System of Environmental Economics Accounting (SEEA) - coastal and marine ecosystem economic accounting in Karnataka state, India

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Abstract

Coastal and marine ecosystems are important natural environments producing valuable goods and services that are essential for human well-being. System of Environmental Economics Accounting (SEEA) Experimental Ecosystem Accounting (EEA) enlightens the relationship between ecosystem function, human dependency, and economics. Economic valuation of ecosystem goods and services that contribute to welfare economics shall create awareness about the environmental benefits, and motivate public participation in their conservation, human well-being, equity, and sustainable management. The SEEA-EEA framework supports continuous monitoring of ecosystem conditions, changes, and supply of goods and services, which supports decision-making on sustainable management of the natural environment and National Natural Resource Accounting. Six coastal ecosystems and habitats such as mangroves, salt marshes, sand dunes, mudflats, corals, and Nesting Grounds of Birds (NGB) are distributed in the coastal stretches of Karnataka State of India. Application SEEA-EEA framework results in monetary benefits from the 6 coastal ecosystems of Karnataka has been estimated for USD 1,64,12,630 /yr.

Keywords: accounting, SEEA, ecosystems, goods and services, coastal and marine, karnataka

1. Introduction

The economy has a complex relationship with the natural environment. Coastal and marine ecosystems are important natural environments producing valuable goods and services that are essential for human well-being. Stock and flow of the coastal ecosystem services have been used directly and indirectly by the economic units viz., households, enterprises, and Government for production and consumption and play a major role in the overall economic system. Fishery, fuel wood, fodder, tourist attraction, and similar direct uses have been well recognized as ecosystem services. Apart from the direct benefits, regulating services such as protection from cyclones, storms, floods, and tsunamis, prevention from soil erosion, water quality maintenance, carbon sequestration, etc., are also widely recognized as coastal ecosystem services. Many of the goods and services produced by the coastal ecosystems are not easily quantified and accounted for since; they are not being traded in the formal market (Daily *et al*, 1997) [3]. Hence, many of the coastal ecosystem goods and services have been often neglected or even ignored by the economy, industry, coastal communities, and other stakeholders though they are basically dependent on various ecosystem benefits. Systematic accounting of the benefits enlightens the relationship between ecosystem function, human dependency, and economics (Costanza and Farber, 2002) [1]. Recognizing the importance of ecosystem accounting, efforts have been taken at the international level to estimate economic values for non-market benefits and incorporate them into the National GDP. System of Environmental-Economic Accounting 2012-Central Framework (SEEA-CF, 2014) [6] is guiding the incorporation of all environmental services into the System of National Accounts (SNA, 2009) [8]. This study has aimed to estimate the equivalent economic benefits of coastal and marine ecosystems of Karnataka State, India using SEEA-EEA (SEEA EEA, 2014) [7] principles.

2. Study area and methods

Karnataka is the fastest growing State in India possessing rich natural resources comprising 4.34 lakh ha of forest, 5.65 lakh ha of inland water resources, 8000ha of brackish water area, and 320 km long coastal stretch6. The coastal stretch of Karnataka State is the study area to account economic benefits of ecosystems services (Fig. 1). Coastal districts such as Dakshina Kannada, Udupi, and Uttara Kannada covering 8 coastal taluks are distributed in this coastal stretch with a total population of 27,00,5377. District and taluk coastal length, distributed. Six coastal ecosystems and habitats such as mangroves, salt marshes, sand dunes, mudflats, corals, and Nesting Grounds of Birds (NGB) are distributed in this coastal stretch. The above ecosystems have been classified as Ecologically Sensitive Areas (ESAs) under Coastal Regulation Notification8 thereby human activities have been prohibited and regulated by Government.

In economic statistics, data have been collected and compiled under the statistical economic units of households, enterprises, government, and the rest of the world (export & import). However, under ecosystem accounting, spatial areas (land uses & benefits) are the statistical units hence, information about ecosystem extent, condition, stock, and flow shall be compiled. The activity of measuring the extent and condition of the ecosystem assets is the preliminary activity for SEEA–EEA processes. Measuring its extent and condition shall provide

detailed information about the ecosystem stocks, flows, production capacity, and supply benefits for human well-being. Accounting ecosystem assets in physical terms consist of measuring ecosystem extent, its condition, and expected ecosystem service flow at a particular point of time or accounting period. This activity registers a list of the quantity and quality of ecosystem services generated at a particular point in time and the expected future service flow from a specific ecosystem asset at a point in time.

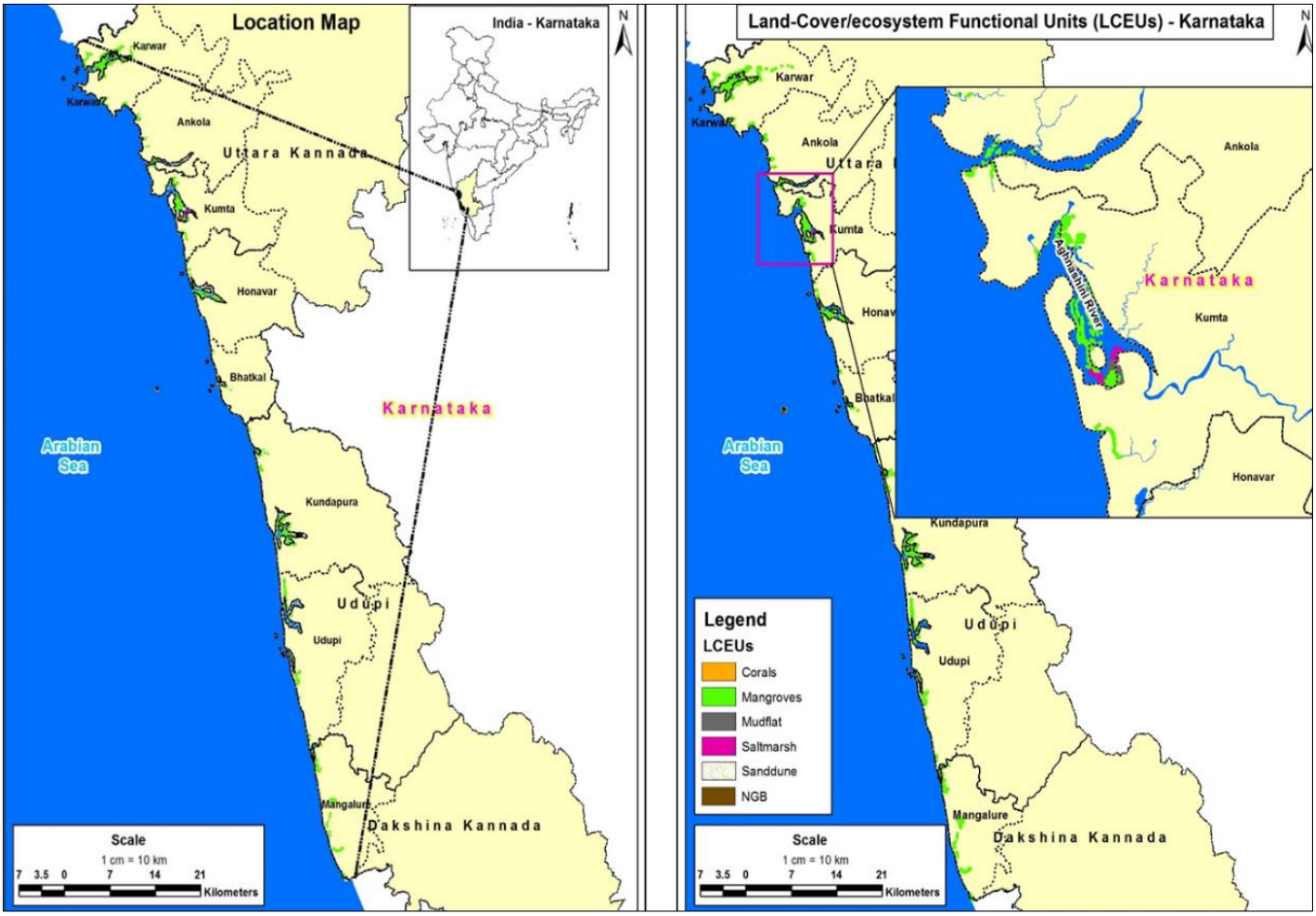

Fig 1: Karnataka study area map

Information on land use and benefits from the Karnataka ecosystems has been collected using different methods and scales. Remote sensing applications have been used to account for ecosystem extent, ecosystem condition, and classification of Land-Cover/ecosystem Functional Units (LCEUs) types. Primary and secondary data on ecosystem services and monetary benefits have been collected from relevant Government departments, landowners, and other stakeholders from their ledgers. In addition, administrative, Government, and academic data have also been used in this ecosystem accounting process. Primary data on the flow of provisioning, regulation, and cultural services and the quantum of benefits from various LCEUs of the ecosystem as intermediate to final product and beneficiaries as economic units were collected by interviews with local, elite, and personnel on various economic units. Structured questionnaires were also used to collect data from various stakeholders of ecosystems such as fishermen, local households, and tourists. Primary data on fishery production, shell collection, fuelwood, timber, groundwater utilization, and tourist visits were collected from the officials of the organizations and validated with open-source secondary data.

Integrated Valuation of Environmental Services and Trade-offs (InVEST) software was used to map and quantify the marginal change in regulating services such as protection from floods and storms, water quality maintenance, and carbon sequestration. Necessary physical, geological, and geomorphological information to provide input for InVEST model has been collected from the hosting organization (NCSCM) repository and open-source information. The market price was used to estimate goods such as fishery and shell collection. Non-market consumptive goods such as fuelwood, timber, and fodder benefits were estimated using the substitute cost method. The travel cost method was used to estimate tourism and recreational benefits and spiritual services of the ecosystems.

3. Results

The extent and condition, accounting for the physical flow covering provisional services, regulation services, cultural services of the Karnataka coastal ecosystems, and its equivalent economic value have been discussed in the following chapters.

3.1. Extent and condition

Assessment of ecosystem assets requires measurement of three key subjects such as ecosystem condition, ecosystem extent, and expected ecosystem service flows (productivity)in different time periods. Assessment of ecosystem extent is

generally by measuring land cover to determine areas and changes in various LCEUs. These accounting activities contribute to tracking the changes wrought by natural or man-made activities on the ecosystems to decide whether they are influencing them positively or negatively on the environment. Using the above information, protective measures against ecosystem degradation or ecosystem enhancement decisions can be adopted. Details of the opening and closing conditions of the extent of the Karnataka coastal ecosystems are given in Table-1. The extent study reveals that the coastal ecosystems have been distributed in 1882ha with the major share of mangroves. While comparing the previous data (SAC, 2011) [5], the total of LCEUs (EAU) extent is less than 29%. Rogers (1996) also indicates a 64% loss of LCEUs., and shows ambiguity in extent assessments. NCSCM has reclassified the LCEUs with a number of patches of the LCEUs to make accuracy in extent in this accounting period. In addition, there is no previous record of coral reef extent and NGB in Karnataka which are new inventories for this accounting period. Unlike the assessment of the extent of ecosystems, measuring its ecosystem condition has two stages such as identification of relevant key characteristics or parameters as indicators such as water, soil, biodiversity, carbon, and nutrient flows and valuing its changes in its reference condition as the indicators are reflecting changes in the LCEUs or ecosystem as a whole. Usually, changes in the condition are reflected in changes in the expected flows of ecosystem services. Accordingly, the relative beginning condition of the indicators has been collected from secondary sources, and their change during the accounting period has also been recorded in the LCEUs of Karnataka. A reference condition provides only a comparison point or baseline to which current indicators can be scientifically compared over time.

Table 1: Land Cover Ecosystem Functional Units (LCEUs) of Karnataka 1996, 2008 Data and 2011

LCEUs	LCEU Patches	Ecosystem Extent in Ha		
		NCSCM (2011)	SAC., 2008 Published in 2010	Rogers., 1996
Mangroves	1768	1646.88	967	550
Sand dunes	5	46.86	-	-
Mudflats	93	81.06	1663	1506.25
Salt marshes	6	56.23	-	3287.50
Corals	1	16	-	-
Nesting grounds of birds	1	35.08	-	-
Total	1874	1882.1	2630	5343.75

Usually, Basic Spatial Unit (BSU) attributed with information on standard physical, chemical, and biological characteristics of the ecosystems have been accounted to compare the changes in the ecosystem. To account for the condition and extent, annual or five to ten years based on the administrative requirement, flows and benefits shall be estimated. The marginal change in the condition (characteristics/quality) of the ecosystem for 4years time period (2008-2011) has been given in Table-2. The condition table indicates there was a flow of 1.58 lakh tone fishery11 have been produced from the mangroves; however, the present estimate indicates the flow of fishery is 457.2 tones/yr., including shell collection. Similarly, in mudflats sediment composition has been changed 12,13 with the domination of sand. Changing sediment composition alters the distribution, diversity, and production capacity of clams however, there is no site-specific information hence, the application of the data for estimating the condition is very difficult. Biodiversity, soil, and water quality opening and closing conditions of various LCEUs of Karnataka have been given in Table 2.

The study includes a collection of all secondary information on the condition of the ecosystem and attempts to compare it with the past condition. There is a huge data gap to compare thematic and time series conditions of various parameters. Aggregated secondary data are also distantly relevant for comparison. To account for the condition of the ecosystems, we need continuous monitoring programs to supply information for the condition table.

Table 2: Condition of Karnataka's coastal ecosystems

Opening condition (based on secondary data)	Mangroves Extent: Mangroves-966.6ha; water spread-11583.35; *All Karnataka* mangroves species-14;prawn-80; crabs/lobster-15; bivalves-20; demersal fish-1.02 lake tonne; crustaceans .29 lake tonne; molluscs-.27 lake tonne; *Aghanashini:* Soil quality-Organic carbon - 0.24-1.60%; Total nitrogen-0.12-0.34%;Total Phosphorus-0.097-0.169%; total potassium0.018- 0.058% potassium1-5 mg/l; sodium8-59 mg/l;chloride-4-30 mg/l(2014)[21] *Kundapura:* bird sp. 79,resid.-71%, migr.-29%; insects sp.305 ; Kundapura- water quality-potassium (0.064 to 20.33 mg/l); sodium (0.022 to 878.04 mg/l); chloride (0.704 to 380.70 mg/l)	Mudflats Extent: 1662.98ha; 1506ha *Aghanashini*; sedimentation rate-0.13 to 2 cm/yr.; sand-avg10.63%; silt-avg42%; clay-avg47.32%; Org. Carb., avg 3.08%; Sand- avg-78%;silt avg7.33%; clay avg.,15%; Org. Carb-avg-0.573%	Salt marsh Extent: 3287ha	Sand Dune Extent: No information. legume sp.-13; Ipomoea sp. 41; Launaeasp., 28; flora 145 sp; sand binding creepers sp. 10; Erect herbs sp.10; shrubs sp.5; climbers sp.6; Ant Sp.-31;	NGB Extent: No information.; Netrani Island-bird sp.40, migra.,16; resident birds., 24; sea eagles dist. -400	Coral Reefs Extent, Netrani Island-: No info. depth-6-40m; visibility 15-30m; coral sp., 14; fish sp., 92;sponges-4;Jelly fish-2; seaweed-7;Holothuria-1; gastropods-48;crabs-17; shrimp-2; lobster-4
Improvements by natural	-					
Improvements by man-made activities (mangroves)	0 sq km to 3 sqkm (1987-2017); Honnavar Division-665.50 ha(2000-01 to 2005-06); Karwar Division-190ha. (2002-03 to 2004-05); Mangalore Division-227ha. (1992-03 to 2002-03); Kundapur Division-160ha. (1995-96 to 2002-03)					
Reduction due to extraction	-					
Reduction by human activity (mangroves)	Declined from 6000ha in 1987 to a mere 300 ha in 1997 and 50% of mangroves were destroyed due to aquaculture farms at Kadwad and Kanasgiri backwaters					
Reduction by the catastrophic loss of human activity	-					
Reduction by catastrophic of nature	-					
Inventories/ Discovery				47ha	35ha	16ha
Reclassification / Reappraisals	Added 681	Red. 1582ha	Red. 3231			
Closing condition	Extent - mangroves- 1647ha; water spread area 11011.46ha; mangrove sp. 16;*Aghanashini*fish sp., 80; fish sp. 50; molluscs-8; crustaceans-4; *All Karnataka*-fishery- 457.2 tonnes; *Gangolli*- Organic carbon0.01%; Nitrogen-2.5 mg/kg; Phosphorus-1.0 mg/kg; Potassium-0.5mg/kg	Extent -Mudflat-81ha[26] *Aghnashni* range of sediments less than 0.002mm to more than 4mm[24]; Edible bivalves species-9; bivalve species-8; crabs species-30; Bird species 120; crabs species 30; fishery- 3.2 tonnes; *Aghnashni*-	Extent- salt marsh-56ha; crabs sp.13; ducks >5000; fishery 6.14 tonnes; *All Karnataka* fauna -93sp; flora - 6	Extent- sand dune 47 ha; Palm tree - 119; Casuarina tree – 27,669; crab sp., 9	Extent- NGB 35ha *Aghnashni* estuarine bird sp.-120; Netrani Island bird sp.21	Extent- coral area-16.10ha[26] Netrani Island - coral sp.-14,fishes-92 sp; seaweeds-7; sponges-6; jellyfish-2;Holothuria-1; gastropods-48; crabs-17; shrimps-2; lobsters-4 ; bird sp-21

3.2. Accounting physical flow of services

Accounting for the physical flow is the initial step for the comprehensive measurement of ecosystem service flows. Physical accounting of ecosystems organizes assets, flows, benefits, and support developments, monitoring, and evaluation of policies for environmental governance. Accounting physical flow of ecosystem services is primarily based on the estimation of benefits acquired by people in a particular assessment year.

Measuring the flow of provisioning, regulating and cultural benefits assess the capacity of the LCEUs to generate an expected combination (or basket) of ecosystem services. To account for physical flow in spatial boundaries, LCEUs or ecosystem patches in various administrative units such as taluks, districts, and states have been estimated. Since, a basket of services flowing (many services) from a single LCEU, this spatial unit is suitable for the estimation of physical flow. There is very limited or no basic information on the flow of ecosystem services for different services in various scales (BSUs, LCEUs) for Karnataka LCEUs. Benefits out of LCEUS of Karnataka have been classified as provisioning, regulating, and cultural services following the SEEA-EEA (2014) [7] framework.

The benefits identified from the ecosystems have also been classified using the CICES, Common International Classification of Ecosystem Services (Haines-Young & Potschin., 2018) [4] to assure the services are under the ecosystem process. The CICES classification is a digital bar code of ecosystem products its classification boundary is aligned with the measurement boundaries of the ecosystem by the exclusion of abiotic benefits, rejection of cultivated crops, and elimination of supporting services of ecosystems. Fishery, shells for calcium carbonate, groundwater from the surface layers, palm fruit, sand for construction purposes, fuelwood, timber, fodder, fencing using twigs and boughs of mangrove trees, and casuarina plantation benefits have been classified as provisioning services. Protections against storms and floods, water quality maintenance by nutrient filtration from discharges, and carbon sequestration have been classified as regulation benefits out of the coastal ecosystems of Karnataka. Recreational benefits such as tourism, bird watching, and spiritual service are classified as cultural services.

3.3. Provisioning services

Among the ecosystems (LCEUs) mangrove, mudflat, and salt marsh creeks have been used for fishing for commercial and subsistence fishing. Fishery production including finfish, crabs, and bivalve meat is estimated to be 253.8 tonnes. Among the fishery, bivalve collection has been estimated to be 209.91 tonnes for the accounting period. The clams have been collected by the local communities to market the soft parts for edible purposes and the hard shell for lime purposes. Fishing in the LCEUs of corals and the nesting ground of birds around Netrani Island is very limited since this area has been used for navy and military training activities. Aghanashini estuary which has been classified under mangrove and mudflat ecosystem is known for its abundance and production of bivalve species, especially during the post-monsoon season (from November to May).

Sands deposited in the channels of mangrove LCEUs have been auctioned for mining, which has been used for construction purposes in this area. The sand of around 222 tonnes has been mined from the mangroves of Honnavar taluk for construction activities. Surface groundwater stored in the LCEU of sand dunes has been used by the local communities for drinking, sanitation, horticulture, agriculture, and livestock management. Palm trees that have been densely distributed in the sand dune LCEUs provide tender palm fruit known as ice apple that attracts local communities for its delicious, translucent jelly and providing a cooling effect in the summer. In addition, the mangrove leaves have been used as fodder for live stocks, and branches have been used for fuel wood, timber, and fencing purposes. The salt marsh-grown plants have also been used for cattle grazing and livestock management. In addition, the casuarina plantation by the Government is producing logs (balance stock) of about 484 tonnes/yr. is an important benefit of sand dunes. The number of provisional benefits from the ecosystem services has been given in Table 3.

3.4. Regulation services

The InVEST model application for the protection benefit of Karnataka coastal ecosystems results that the LCEUs have reduced the vulnerability of the livelihoods of adjacent villages. Coastal vulnerability maps of Halkar village revealed that with the presence of coastal ecosystems, the vulnerability of shoreline Exposure Index (EI) is low (1.5 to 2.5) however, without these ecosystems the vulnerability of the village increase to moderate (2.5 to 3.5). The above LCEUs of Halker village, reduce the vulnerability to the population of 1750 individuals., 438 houses, 105ha of agricultural land, and a 3.8 km length road network.

Carbon accounts provide information on carbon sequestration and storage of carbon. In addition, carbon accounting provides inputs for a wide range of analytical and policy contexts including recommendations for protecting and restoring natural ecosystems. The carbon sequestration rate using InVEST coastal blue carbon model reveals that mudflats sequester carbon at a higher rate 1.7 tonnes /ha., followed by salt marsh (1.3 tonnes /ha), sand dunes (1 tonne /ha) and mangroves (0.8-0.9 tonnes /ha) LCEU of Karnataka. While applying the carbon sequestration rate of the LCEUS to the total carbon stock of Karnataka (226332 tC/yr.) the LCEUS is sequestering 1740 tC/yr. Share of the LCEUs such as mangroves, saltmarsh, mudflats, and sand dunes in total carbon sequestration of Karnataka has been accounted as 1482 tC/yr, 73 tC/yr, 137.8 tC/yr, and 46.9 tC/yr., respectively.

Nitrogen and phosphorus are the important nutrients released in the discharges of agriculture, aquaculture, and domestic sewage. Overloading the above nutrients in the natural environment is harmful to biodiversity and ecosystem functioning. Fig 6. Nutrient delivery ratio model maps of Karwar represent the actual flow from pollutant sources to the nearby ecosystem of (Mangrove) with an annual accumulation of TN & TP is 1.5 kg/pixel, 0.5 kg/pixel. Nutrient delivery ratio model maps of Kumta represent the actual flow from pollutant sources to the nearby ecosystem of (Salt marsh) with an annual accumulation of TN & TP is 3.4 kg/pixel, 1.5 kg/pixel.

The LCEUs are filtering the nutrients by their retention capacity and alleviating the harmful red-tide phenomenon in the coastal waters. The InVEST nutrient delivery model has revealed that the nitrogen and phosphorus retention capacity of mangroves are ranging between 17 and 40 kg/ha/yr., and 7-13 kg/ha/yr., respectively. Similarly, the nitrogen and phosphorus

nutrient retention capacity of salt marshes have been accounted as 22.5kg/ha/yr. and 9.9 kg. /ha/yr., respectively. Accordingly, the total average nutrient (nitrogen + phosphorus) retention potential of mangrove ecosystems of Karnataka is 41.94 tonne/yr. whereas, in the salt marsh, it is 1.83 tonne/yr. The mangrove ecosystem with 70–80% of retention capacity, accumulates 17 - 40 kg/ha/yr. of total nitrogen and 7 - 13 kg/ha/yr. of total phosphorus in Karnataka. These values are more or less equal to the Gujarat mangrove ecosystem with an average accumulation of 55.74 kg/ha/yr. and 12.38 kg/ha/yr. of total nitrogen and total phosphorus respectively48. The salt marsh ecosystem has a 60-70 % retention capacity to accumulate 22.6 kg/ha/yr. of total nitrogen and 9.9 kg/ha/yr. of total phosphorus.

3.5. Cultural services

Mangroves along 15 creeks of Karnataka attract tourists. Karnataka State has implemented a green wall project along the coast to protect the community from natural hazards which have grown thick and attracted tourists to these places. Tourism in mangrove areas is yet to become a mainstream activity, though 1600 tourists/yr. visit these mangroves. Due to the abundant distribution of bird flocks in mangroves, about 1200/yr. bird watchers and photographers are visiting these mangroves during seasons. In addition, mangroves are an interesting research topic for invention for researchers in Karnataka. It has been estimated that the mangroves of Karnataka are research subjects for 30 research papers and in a year at least one researcher has been awarded a doctoral degree in mangrove topics. Owing to its scenic beauty with beaches, sand dunes are attracting people for recreation purposes. It has been estimated that about 6000 tourists/yr., are visiting sand dunes. In addition, it is attracting communities to perform fitness activities in the morning and evenings in many stretches of Karnataka dunes. Netrani is a coral island located about 19 km away from mainland Murudeeshwar Beach. The coral reef biodiversity of Netrani Island is popular for its visibility (15mtrs). The rich marine life on Netrani island has promoted eco-tourism, especially SCUBA diving and snorkeling activities49, 50. Reports indicate exclusive tourists from Bhatkal, Mangalore, Goa, Mumbai, and Bangalore for SCUBA. Around 500 tourists visit this island during the winter season to dive in the corals. In and around this Netrani Island, bird flocks have been distributed in seasons hence they have been classified as BNG under CRZ 201952 Notification. The island also has spiritual value since fishermen and people from local villages visit the island once a year to offer their prayers in the temples as per their tradition.

Table 3: Physical flow of ecosystem services/year

Ecosystem services	EAU	Karnataka coastal ecosystems					
	LCEU	Mangroves	Sand dunes	Mudflats	Salt marshes	Corals	Nesting grounds of birds
	Extent (ha) + CICES	1646.88	46.86	81.06	56.23	0.16	35.08
Provisioning services	Fishery (tonnes) 1.1.6.1	244.46	-	3.2	6.14	-	-
	Ground water (Kilo liter) 4.2.2.2	-	171.5	-	-	-	-
	Palm fruit (tonnes) 1.1.1.1	-	4.76	-	-	-	-
	Shell collection (tonnes) 1.1.6.2	177.6	-	32.31	-	-	-
	Sand mining (tonnes) ISIC – B0810	222	-	-	-	-	-
	Fuelwood (tonnes) 1.1.1.2	313.91	-	-	-	-	-
	Timber (tonnes) 1.1.5.3	32	-	-	-	-	-
	Fodder (tonnes) 1.1.3.2	6.72	-	-	438	-	-
	Fencing (tonnes) 1.1.5.2	9.46	-	-	-	-	-
	Casuarina tree (tonnes) 1.1.1.2	-	484	-	-	-	-
Regulating services	Protection against storms and floods hectare/Houses) 2.2.1.3	1286 ha / 35804	71 ha	19 ha	22 ha	-	-
	Water quality maintenance (nutrient in tonnes) 2.1.1.1	41.94	-	-	1.83	-	-
	Carbon sequestration (tonnes) 2.2.6.1	1456	46.9	137.8	73.1	-	-
Cultural services	Tourism (No. of visits in thousand) 3.1.1.1	1.6	59.9	-	-	0.5	-
	Spiritual service (No. of visits in thousand) 3.2.1.2	-	-	-	-	-	1.6
	Bird watching and photography (No. of visits in thousand) 3.1.1.2	1.2	-	-	-	-	-
	Fitness activities (No. of visits in thousand) 3.1.1.1	-	4.8	-	-	-	-

3.6. Monitary accounting

Valuation of ecosystem assets and services in the context of monetary terms is a complex process since many of the ecosystem goods and services of the ecosystems have not been traded on markets consequently, economic principles must be applied to estimate the prices of various ecosystem services and assets. Marketed ecosystems goods pricing has demand and supply principles and provisioning and cultural service can be estimated using market pricing methods. Market prices are defined as amounts of money that willing purchasers pay to acquire goods, services, or assets from willing sellers. Non-monetary transactions are transactions for which a market price is not observable or does not exist. The value of these transactions must therefore be measured indirectly or otherwise estimated.

There are many ecosystem valuation methods in practice and the methods are capable of estimating values to identify missing prices of ecosystems including the benefits of regulation services. Further, it is relevant to estimate exchange values for ecosystem services and ecosystem assets when similar services are existing under production, consumption, and wealth since the basis for economic accounting is the exchange value concept.

SEEA-EEA along with SEEA–CF has guided the concepts and principles to augment ecosystem values in SNA. Using the principles of the above guidelines, the monetary benefits from the 6 coastal ecosystems (LCEUs) of Karnataka have been estimated at USD 1,64,12,630.1 /yr. Among the total, regulation services share USD 1,51,15,067.8 /yr. (93%) followed by provisioning service USD 12,51,629.6 /yr. (7%) and cultural service USD 45,932.6 /yr. (0.3%). Among the provisioning services, subsistence fisheries contribute USD 11,61,169.8 /yr. which is 93% of the total provisioning services of the coastal ecosystems. The shelterbelt plantation of Casuarina provides a monetary benefit of USD 22,923.5 /yr. The economic benefits of the services from various coastal ecosystems have been given in Fig. 7 and Table 4.

Among the regulation services, the ecosystem function of protection against storms and floods during calamities has a major share of USD 1,44,48,209 /yr, which is 88%of total benefits estimated from all coastal ecosystems. Regulation services from coral reefs and NGB that are falling inside the sea have not been studied since, there is a data gap in the regulation function of the above ecosystems and, there are no direct beneficiaries identified through regulation services of the ecosystem. Damage cost avoided by coastal ecosystems was calculated by estimating the value of assets protected by the coastal ecosystems. Asset values were estimated based on the norms provided by the Ministry of Home Affairs, Government of India for assistance from the State Disaster Response Fund (SDRF) as minimum standards of relief value. Accordingly, 35804 houses/buildings lying behind the landward side of the ecosystems have been protected by the LCEUs. Mangroves play an important role in protection services and share USD 1,32,61,330.8 /yr in the ecosystem services of Karnataka.

Water quality maintenance by nutrient retention capacity reduces environmental pollution and harmful algal growth and renders sustainability of environmental protection and the existence of associated biodiversity. This nutrient filtration activity of the LCEUs is similar to SBR's (Sequential Batch Reactor) operating cost to remove 1kg of nitrogen and phosphorus from polluted water which is estimated as Rs. 689. Accordingly, the nitrogen and phosphorus retention capacity of the LCEUs using InVEST model results that the virtual stock value is USD 6,19,147.8 /yr. for mangroves from Rs. 17,548/ha/yr. Similarly, the nitrogen and phosphorus retention capacity of salt marsh virtual stock value is USD 26,994 /yr. with 22,394/ha/yr.

Using InVEST model, it has been estimated that the total carbon stock in Karnataka coastal ecosystems is 226332 tonnes, and its carbon sequestration capacity is 1714 tonnes/yr., and prices were fixed based on the Social Cost of Carbon (SCC). SCC is an estimated economic cost caused by an additional tonne of carbon dioxide emissions or its equivalent which is avoided damage cost method54, which has a value of USD 20,716.8 /yr. The outputs of InVEST model indicate that the carbon sequestration from mangroves, saltmarsh, mudflats, and dunes are 1456 tC/yr, 73 tC/yr, 137.8 tC/yr, and 46.9 tC/yr respectively. Among the coastal ecosystems, mangroves contribute more to carbon sequestration due to the area distribution however, the carbon sequestration potential is high in the mudflats ecosystem at 1.7 tC /ha followed by the saltmarsh ecosystem at 1.3 tC /ha, dune ecosystem at 1 tC /ha and mangroves ecosystem 0.9 tC /ha.

Cultural services of the coastal ecosystem are providing the economic benefit of USD 45,932.6 /yr to the tour operators, Government, and coastal communities. Tourism and recreation in corals share (USD 21,423.8 /yr) followed by dunes (USD 17,781.8 / yr). Various LCEUs and their economic benefits in cultural services have been given in Table 5.1.

Table 4: Monitory benefit of Ecosystem Services/yr. (2011 value/ $/ yr.)

Ecosystem services	EAU	Karnataka coastal ecosystems						
	LCEU Unit	Mangroves	Dunes	Mudflats	Salt marshes	Corals	Nesting grounds of birds	Total
	Extent (ha)	1646.88	46.86	81.06	56.23	0.16	35.08	-
Provisioning services	Fishery	11,50,457.9	-	4,284.8	6,427	-	-	11,61,169.8
	Groundwater	-	8.6	-	-	-	-	8.6
	Palm fruit	-	214.2	-	-	-	-	214.2
	Shell mining	214.2	-	42.8	-	-	-	257
	Sand mining	8,569.5	-	-	-	-	-	8,569.5
	Fuelwood	19,281.4	-	-	-	-	-	19,281.4
	Timber	214.2	-	-	-	-	-	214.2
	Fencing	10,711.9	-	-	-	-	-	10,711.9
	Fodder	428.5	-	-	27,850.9	-	-	28,279.4
	Casuarina tree	-	22,923.5	-	-	-	-	22,923.5
Regulating services	Protection against storms and floods	1,32,61,330.8	9,21,223.3	1,07,119	1,58,536	-	-	1,44,48,209.2
	Water quality maintenance	6,19,147.8	-	-	26,994	-	-	6,46,141.7
	Carbon sequestration	17,674.6	557	1,628.2	857	-	-	20,716.8
Cultural services	Tourism	2,999.3	17,781.8	-	-	21,423.8	-	42,204.9
	Spiritual service	-	-	-	-	-	1,585.4	1,585.4
	Bird watching and photography	857	-	-	-	-	-	857
	Fitness activities	-	1,285.4	-	-	-	-	1,285.4
Total		1,50,91,887.2	9,63,993.8	1,13,074.8	2,20,665	21,423.8	1,585.4	1,64,12,630

4. Conclusion

It has been inferred from this study that regulation services especially protection services an important benefit received from all coastal ecosystems (LCEUs). The fishery is an important provisioning service in all LCEUs except dunes. Fishery activity in the creeks of mangroves, mudflats, and salt

marshes is meager and has many scopes for increasing by extensive cultivation of oysters, mussels, and clams. The cage culture of fish has been practiced in creeks. Similar cage culture activities may be extended for crabs and shrimps which may increase the economic benefits from ecosystems. International and national level studies suggest that honey and medicinal benefits are extracted from mangroves. These benefits do not deteriorate the natural resource but help in the sustainable development of the economy. Hence, the local community could be encouraged to involve in honey collection and awareness can be generated on traditional uses of mangrove plants for medicinal purposes. Among the provisioning services, fuel wood collection in mangrove areas is significantly contributing to the ecosystem services. The above economic activity shall be closely monitored since the stock is being widely harvested by households.

There is no significant research on qualitative and quantitative nearshore coral reefs and the demarcated bird nesting area of Netrani Island. Hence, the estimation of services from these LCEUs in this economic accounting period has limitations. Studies shall be initiated to provide input on the quality and quantity of socio-economic benefits from the above LCEUs. Palm trees and casuarina plantations are important economic activities in the dune LCEUs. Palm trees stabilize the dune, protect it from storms, and enhance the coastal aquifer hence, palm trees in the dunes may be protected from depletion by manmade activities.

Dunes and corals in Karnataka generate significant economic benefits through tourism. Mangroves do not contribute substantial tourism benefits except for some informal recreational activities such as bird watching by local people. Mangroves in Karwar, Kundapura, and Kumta taluks have great potential of providing ecotourism benefits. The distribution of mangroves in these regions is high and these places have nearby tourist places such as beaches and temples which will attract a significant portion of tourists to mangroves. Tourism is one of the important income-generating activities that supports the growth of the National GDP and hence, natural resources can be marketed with precautions.

Mussel collection is the only provisioning service from the mudflat LCEUs however while comparing the opening and closing stock of mussels in extent and condition Table-2, the stock is being depleted. A huge mudflat area has been reclassified as mangroves, Table-2. Water spread areas have been reduced in the LCEUs. In addition, the extent and condition of Table-2 indicate there are many adverse changes in the water, soil, and biological quality of the LCEUs. Continuous monitoring and community participation in ecosystem management shall replenish and regenerate the quality and quantity of the LCUS's capacity for a sustainable flow of resources in the subsequent accounting period. There are many data gaps to estimate the condition and extent of the LCEUs of Karnataka hence, continuous physicochemical studies on important physicochemical parameters of in water and soil of the LCEUs shall support the next SEEA-EEA accounting period. Biological organisms are not the only stock of the LCEUs but also support continuous functioning and flow of resources. Detailed, site-specific biological studies shall support monitoring the changes of the LCEU for accounting and also take policy decisions for replenishment of stock.

The monetary values of the present account period could be used in National, State, and regional policies and cross-sectoral plans to integrate environment and economics. Using the monetary value, departments may assess the existing policies to choose alternative policies matching the stock, flow, demand, and supply toward sustainable development.

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References

1. Costanza R, Farber S. Introduction to the special issue on the dynamics and value of ecosystem services: integrating economic and ecological perspectives. Ecol. Econ. 2002;41:367-373.
2. CSIR-NEERI. Environmental Impact Assessment Studies for Development of Sea Port at Tadadi, Karwar, Karnataka. CSIR-National Environmental Engineering Research Institute, 2014, p45(E-8).
3. Daily GC. Valuing and Safeguarding Earth's Life Support Systems. Island Press, Washington, DC, 1997, 365–374.
4. Haines-Young R, Potschin MB. Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure, 2018, 1-55.
5. SAC. National Wetland Atlas: Wetlands of International Importance Under Ramsar Convention. Chandrika Corporation, Ahmedabad, India, 2011, p53.
6. SEEA - CF. System of Environmental-Economic Accounting 2014 - Central Framework. United Nations Document symbol: ST/ESA/STAT/Ser.F/109, 2014. ISBN: 987-92-1-161563-0.
7. SEEA EEA. System of Environmental-Economic Accounting 2012 - Experimental Ecosystem Accounting. United Nations Document symbol: ST/ESA/STAT/Ser.F/112, 2014, p1-198.
8. SNA. System of National Accounts 2008. United Nations, New York, 2009.