belt may reduce tsunami flow rate by as much as 90% . To get a clearer picture of the study, a Model village with mangrove ecosystem is taken into consideration (Table 1). Say, the village has a population of 300 households, and a mangrove cover of 25 ha.

Table 1: Disaster risk reduction potential of mangroves

A.	Number of houses	300
B.	Average house price(US$)	8200
C.	Value houses (US$) (A*B)	24.6
D.	Likelihood of any severe weather event in coastline per year	10%
E.	Value shoreline protection (C*D in US$)	246 lakhs
F.	Mangroves in model village	25 ha
G.	Value shoreline protection(US$ / ha / year)	9.84 lakhs USD

Carbon sequestration

Due to their high biomass density and productivity mangroves play a significant role in carbon sequestration. According to previous studies mangroves, including associated soil, could sequester approximately 22.8 million metric tons of carbon each year. Covering only 0.1 per cent of the earth's continental surface, the forest would account for 11 per cent of the total input of terrestrial carbon into the ocean and 10 per cent of the terrestrial dissolved organic carbon exported to the ocean. To evaluate this service, replacement cost method is employed.

Biodiversity

Mangroves in their undisturbed state are regarded as a refuge for rich biodiversity. Biodiversity value combines direct, indirect and non-use value and is a valuation of human preference rather than actual value (UNEP/GPA, 2003).This services can be evaluated by benefit transfer method (BTM). The procedure estimates the value of an ecosystem service by transferring an existing valuation estimate from a similar ecosystem (TEEB, 2010). The following equation is used to evaluate the biodiversity value of mangroves.

Value y = Value x (PPP GNPy /PPP GNPx) Ei
Where
PPP GNP =Purchasing power parity GNP per capita
Ei = Elasticity of values with respect to real income (UNEP/GPA (2003) assumed Ei =1.00)
Ei = 1.00 implies a 1 per cent change in WTP relative to a 1 per cent change in real income.

Tourism/ recreation

Tourism has always been a major source of income for any coastal population and since mangroves provide rich biodiversity and an impressive landscape, tourism could represent a reasonable part of the economic value of mangroves. The study recommends applying the Travel Costs Method (TCM) where primary data is available. The basic premise of the travel cost method is that the time and travel cost expenses that people incur to visit a site represent the "price" of access to the site. Thus, peoples' willingness to pay to visit the site can be estimated based on the number of trips that they make at different travel costs.

Step one is to define a set of zones surrounding the site, followed by collection of information on the number of visitors from each zone, and the number of visits made in the last year. The next step is to calculate the visitation rates per 1000 population in each zone and then calculate the average round-trip travel distance and travel time to the site for each zone. Consequently using regression analysis, derive the equation that relates visits per capita to travel costs, with the aid of demand function for visits to the site, using the results of the regression analysis. Finally estimate the total economic benefit of the site to visitors by calculating the consumer surplus, or the area under the demand curve.

Food security & Livelihood sustenance:

The most valuable direct use of mangroves is as a breeding and nursery habitat for juvenile fish. To calculate the compounded annual growth rate (CAGR) for the marine fisheries industry the following formula is applied:

Where:
CAGR (t_0,tn) = $[V(tn)/V(t_0)]$ $(1/tn - t_0)$ - 1
CAGR = Compounded annual growth rate
t_0= time 0
tn= time n
V (t0) = Fish catch in time 0
V (tn) = Fish catch in time n

Apart from fisheries, which also serves as a tool for food security, the other livelihood opportunities that the mangroves offer is firewood collection, apiculture and aquaculture which can be evaluated using Replacement cost method and market price.

The missing piece of the jigsaw: Social component

Most of the ecosystems services and their impact assessment doesn't take into consideration the Socioeconomic impact assessment which is very vital for the conservation as well as the livelihood of the primary stakeholders. Thereby its mandatory to incorporate the often forgotten social component of the multiple stakeholders involved in the system so as to achieve an unbaised representation of them in the proactive participation of any policy implemenation

The stepwise methodology: Socio economic assessment

The social component needs to be included while policy formulation with the following dimensions. The step wise procedural format to assess the socio-economic impact is given below

- Probability - How likely is the outcome
- Primacy - Is the outcome a direct result of the development or is it an indirect are, part of the clean predictable events flow up from the developmental interventions.
- Onset - what point will the outcome occur, immediately or later on?
- Duration - Is this a temporary effect or permanent one?
- Magnitude - How extension is the outcome?
- Distribution - Who will be affected?
- Scope - What will be the geographic limits?

Procedural frame work

- Profiling – Identifying existing condition, providing a base line
- Projecting – Predicting likely changes and their effect (eg. By using results from similar areas, extrapolating of trends or creation of scenario
- Assessing - Determining the importance of the effects and ways of avoiding or mitigating them
- Evaluation - Considering the acceptability of the impact on the society, impediments and viable alternatives.

Steps in social impact assessment will include:

Step – I

- Identify the main group affected – both inside and outside – special attention to rural poor.
- Number of households
- Multidimensional involving all the economic sectors

Stp – II

- Describe the economics of the livelihoods in terms of subsistence production and cash income.
- Quantitative estimates should be made of incomes and any common property resources.

Step – III

- Estimate the environmental changes caused by the project on the livelihood
- Quantitative estimate on the changing scenario on the stakeholders
- Prepare an impact rating for all groups (perhaps on a numerical scale)

Step – IV

- Assess likely change in the general quality of life of men, women and children in the area affected by the project.
- Indicators of quality of life
- Human Development Index
- Security of life and livelihood of different groups
- Extent of social conflict
- Health, nutrition case of communication and safety

Step – V

- Estimate the initial and recurrent costs of any environmental mitigation measures including compensation needed to offset effects the subject project (costs of reselling and retraining fisherman house or those whose land is acquired. Inorder to ascertain the socioeconomic impact on the different stakeholders different econometric models like Contingent valuation methods, hedonic models and travel cost method will be employed.

The methods for social impact assessment will include:

- Historical - Collection and assessment of existing information (Census data, vital statistics, previous studies)
- Survey methods - sample surveys, opinion leader or Delphi panel surveys
- Unobtrusive techniques - monitoring media such as newspaper editorials or call radio shows, observing behaviour in public places.

Participatory rural appraisal (PRA)

PRA is a process of gathering and analyzing from and about rural communities in a brief time period (weeks) in which, formal survey and totally non-structured interviewing are done. The PRA technique reveals information on values, opinions, objectives and local knowledge as well as "hard" data on social, economic, agricultural and ecological parameters. The noteworthy feature of PRA is that the quality depends largely on the teams, skill and judgment, for which the involvement of the people in the subject area is essential.

The advantages of PRA are attributed due to its cost-effectiveness in terms of money, time, materials and manpower. It is holistic in nature and will include the opinions and judgments of decision makers, researchers as well as stakeholders.

Methodological framework

The below given methodological framework for the coastal ecosystem conservation and evaluation (Figure 6.)is meant to ensure that the stakeholders, ie Environment, resources and resource users have linkages made, with the inclusion of variables such as climate change , anthropogenic as well as natural systems in order to have deliverables in terms of valuation, management systems and communication tools.

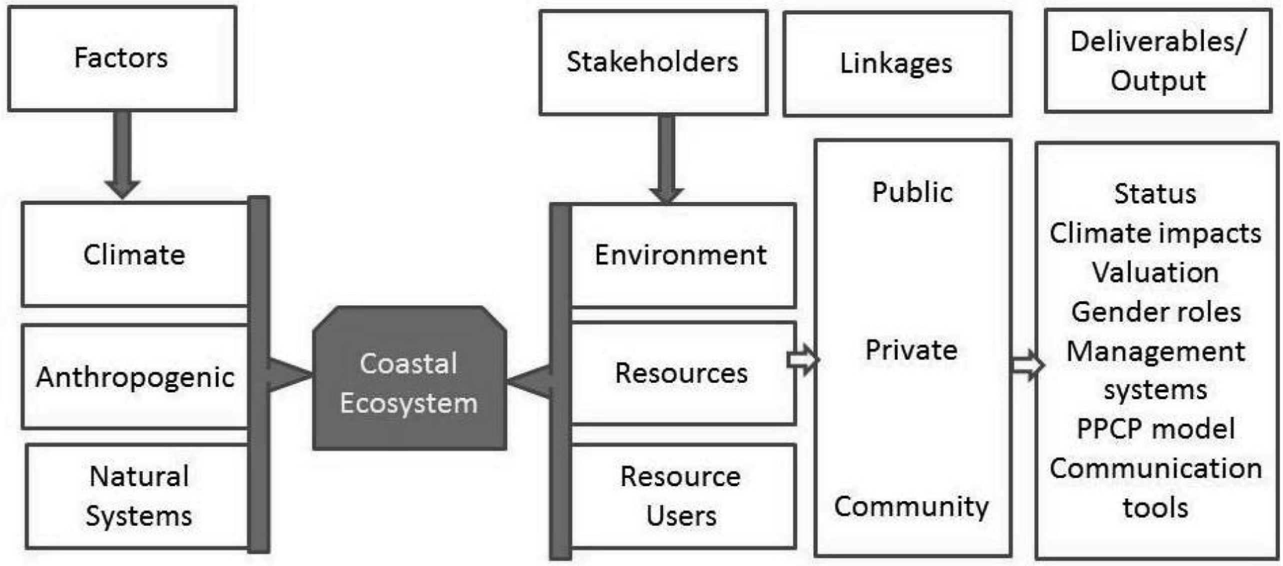

Fig.6 Methodological framework for integrated coastal sustenance