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Valuation of Aghanashini Estuarine Ecosystem Goods and Services

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ABSTRACT Valuation through the quantification goods and services aids in the wise use and prudent management of an estuarine ecosystem. The present study focusses on the valuation of goods and services from an estuary at Aghanashini, Uttara Kannada district, Karnataka. The provisioning services provided by this estuary is about 11,35,847 Rs/hectare/year, which highlights the significance of an estuarine ecosystem in sustaining livelihood of 6000 - 7500 families. The total economic value (provisioning, regulating, supporting and cultural services) of Aghanashini is 5 million Rs/hectare/year. This highlights the contributions by estuarine ecosystems in sustaining the economy of the district while supporting people's livelihood. Quantification of ecosystem benefits would help in evolving appropriate strategies with the managerial decisions. This also emphasizes the need for green gross domestic product through incorporation of values of the natural goods in the national and regional accounting to ensure the sustainability of natural resources such as water, energy, land, etc.

INTRODUCTION

Ecological values refer to the level of benefits and services provided with the complex interactions among the biotic and abiotic components to sustain humans (Milon and Alvarez 2019; Ramachandra et al. 2018a,b,c). Ecosystem services include services and benefits such as food, erosion control; climate regulation; water purification; bioenergy, etc. and are very crucial for the biota's survival (Ramachandra et al. 2018b,d). The structural components of an ecosystem include physical features (such as land cover, water, sediment and soil profile, the gradient conditions in water body), biotic compositions (like species, number of individuals and their biomass), etc. Interactions between these elements, that is, the flow of nutrients, energy, etc. between different ecosystems constitute the functional aspects of an ecosystem. Ecosystems can be broadly categorized as aquatic and terrestrial ecosystems, on the basis of their major source and sink of nutrient, that is, water or land (Ramachandra et al. 2018a,b). Aquatic ecosystems with rich nutrient contents is substantially different from terrestrial ecosystems and both these ecosystems are dependent upon each other, as there is an overlap of the functional boundary between the two, irrespective of the physical boundaries (Ramachandra et al. 2018c).

An estuary is a dynamic zone between land and Sea with the salinity transitional to that of marine and fresh water, which makes them unique in their ecological and biological functions (Anoop et al. 2008). Estuaries support wide range of terrestrial and aquatic life with the distinctive ecological, geological, and biological domains of vital importance (Wilson and Farber 2005). These are major specialized ecosystems where organic matter builds up in large quantities and offers ideal biotic conditions to sustain considerable aquatic population (Boominathan et al. 2008; Rao and Suresh 2002). Estuaries are the transition zones with salinity gradient where the water quality change from fresh water to saline as landscapes change from land

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to sea. These regions are protected by mangroves, reefs, mud or sand, barrier islands and land that define an estuaries seaward boundary and shield an estuary from the ocean waves, winds and storms (Ramachandra at al. 2018d). Most of the Western Ghats rivers join Arabian Sea forming productive estuaries, which sustains the livelihood of millions of people.

Fresh water influx and density difference between the two merging water entities, a constant replenishment of nutrients and versatility in their structure make it a nursery ground for many marine organisms (Ramachandra 2018e). Diverse estuarine habitats include shallow open waters, fresh water and salt marshes, sandy beaches, mud and sand flats, rocky shores, mangrove forests, river deltas, tidal ponds, sea grass beds, etc. These habitats are essential for the survival of biota, which depend on the estuarine ecosystem for breeding, feed, living, etc.

Marine organisms including fish species and oysters, during various stages of their lifecycle, depend on the estuarine ecosystem (Bhat et al. 2010; Ramachandra et al. 2018c,d; Wilson and Farber 2005), while other species (salmon and shrimp) on a seasonal basis for reproduction and growth depend on estuaries (Wilson and Farber 2005).

The valuation of goods and services from the global terrestrial and aquatic ecosystems (Costanza et al. 1997; Costanza and Folke 1997) reveals the annual value of 16 to 60 trillion USD with an estimated average of 33 trillion USD ($), which is about 1.8 times higher than the current global gross national product (GNP). The relative share of marine compared to the terrestrial (forests and wetlands) is about 62 percent. The mangrove vegetation contribute significantly in the regional socio-economic development through commercial products, fishery resources apart from the prospects of eco-tourism (Kathiresan and Narayanasamy 2005; Prakash et al. 2010). Mangroves provide habitat to a wide array of diverse biota, which include bacteria, fungi, insects, fish, prawns, shrimps, birds, etc., including a variety of flora – sea weeds, small plants and creepers (Hirway and Goswami 2007). Valuation of mangroves per household based on the avoided damage cost is estimated as 116.28 USD and 983795.7 USD as land accretion value over a period of 111 years. Economic analysis of twelve year mangrove plantation in the Gazy bay in Kenya account 379.17 USD/ha/yr towards extractable wood products, US$ 44.42/ha/yr with the carbon sequestration and US$ research and education services account to 770.23/ha/yr. The total economic value for *Rhizophora* plantation of twelve years old is estimated as 2902.87 USD/ha/yr. An economic valuation of mangrove resource utilization in the Gaz and Hara delta, South Iran show the total economic value as 10000-20000 US$/ha/year (Ghasemi et al. 2012).

Ecosystem Goods and Services

Ecosystem provides various vital benefits and services, which are very crucial for the endurance of dependent biological organisms and welfare of the human society (Ramachandra et al. 2017a,b; MEA 2005). Ecosystem functions include natural processes (hydrological, biogeo-chemical cycling) that provide goods and services supporting the society directly as well as indirectly (de Groot and Vander Meer 2010; MEA 2005). The ecosystem benefits include (i) provisioning services (food and water), (ii) regulating services (flood and disease control), (iii) cultural services (spiritual, recreational and cultural), and (iv) supporting services that is maintaining conditions for sustaining life (Fischlin et al. 2007; Hassan et al. 2005; MEA 2005; Ramachandra et al. 2017a; Wilson and Farber 2005).

Estuarine and coastal ecosystems are vulnerable natural systems (Barbier et al. 2011) with the intense anthropogenic stress, evident from the loss (MEA 2005) of salt marshes (by 50%), mangroves (35%), coral reefs (30%), and sea grasses (29%). In addition, propagation of invasive species, declining water quality, and decreased coastal protection from flooding and storm events, etc. have contributed to the loss of biodiversity and ecosystem functions in estuarine and coastal ecosystems (Barbier et al. 2011). Insights of the ecosystem function would aid in optimizing alternative uses of ecosystem functions and services (Barbier et al. 2011; Costanza et al. 1997; Costanza and Folke 1997). This would aid in evolving prudent policy and managerial decisions in favor of environmentally prudent practices (Barbier et al. 2011), which maximizes societal welfare (Turpie et al. 2010; Ram-

achandra et al. 2017a,b; Ramachandra and Rajinikanth 2003; Ramachandra et al. 2002).

Figure 1 illustrates a framework for assessing the ecosystem goods and services (Costanza et al. 1997; Costanza and Folke 1997; MEA 2005; Ramachandra et al. 2017b), which are broadly classified into four different functions namely – regulation, production, habitat and cultural. These can be grouped as (i) ecological (determined by the regulation and habitat functions), (ii) socio-cultural (identifies vital environmental functions, physical and mental health, education, cultural diversity), (iii) heritage, freedom and spiritual values (Costanza et al. 1997; Costanza and Folke 1997; MEA 2005; Ramachandra et al. 2017a) and (iv) economic values, that is, willing to give up in other goods and services (Ramachandra and Rajinikanth 2003; Ramachandra et al. 2002; Ramachandra et al. 2017a,b; Turpie et al. 2010).

Total Economic Value (TEV)

The total economic value (TEV) is the sum of (i) use value (UV) and (ii) non-use value (NUV), accounting all benefits from an ecosystem. (UNEP/GEF 2007; UNEP 2013; TEEB 2011). Figure 2 outlines the framework for TEV of an estuarine ecosystem. Use value refers to the tangible or physical aspects of resources, which provide direct (personal) utility or satisfaction and which have direct market prices for quantification and indirect (consist of the various functions that a natural system may provide), such as shoreline protection functions, carbon sequestration, and nutrient or contaminant retention (Ramachandra et al. 2017a; UNEP/GEF 2007; UNEP 2013; TEEB 2011). This reflects changes in the value of production or consumption of the activity or property (that it is protecting or supporting) and the availability of this resource in the future (UNEP/GEF 2007; UNEP 2013; TEEB 2011), which relates to future direct or indirect use of the resource (Barbier et al. 2011; Ramachandra et al. 2017a). Non-use values of an ecosystem are bequest and existence values (related to aesthetic, cultural, and moral aspects), regardless of whether it will be used or not (UNEP/GEF 2007; UNEP 2013; TEEB 2011).

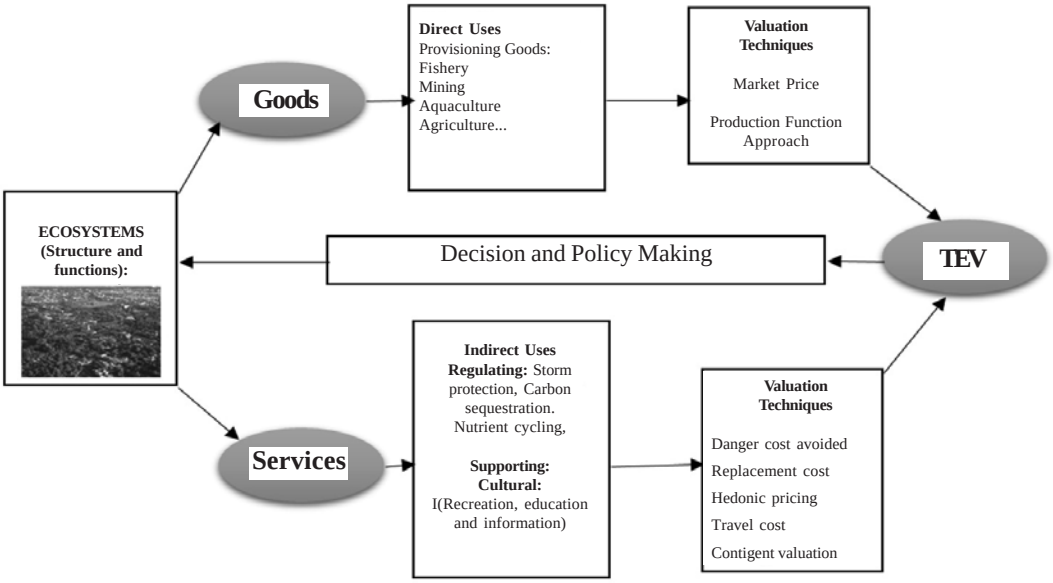

Fig. 1. Assessment of ecosystem goods and services
Source: Author

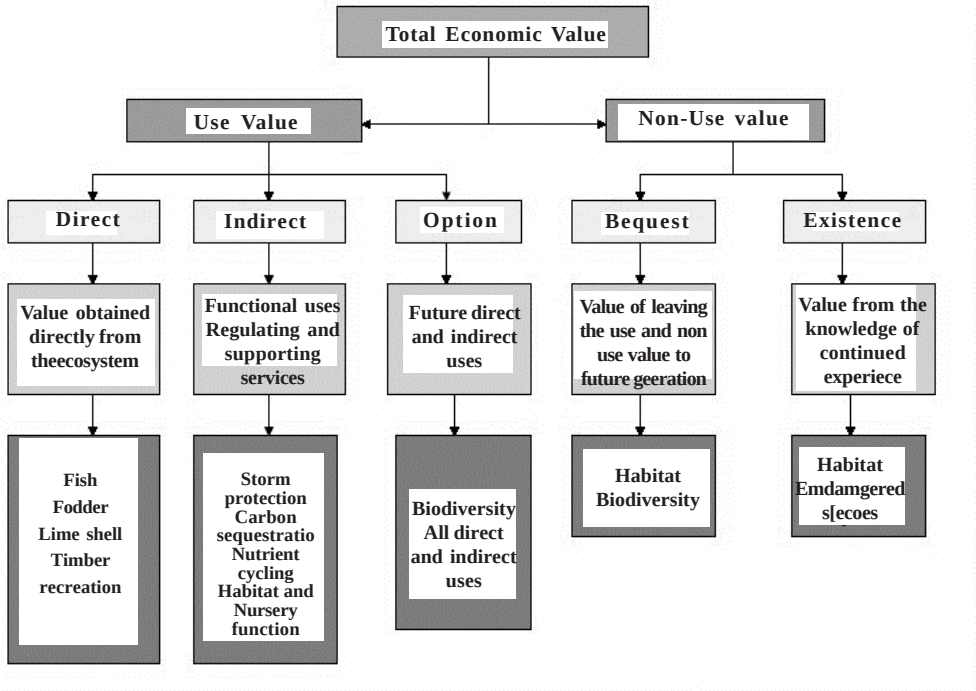

Fig. 2. Framework for economic valuation of estuarine ecosystems
Source: Author

Techniques for Quantification of Ecosystem Goods and Services

The techniques for valuation of ecosystem based on the type of goods and services are grouped into four categories as:

(i) direct market valuation considering the market price of the resources that are being used directly and indirectly (UNEP/GEF 2007; UNEP 2013; TEEB 2011),

(ii) indirect market valuation (assessing the values that can be used through the willingness to pay (WTP) or loss of these services through willingness to accept compensation (WTA) (Barbier et al. 2011; Ramachandra et al. 2017a). The techniques include avoided cost (AC), replacement cost (RC), factor income (FI), Hedonic pricing (HP) and travel cost (TC) methods (Barbier et al. 2011; Costanza and Folke, 1997; Costanza et al. 1997; Ramachandra et al. 2017a),

(iii) contingent valuation via economic values for non–marketed goods, such as environmental assets, amenities, and services are estimated through surveys to ascertain respondents' preferences regarding an increase or decrease in the level of environmental quality (UNEP/GEF 2007; UNEP 2013; TEEB 2011). The preferences are valued through surveys to ascertain willing to pay for the preservation or improvement of a certain resource or environment or to accept payment for doing away with the said resources, or through group valuation based on of deliberative democracy principles and the assumption that public decision making result from open public debates (Barbier et al. 2011; Costanza and Folke, 1997; Costanza et al. 1997; Ramachandra et al. 2017a) and

(iv) benefit transfer method of using values estimated for an alternative policy context or location as a basis for estimating a value for the policy context or site loca-

tion in question (Barbier et al. 2011; Ramachandra et al. 2017a). Benefit transfer technique involves (a) identification of resources or services to be valued, (b) identifying relevant existing studies, (c) evaluating applicability and (d) conducting the benefit transfer. This method is used for damage assessment, where there is a need of existing estimate of value of the natural resource or services provided by the resource.

Objectives

The main objective of the current communication is to estimate the total economic value of Aghanashini estuarine ecosystem of Uttara Kannada in order to enhance natural resource productivity through prudent management. This includes estimating values of (i) provisioning services; and (ii) indirect products and services of the estuarine ecosystem such as regulating, supporting and information services.

MATERIAL AND METHODS

Study Area

The Uttara Kannada district lies at $74^0 9'$ to $75^0 10'$ E and $13^0 55'$ to $15^0 31'$ N extending over an area of 10,291 sq.km in the mid-western part of Karnataka state, India (Fig. 3). It is surrounded by Belgaum district and Goa territory in the north, Dharwad in the east, Shimoga and parts of Dakshina Kannada in the south and the Arabian Sea to the west. Uttara Kannada district is one of the northernmost districts in Karnataka State (Ramachandra, et al. 2018a,b,c). The district consists of a narrow strip of the coastline with a spatial extent of 3300 sq.km, which is relatively flat and starts sloping gently upwards towards the east (Deepthi et al. 2017), comprising five taluks namely Karwar, Ankola, Kumta, Honnavar and Bhatkal (Ramachandra et al. 2018d,e).

Aghanashini Estuary

Aghanashini River running its course of about 121 km, winding through gorges flanked with evergreen forests and valleys lush with spice gardens and rice fields, the river widens into an estuary covering about 4801 ha before its confluence with the Arabian Sea in the west coast between the villages Aghanashini in the south and Tadadi in the north, lies between 14.391° to 14.585° N and 74.304° to 74.516° E of Kumta taluk (Deepthi et al. 2017) in the Uttara Kannada district of central west coast in the Karnataka State of India (Fig. 3). Villages (about 21) along

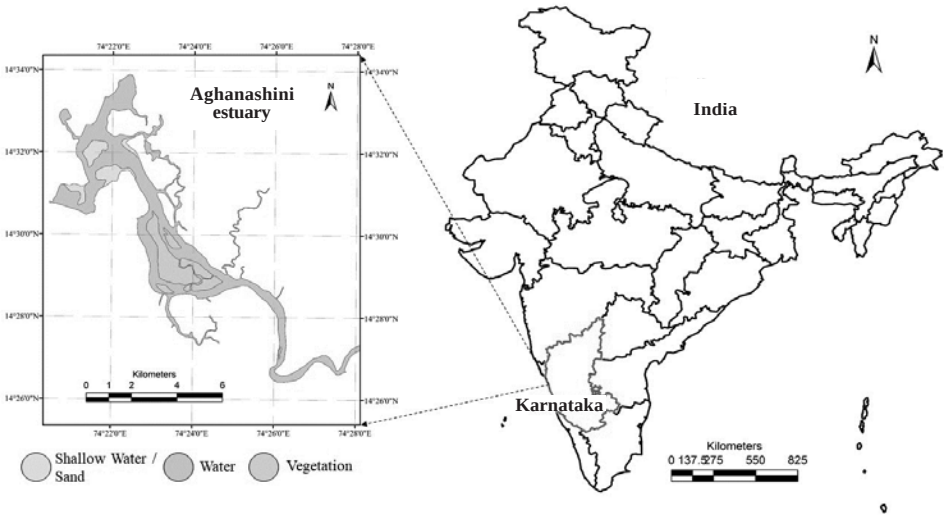

Fig. 3. Aghanashini estuary, Uttara Kannada district, Karnataka, India à
Source: Author

the estuarine banks are traditionally dependent on agriculture and fisheries.

Methods

The secondary data was obtained from various sources for assessing the resource availability and consumption scenarios in the estuary. Field survey were carried out regarding the fish resources, sand mining and salt production in the estuary. This involved actual measurements (quantifications) and discussions with the local people. The secondary data regarding the ecological functions of the estuaries was collected from Central Marine Fisheries Research Institute (CMFRI) centres of Cochin and Karwar; Department of Marine Biology, Karnataka University, Karwar; Cochin University of Science and Technology, Biodiversity portal (Sahyadri 2018). The socio-economic data related to the coastal *taluks* including the villages around the estuary were obtained from 2011 Census Report, Govt. of India; District Administrative Reports, Govt. of Karnataka. The data regarding the production of Gazani paddy and Coconut in the estuarine region was obtained from Karnataka State Horticulture Department. The direct and indirect values obtained from the estuaries were calculated.

Market valuation technique was employed for valuing the goods and services having direct market prices such as fishing, gazani (salt tolerant) paddy cultivation, timber and fodder obtained from the mangrove vegetation, aquaculture, sand and lime shell mining, navigation, ferry services and port activities. The market price values were assigned to these goods based on the interaction with the locals residing in that region. The annual gross revenues obtained from these resources were obtained as per the equation 1.

Net benefit from the fisheries = Total fish production in the estuary (tons) x Price per ton

Net income from mining/agriculture products = $\Sigma(P\ Q)$ ……1

Where, P = price of the product; Q = quantity of the product

Besides providing the direct use value goods, the estuaries also provide various other important benefits such as climate regulation, shoreline stabilization, natural hazard mitigation, habitat and refugia for various organisms, nutrient circulation, recreation and aesthetic benefits, etc. CVM (Contingent Valuation Method) was adapted to survey indirect values obtained from an ecosystem which is based on the people's Willingness to Pay (WTP) for protecting the ecosystem. For the current valuation study, the values for the indirect ecosystem services were adapted from the published literatures (Ramachandra et al. 2017a; Bann 2003; Barbier et al. 2011; Costanza et al. 1997; Costanza and Folke 1997; UNEP 2013; NEP/GEF 2007; TEEB 2011). The values were converted into Indian Rupees (INR) and are given in Table 1.

The direct, indirect and recreational benefits of the estuaries were aggregated to obtain the Total Economic Values (TEV). These economic values can be considered as underestimates as the natural ecosystems are much more worthy in terms of the benefits they provide. The valuation of natural resources is useful for policy formulations and decision making.

RESULTS AND DISCUSSION

Estuaries support local livelihood through the provision of goods (fish, fodder, sand, salt, etc.), employment and a variety of ecological services (Boominathan et al. 2008; Thomson 2003; Wilson and Farber 2005). Majority of estuarine communities are dependent on the ecosystem for activities related to fishery (Anoop et al. 2008; Bhat et al. 2010; Thomson 2003). Diverse ecological services provided by an estuary include regulation of various gases, sequestration of carbon, water flow, retention and soil formation, nutrient cycling, pollination, related biological processes, bioremediation, recreation, repository of genetic resources, etc. (Boominathan et al. 2008; Ramachandra et al. 2017b; Thomson 2003).

The estuaries are the repositories of mangroves biodiversity which also serve as a wall (green shield) for the coastline apart from providing numerous other benefits. Mangrove species grow in varied salinity levels and occur mainly in intertidal regions (Hirway and Goswami 2007; Kathiresan, and Narayanasamy 2005; Bhat et al. 2010; Prakash et al. 2010), receiving organic materials from estuarine or oceanic ecosystems. Goods provided by mangrove ecosys-

Table 1: Economic values assigned to different indirect ecosystem services

Function	*Country/ Region*	*Technique used*	*Unit (rs/hectare)*	*References*
		Regulating Services		
Erosion control	Gujarat	Damage cost avoided	137606	Hirway and Goswami 2007; Prakash et al. 2010
Flood control	Srilanka	Replacement cost	158249.67	Barbier et al. 2011; Gunawardena and Rowan 2004; Sathirathai and Barbier 2001
Storm protection	Srilanka	Replacement cost	45000	Kathiresan and Narayanasamy 2005; de Groot and Vander Meer 2010
Nutrient retention	Orissa	Replacement cost	11034.5	Costanza et al. 1997; Costanza, and Folke 1997; de Groot and Vander Meer 2010
Disturbance regulation	Global	Benefit transfer	25515	Costanza et al. 1997; Costanza and Folke 1997; de Groot and Vander Meer 2010
Waste treatment	Global	Benefit transfer	301320	Costanza et al. 1997; Costanza and Folke 1997
Nutrient cycling	Global	Benefit transfer	949500	Barbier et al. 2011; Costanza et al. 1997; Costanza and Folke 1997; de Groot and Vander Meer 2010
Carbon sequestration	Ashtamudi estuary, Kerala	Damage cost-avoided	9110.2	Anoop et al. 2008; Barbier et al. 2011; Costanza et al. 1997; Costanza and Folke 1997; de Groot and Vander Meer 2010
Gas regulation	Global	Benefit transfer	9600	Barbier et al. 2011; Costanza et al. 1997; Costanza and Folke 1997; Fischlin et al. 2007
Climate regulation	Global	Be nefit transfer	4800	Barbier et al. 2011; Costanza et al. 1997; Costanza and Folke 1997; Fischlin et al. 2007
Oxygen provision	Global	Benefit transfer	5280	Barbier et al. 2011; Costanza et al. 1997; Costanza and Folke 1997; Fischlin et al. 2007
water regulation	Global	Benefit transfer	209088	Barbier et al. 2011; Fischlin et al. 2007
water supply	Global	Benefit transfer	145920	Barbier et al. 2011; Fischlin et al. 2007
Ground water recharging	Global	Benefit transfer	192000	de Groot and Vander Meer 2010; Fischlin et al. 2007; Barbier et al. 2011; Hassan et al. 2005; MEA 2005
Natural hazard mitigation	Global	Benefit transfer	9600	Ramachandra et al. 2002; Ramachandra and Rajinikanth 2003; UNEP 2013; UNEP/GEF 2007
		Supporting Functions (Sahyadri 2018)		
Habitat/refugia	Global	Benefit transfer	5895	Costanza et al. 1997; Costanza, Folke 1997; de Groot, Vander Meer 2010
Breeding ground and Nursery	Thailand	Benefit transfer	5271.3	Costanza et al. 1997; Costanza, Folke 1997; de Groot, Vander Meer, 2010
Biodiversity	Global	Benefit transfer	216000	Costanza et al. 1997; Costanza, Folke 1997; de Groot, Vander Meer 2010
		Information Functions (Sahyadr 2018)		
Recreation	Global	Benefit transfer	17145	Barbier et al. 2011; Costanza et al. 1997; Costanza and Folke 1997; de Groot and Vander Meer 2010
Cultural and artistic	Global	Benefit transfer	1305	Bann 2003; Barbier et al. 2011; Costanza et al. 1997; Costanza and Folke 1997; UNEP 2013; NEP/GEF 2007; TEEB 2011
Aesthetic	Global	Benefit transfer	100	Barbier et al. 2011; Costanza et al. 1997; Costanza and Folke 1997
Science and Education	Kenya	Research funds	34660.35	Bann 2003; Barbier et al. 2011; Costanza et al. 1997; Costanza and Folke 1997; UNEP 2013; NEP/GEF 2007; TEEB 2011

tems are forestry products (firewood, charcoal, timber, etc.), non-timber produce (honey, etc.) and fishery produce (fish, prawn, crab, mollusk etc.). Twigs of mangroves are used for making charcoal and firewood due to high calorific worth. Mangrove swamps act as traps for the sediments, and sink for the nutrients. The root systems of the plants keep the substrate fixed, and thus contribute to a lasting stability of the coast (Kathiresan and Narayanasamy 2005). The relative share of marine compared to the terrestrial (forests and wetlands) is about 62 percent. A detailed socio-economic appraisal of the traditional, modern, recreational and non-use values for Kali estuary, Karnataka and Cochin estuary, Kerala show aggregate value of Rs. 1163.56 lakhs and Rs. 44,380 lakhs (ten lakhs is equivalent to one million) respectively (Thomson 2003). The overall benefits due to eco-services by mangroves is INR 2246.93 crores per year in Gujarat (Hirway and Goswami 2007), 18570 Rs/ha/year (lagoon fishery, Rekawa lagoon, Srilanka), 34,500 Rs/ha/year (coastal fishery) respectively (Gunawardena and Rowan 2004). The storm and erosion control services of mangroves accounts to about 21000 Rs/ha/year through replacement cost approach. The annualized value of coastal protection through replacement cost technique is about 3697 USD/hectare. The net present value for 20 year period with 15 percent discount rate was obtained as US $ 632.27 /ha and including indirect use values is USD 27,264 - 21,610 / ha. (Sathirathai and Barbier 2001).

The economic valuation of Aghanashini estuary considering bivalve production (Boominathan et al. 2008) reveals the revenue generation of 57.8 million per year, 497990 man days of fishing opportunity in the estuary with the annual income of 56695 INR/person (Bhat et al. 2010). The integrated value of tangible goods (fish, salt, shrimp culture, bivalve food, mangrove fodder, lime and sand) for an estuary is estimated as 2,97,813 INR/hectare/year (Prakash et al. 2010). The NPV of total direct benefit is about 1928 million INR in the Ashtamudi estuary (Anoop et al. 2008). The annual effort is estimated as 23000 man days for fishery through hand picking in Aghanashini estuary. Shells deposit of 7600 tons annually are being extracted from Tadri estuarine bed for industrial use (poultry feed, etc.) and the income is estimated as 40-50 million INR per year (Bhat et al. 2010).

The present study focused on accounting the economic value of Aghanashini estuary located in the Uttara Kannada district of Karnataka State. The estuary has been providing a variety of living and non-living resources to the local communities with the scope for generation of employment, income, amenities and pleasure. Apart from the direct benefits these ecosystem provides many indirect benefits to surrounding communities. However, the decision makers have not considered the significance of this precious ecosystem as evident from the unplanned developmental activities.

Demarcation of Study Area and Quantification of Ecosystem Goods and Services from the Estuarine Ecosystem

The Aghanashini estuary with a spatial extent of 4801 ha is the largest estuary in Uttara Kannada supporting 64709 peoples (6000-7500 families). Major goods and services from the estuaries were compiled through field investigations, literature survey and discussion with local persons. These goods and services are then classified as per the standard protocol (Ramachandra et al. 2017a; Bann 2003; Barbier et al. 2011; Costanza et al. 1997; Costanza and Folke 1997; MEA 2005) as (i) provisioning, (ii) regulating, (iii) supporting and (iv) information services.

Provisioning Services

Provisioning services are estuarine fishery (fish, finfish, shellfish and aquaculture), mining products, mangrove resources, salt production, agriculture including the saline paddy and coconut and water transport activities like ferry services, navigation and the port activities. In order to calculate the total value, the market price approach was used.

Estuarine Fishery

The fishery sector contributes the major livelihood options of the estuarine dependent communities in the coastal villages. It includes the common estuarine fishes, clam, oyster, mussels, bivalves, prawns and aquaculture. The market

price of fish and quantity obtained for each category of fish resources are given in the Table 2. The annual revenue is 4.12 billion Rs. The 94.64 percentage (3.9 billion) revenue comes from aquaculture activities in the estuarine belt. Aghanashini estuary fishes contribute 120.7 million Rs. Aghanashini estuarine villages have been benefited by the bivalve collection with a total annual income of 57 million Rs. The total revenue from shell fish collection in this estuary is 73.5 million Rs. comprising of bivalves, clams, oyster, mussels and other molluscans. Aghanashini estuary provides the 92.93 percent of the income from estuarine fisheries in Uttara Kannada.

Table 2: Estuarine fisheries value

Item	*Total fish catch - ton*	*Price Rs / ton*	*Income Rs / year*
Fishes	12076	150000	120,762,000
Bivalves	2851	200000	57,018,710
Clam	76	15000	11,325,000
Oyster	0.642	200000	128,450
Mussels	28	120000	3,360,000
Other molluscs	14	120000	1,673,700
Crab	56	325000	18,200,000
Prawns	38	250000	7,665,000
Aquaculture	8680	450000	3,906,000,000
Total – Rs.			4,126,132,860

Source: Current study

Agriculture Products

The estuarine belt of Uttara Kannada support saline tolerant paddy (gazani) and coconut cultivation. Total quantity of production and market price of coconut and paddy is given in the Table 3. The returns from gazani paddy are highest in the Aghanashini estuarine region with a value of 43.9 million Rs. The total agricultural production from the estuary is 49.5 million Rs. and it contributes 29.64 percent of the district total.

Table 3: Goods from estuarine agriculture

Item	*Total production ton*	*Price Rs / ton*	*Income Rs / year*
Gazani paddy	2443	18000	43,977,600
Coconut	62	90000	5,614,776
Total– Rs.			49,592,376

Source: Current study

Table 4: Estimation of revenue from mining activities

Item	*Quantity extracted*	*Rate (Rs /unit)*	*Income (Rs /year)*
Sand (Cu.m)	17308	400	6,923,077
Lime shell (ton)	80000	15000	1,200,000,000
Silt(Cu.m)	9855	200	1,971,000
Total– Rs.			1,208,894,077

Source: Current study

Mining Products

Mining and dredging activities are happening in the estuary of Uttara Kannada at significant level. Amount dredged and the price of unit quantity are given in the Table 4 and these are the livelihood options for many poor people in this region. This shows it occurs in higher degree in Aghanashini. The net returns from the region are 1.2 billion Rs. annually; out of these 99.26 percent comes from lime shell collection only.

Table 5: Estimation of net income from mangrove product harvesting

Item	*Quantity produced- ton*	*Price (Rs /ton)*	*Net income (Rs/Yr)*
Fodder	7200	600	4,320,000
Timber	215	150	32,199
Charcoal	64	150	9,660
Thatch	322	2000	643,973
Fish poison	6	1000	6,000
Medicine	24	18000	432,000
Total – Rs.			5,443,831

Source: Current study

Mangrove Products

Mangrove forest is being used by the local inhabitants as fodder for live stocks and timber for fire wood needs and construction activities. Table 5 lists the mangrove resources with market price and quantity. The Aghanashini estuary contributes 31 percent of total mangrove product harvest of Uttara Kannada; the income is 5.4 million Rs/ year.

Table 6: Salt production in the estuarine catchment

Quantity produced-	*Rate (Rs /ton)*	*Value generated (Rs/Yr)*
10000	5000	50,000,000

Source: Current study

Salt From Estuaries

Table 6 shows that salt production in the Aghanashini estuary of Uttara Kannada is about 50 million Rs. per year and this traditional enterprises are at Gokarna and Aghanashini villages (Bhat et al. 2010).

Table 7: Revenue from water transport and port activities

Activity	*Value generated Rs/year*
Ferry services	200,000
Navigation	80,000
Port activities	1,418,000
Total – Rs.	1,698,000

Source: Current study

Transport

Table 7 gives the revenue generated from ferry services, navigation and port activities in the estuarine waters. The net income from water transport activities is highest in Aghanashini (52%). The value from ferry services is about 1.6 million Rs. per year.

Total Provisioning Services

Provisioning services quantification through the compilation of all direct benefits for Aghanashini estuary is given in Table 8. Aghanashini make up the 79.5 percent (5.45 billion Rs. annually) of the district total and the value per hectare of estuary is 11,35,847 Rs. per hectare per year (Aghanashini).

Table 8: Provisioning services from Aghanashini Estuary (Area: 4801 ha), Uttara Kannada

Provisioning services	*Value (Rs.) per year*
Fishery	4,126,132,860
Agriculture	49,592,376
Mining activities	1,208,894,077
Mangrove product harvest	4,806,298
Water transport	1,698,000
Salt production	50,000,000
Total value (Rs/Year)	5,453,199,811
Production (Rs/ha/year)	1,135,847

Source: Current study

Indirect Uses

The indirect uses of estuarine ecosystem consist of the Regulating services, Supporting services and Cultural services (Bann 2003; Barbier et al. 2011; Costanza et al. 1997; Costanza and Folke 1997; MEA 2005; Ramachandra et al. 2017a; Sahyadri 2018; TEEB 2011; UNEP 2013; NEP/GEF 2007). Table 1 lists 23 indirect benefits provided by estuarine ecosystem. All these services are valued by taking the unit value of these benefits (Rs/ha/year) from other studies and adjusted according to the spatial and environmental conditions of our study region.

Regulating Services

The regulating services of estuary ecosystem are coastal erosion control, Flood control, storm protection, carbon sequestration, disturbance regulation, remediation, climate regulation, gas regulation, water supply, nutrient retention and cycling, natural hazard mitigation, ground water recharging and oxygen provision. Table 9 gives the details of regulating services calculat-

Table 9: Services and goods of estuaries

Services	*Aghanashini*
Coastal erosion control	13,980,762
Flood control	16,078,167
Storm protection	4,572,000
Nutrient retention	1,121,103
Disturbance regulation	2,592,324
Waste treatment	1,446,637,320
Nutrient cycling	4,558,549,500
Carbon sequestration	925,596
Gas regulation	46,089,600
Climate regulation	23,044,800
Oxygen provision	25,349,280
Water regulation	1,003,831,488
Water supply	700,561,920
Groundwater recharging	921,792,000
Natural hazard mitigation	46,089,600
Total Value Rs/Year	8,811,215,461
Production Rs/ha/year	1,835,288

Source: Current study

ed considering the spatial extent of the estuary and unit value (Rs/ha/year). The regulating services value from total estuarine area is 8.81 billion Rs/ Year. This is mainly due to the higher mangrove cover and spatial extent of the estuary. The regulating service value per hectare in Aghanashini is Rs. 1,835,288.

Supporting Services

The supporting services selected for economic valuation are Habitat/refugium function, Nursery and breeding ground, biodiversity. The estuarine ecosystem support and provide habitat for diverse flora and fauna, serving as a pool of biodiversity. The estuary and associated mangrove ecosystem and salt pans provide the platform and conditions for breeding and spawning of many marine and fresh water fishes. Table 10 reveals that the supporting service value of Aghanashini region accounts to the 9.34 billion/ year (which constitutes 82.935% of the district). The value per hectare from Aghanashini is 1,946,030 Rs. towards supporting services.

Table 10: Supporting services from estuaries in Uttara Kannada

Services	*Aghanashini*
Area	4801 ha
Primary production	8,252,265,720
Habitat/refugia	28,301,895
Breeding ground and Nursery	25,307,511
Biodiversity	1,037,016,000
Total Value (Rs/year)	9,342,891,126
Production (Rs/ha/year)	1,946,030

Source: Current study

Table 11: Cultural services from Estuaries in Uttara Kannada

Services	*Aghanashini*
Area	4801 ha
Recreation	82,313,145
Aesthetic information	6,265,305
Science and Education	480,100
Science and Education	332,808,680.70
Total value (Rs/year)	421,867,231
Production (Rs/ha/year)	87,871

Source: Current study

Cultural Services

The cultural services include recreation, cultural and artistic information, science and education and the values are given in Table 11.

Aghanashini contributes the highest percentage of Cultural services (43%) among the estuaries in the . These salt pans in this region are the visiting place of migratory birds during seasons. It adds to the aesthetic and recreational potential of Aghanashini. The total value of Aghanashini is 421 million Rs/Year with a per hectare value of 87,871 Rs.

Total Economic Value

Total economic value given in Table 12, highlights that the Aghanashini estuary is highly

Table 12: Total economic value of estuarine ecosystem in Uttara Kannada

Goods and Services	*Details*	*Aghanashini*	*Total (District)*
	Total area (ha)	4801	10,591, 00
	Population	64709	14,36,847
Provisioning services	Total Rs/Year	5453199811	6858828735
	Production Rs/ha/year	1135847	1,938,457
	% contribution	22.7	17.82
Regulating Services	Total Rs/Year	8811215461	19,390,691,963
	Production Rs/ha/year	1835288	8586037
	% contribution	36.7	50.37
Supporting services	Total Rs/Year	9342891126	11,264,961,997
	Production Rs/ha/year	1946030	3143402
	% contribution	38.8	29.27
Cultural Services	Total Rs/Year	421867231	978,291,729
	Production Rs/ha/year	87871	371400
	% contribution	1.8	2.54
Total Economic Value	Total Rs/Year	24,029,173,629	38,492,774,424
	Production Rs/ha/year	5,005,035	3,634,480

productive ecosystem with the total value of 24.03 billion Rs/year and the annual productivity of 5 million Rs/hectare/year. Provisioning service makes up the 22.7 percent of the total value. Cultural service share is about 1.8 percent, while regulating and supporting services are 36.7 percent and 38.8 percent respectively.

CONCLUSION

Ecological systems goods and services play a fundamental role in supporting life and sustaining the economy. Valuation of the ecosystem goods and services is critical to formulate prudent policies for the sustenance of natural resources. An account of the resource potential of Aghanashini estuary of Uttara Kannada district, Karnataka state, India demonstrates that Aghanashini estuary with the total value of 24.03 billion Rs/year and the annual productivity of 5 million Rs/hectare/year is one of the highly productive ecosystem. Provisioning service makes up the 22.7 percent of the total value. Cultural service share is about 1.8 percent, while regulating and supporting services are respectively 36.7 percent and 38.8 percent. This highlights that estuary has been sustaining the economy of the district in a significant manner with the job potential and people's livelihood. Decline in the environmental quality of these ecosystems necessitates the concerted effort to conserve the estuary in a sustainable manner with the active participation of native people.

RECOMMENDATIONS

Aghanashini estuary is a representative, rare, or unique example of natural or near-natural wetland type supports diverse biota including human livelihood, evident from with the total value of 24.03 billion Rs/year and the annual productivity of 5 million Rs/hectare/year with 6500-7000 families dependence on the ecosystem for natural resources apart from aiding as filters, shoreline protection, diverse habitats (mudflats, sand flats, etc.) and diverse micro and macro biota. Hence, Aghanashini estuary should be designated as Biodiversity Heritage Site under Section 37 of Biological Diversity Act, 2002 (BDA 2002)

The study emphasizes the need for green GDP (Gross domestic product) with the accounting of ecosystem goods and services to ensure the sustainability of natural resources (water, energy, land, etc.). In the absence of such accounting, decisions favor environmentally degrading practices by disregarding the societal benefits from the goods and services values of fragile ecosystems.

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