Goods and services and equivalent economic benefits of sand dunes of India

Abstract

Sand dunes are simply an extension of the beach which is a reservoir of sand, during storms when the waves erode the dune and carry the sand into the sea. They are providing habitat for shellfish, birds, rodents, and ungulates. They have been used for coastal defense, water catchment areas, agriculture purposes, mining, and housing. Though there are many ecosystem services for human well-being, estimates of the value of sand dunes are scarce.

Benefit Transfer method to estimate the equivalent economic benefit results were used. The monetary benefit of sand dunes in a one-hectare area of the sand dune has been estimated at Rs.8220002/ha./yr =US$ 176103.66(average). Sand dunes have been distributed in 1231 patches with a total area of 32445 ha. Using the average value of sand dune benefits, the equivalent economic benefit from sand dunes of India cost Rs. 26670 crore/yr.=US$ 5.71 billion. Among the coastal States and UTs, Andhra Pradesh State has a huge area (11594 ha.) of sand dunes which share Rs. 9530 crore/yr.=US$ 2.04 billion which occupies 36% of the total sand dunes of India.

Keywords

Sand dune, coastal, environmental economics, goods and services, India

Comment [RK1]: reviewer comments
1. In general, this manuscript is quite good, the author does not include the purpose of the research in the manuscript so that this paper becomes directionless
2. The conclusion is also not appropriate because there is no research objective listed in the manuscript
3. This manuscript is considered for accept if necessary

Comment [RK2]: What is the purpose of writing?

1. INTRODUCTION

A coastal sand dune is a transitional zone between sea and land that forms a unique ecosystem [1]. They are part of the sand-sharing system composed of a highly mobile beach and a more stable dune [2]. They are aeolian (deposited) landforms established by the supply of loose sediment transported by the ambient winds. The coastal sand dunes have been developed in places where there is an adequate supply of sand in the intertidal zone and where prevailing winds are strong enough for sand movement [3].

Sand dunes are simply an extension of the beach which is a reservoir of sand, during storms when the waves erode the dune and carry the sand into the sea. Without dunes, our beautiful sandy beaches would erode away. Without the dunes, sand would continue to blow inland, drifting over whatever lies in its path. Dune vegetation is extremely efficient at capturing and holding sand and preventing it from being lost from the beach [4]. Sand dunes are usually classified as incipient dune, fore dune, and hind dune. Incipient dunes are located seaward and are immature and distributed with grasses. In an accreting coastline, the incipient dune shall develop as a fore dune. A fore dune shall locate between the incipient dune and the hind dune and is distributed with grasses and shrubs. Fore dunes supply sand for erosion demand in storm conditions. They located inland developed areas and distributed with the vegetation such as trees and shrubs [5]. During storm conditions, incipient and fore dunes may be severely eroded by waves. During the intervals between storms, dunes are rebuilt by wave and wind effects. Dune vegetation is essential to prevent sand drift and associated problems [5].

Sand dune vegetation contains many specific fauna and flora species which can adapt to live in such harsh conditions in salty, marshy and swampy areas. They are providing habitat for fish, shellfish, birds, rodents, and ungulates [6, 7]. Around 20% of landscapes of the world coastal areas have been distributed by sand dunes [8]. In Europe, the protection and restoration of dune wildlife and habitat have become a priority [9]. In many regions of the world, dunes have been used for agricultural purposes [7].

The coastal sand dunes are not as productive exporters of nutrients as many other coastal ecosystems. They serve as sediment reserves, stabilize coastlines, provide areas for recreationand provide breeding and feeding sites for seabirds, turtles, and other coastal species. They have been used for coastal defense, water catchment areas, agriculture purposes, mining, and housing [10]. They store rich diversified genetic resources along with high ecological values [11]. Sand dune living organisms are globally or provincially rare, and many are classified as species at risk [4, 2]. Sand dunes have played a vital role in the economic and social life of coastal people not only by supporting unique values such as medicine, food, fodder, and economy. Though there are many ecosystem services for human well-being, estimates of the value of sand dunes are scarce [12, 13].

2. STUDY AREA AND METHODOLOGY

Coastal sand dunes have been distributed in all coastal states coast of India. All over the mainland coast sand dunes have been distributed in 1231 patches with a total sand dune area of 32445 ha. The average size of 26 ha/patch is the study area of this study. Details of sand distribution in various coastal States, located districts, number of patches, and area (ha) are described in table 1. Millennium Ecosystem Assessment [14] and The Economics of Ecosystems and Biodiversity [15] have developed a framework to estimate environmental goods and services. The framework includes (i) Direct use value; (ii) indirect use value; (iii) option value; and (iv) non-use value. The first three are generally referred to together as 'use value'. Direct use values refer to ecosystem goods and services that are used directly by human beings. They include the value of consumptive uses such as harvesting of food

products, timber for fuel or construction, and medicinal products and hunting of animals for consumption; and the value of non-consumptive uses such as the enjoyment of recreational and cultural activities that do not require harvesting of products. Direct use values are most often enjoyed by people visiting or residing in the ecosystem itself. Indirect use values are derived from ecosystem services that provide benefits outside the ecosystem. Examples include natural water filtration which often benefits people far downstream, the storm protection function of mangrove forests which benefits coastal properties and infrastructure, and carbon sequestration which benefits the entire global community by abating climate change. Option values are derived from preserving the option to use in the future ecosystem goods and services that may not be used at present, either by oneself (option value) or by others/heirs (bequest value). Provisioning, regulating, supporting and cultural services may all form part of the option value to the extent that they are not used now but may be used in the future. Non-use values refer to the enjoyment people may experience simply by knowing that a resource exists even if they never expect to use that resource directly themselves. In this study, the Benefit Transfer method has been applied to estimate the goods and services of sand dunes.

Table 1- Sand Dune – Indian Coastal Districts

Sl. No	State / Union Territory	District	Number of Sand Dune patches in coastal areas	Sand Dune distribution - ha.
1.	Gujarat	Bhavnagar	8	289.06
2.		DevbhumiDwarka	49	515.51
3.		Gir Somnath	20	1231.86
4.		Junagadh	9	1032.34
5.		Kachchh	25	2042.48
6.		Navsari	10	267.62
7.		Porbandar	12	1250.39
8.		Valsad	4	20.90
Sub Total			**137**	**6650.16**
9.	Maharashtra	Ratnagiri	15	58.97
10.		Raygad	3	22.42
11.		Sindhudurg	75	329.99
Sub Total			**93**	**411.38**
12.	Goa	North goa	25	47.23
13.		South goa	75	246.36
Sub Total			**100**	**293.59**
14.	Karnataka	Uttar kannad	4	45.37
15.		Udupi	1	1.50
Sub Total			**5**	**46.87**
16.	Diu &Doman	Diu	4	382.03
Sub Total			**4**	**382.03**
17.		Cuddalore	60	308.37
18.		Kanchipuram	27	304.54

19.	**Tamil Nadu**	Kanniyakumari	8	53.14
20.		Nagappattinam	21	233.76
21.		Ramanathapuram	108	693.74
22.		Thanjavur	1	0.13
23.		Tirunelveli	11	116.44
24.		Tiruvallur	23	216.70
25.		Thoothukudi	18	869.19
26.		Villupuram	21	297.21
Sub Total			**298**	**3093.19**
27.	**Andhra Pradesh**	Krishna	1	21.02
28.		Nellore	120	7547.72
29.		Prakasam	44	1047.31
30.		Srikakulam	36	2640.11
31.		Vishakhapatnam	18	311.93
32.		Vizianagaram	4	26.33
Sub Total			**223**	**11594.43**
33.	**Odisha**	Baleshwar	47	744.55
34.		Ganjam	48	1359.73
35.		Jagatsinghapur	53	1024.30
36.		Kendraparha	10	343.29
37.		Puri	57	6210.05
Sub Total			**215**	**9681.92**
38.	**West Bengal**	North 24 parganas	2	4.90
39.		Purbamedinipur	109	210.43
40.		South 24 parganas	37	48.65
Sub Total			**148**	**263.97**
41.	**Pondicherry**	Pondicherry	8	27.82
Sub Total			**8**	**27.82**
Total			**1231**	**32445.35**

3. META-ANALYSIS (ACCOUNTING) SAND DUNE ECOSYSTEM - GOODS AND SERVICES

Sand dunes provide a wide range of provisioning, regulatory, cultural, and support services [13]. Many of the sand dune goods and services are not yet economically estimated [16]. Important provisional services from the sand dune are the supply of minerals and the supply of groundwater. The sand dunes provide regulatory services such as protection of infrastructure from natural hazards such as erosion, and flood control by regulating sand supply to the system by stabilization of dunes. In addition, the sand dunes act as a barrier between inland and sea and regulate water quality and pollution in the region. The sand dunes provide cultural services such as recreation space, aesthetics, psychological, therapeutic opportunities, and educational resources. The sand dunes provide supportive services by providing habitats to many fauna and flora, and nesting and roosting sites for many avifauna and turtles [17]. In this meta-analysis, the economic values of many ecosystem services of sand dunes have been discussed and the values are applied to India's coastal sand dune patches.

3.1 Provisioning services of sand dunes

Provisioning Services are ecosystem services that describe the material or energy outputs from ecosystems. They include food, water, and other resources [15]. There are many minerals being extracted from sand dunes. The sand of sand dunesis washed and used in the construction industry [13]. However, sand mining from sandhas been restricted in many countries. Mining for minerals and heavy metals from the sand dune of South Africa is very heavy [18] but there was no economic estimate of this benefit. The sand dune is also a suitable site for asparagus cultivation [19]. At the community level, Marram grass has been used to prepare mats, basket-weaving, and thatching [20].

Sand dunes are an important source of coastal groundwater. The permeable sand dune system tends to support a freshwater lens which acts as a barrier to protect from saltwater intrusion into the inland. The freshwater lens is recharged both by direct precipitation and river discharges in the nearshore region [21]. It acts as a buffer against saltwater intrusion. In the Meijendel dunes of the Netherlands, dune aquifers have been used as a source of drinking water for centuries [22]. The aquifer supplies enough water for about 1.5 million people in the surrounding cities. Hence, the Meijendel dune has been managed as a nature reserve to supply drinking water needs. It has been estimated that the revenue from the reserve is $99.2 million/year (1991 estimate) however the cost of management of the reserve was estimated for $3.8 million/year [16].

3.2 Regulation services of sand dunes

3.2.1. Protection service

Sand dunes are naturally protecting the coast from storm surges due to their vegetated sandy structure and their height [23, 4]. As a resilient natural barrier to the hazards such as wind and waves, sand dunes are the least expensive and most efficient natural structures against storm-surge, flood, and erosion to protect the coastal infrastructures [24, 25, 26]. The stabilized sand dunes protect the recreation and tourism beaches, oceanfront properties, near-shore developed lands, and wildlife habitats. The town of Misawa is a good example of where coastal sand dunes mitigated tsunami impacts during the Great Eastern Japan earthquake. According to witnesses of the Misawa villagers, the tsunami could not reach the top of the dune, leaving the village behind the dune undamaged [27].

Sand dune's disturbance regulation function in Mexico was estimated at $67874/ha/yr [28]. In the sand dune of comarques of Catalonia, Spain, the disturbance regulation function of the sand dune was estimated at $67,400 USD/ha/yr [29]. In South Carolina,

the coastal protection function of the sand dune was estimated using a willingness to pay for the home price method of $254.00/30cm. In the same place (South Carolina), the contingency valuation method was applied to estimate an erosion control program which estimated the sand dune value at $4.45/household [30]. In Tramore, Ireland, the protection function of sand dunes was estimated at US$ 90,000/ha/50 year time scale [31].

3.2.2. Carbon sequestration

The coastal sand dunes are not as productive exporters of nutrients as many other coastal ecosystems. However, in sand dune grasslands and dune wetlands, Chrono sequence approaches were used to estimate carbon sequestration rates and estimated the carbon density as 212 tC/ha [32]. In another study, carbon sequestration rate of 1.25-3.12 total carbon dioxide (tCO_2/ha/yr. was estimated for sand dune [33]. Accordingly, CO_2 sequestration function of sand dune was estimated between 18.36 and 45.9 £/ha/yr. [34].

3.3 Cultural services of sand dunes

Coastal dunes also represent an important cultural value. In New Zealand, the earliest human settlements occurred on coastal dunes [35]. Many of the sand dune areas have archaeological evidence of Maori cultural heritage. Similarly, in Peru, the early hydraulic civilizations migrated to coastal dune fields [36]. Scenic attractions of sand dunes attract many painters in the Netherlands which is evident from many Dutch dunes that have been portrayed and also mentioned in a few patriotic Dutch folk songs. In addition, the sand dunes are important educational and knowledge-developingplaces for common people, academicians, and researchers. Since the 19thcentury, studies conducted in these environments generated some of the first ecological theories that help to understand how ecological systems of sand dune ecosystem function [2].

Sand dunes provide tourism and recreational benefits by providing space for walking, beachcombing, sunbathing, and scenic attraction [12].Aesthetic and recreation value of the sand dune and beaches of comarques of Catalonia, Spain was estimated at $36,687 USD/ha/yr [29]. The tourism and recreation function of the sand dunes of Mexico was estimated at $12585/ha/yr [28]. The recreational benefit of Great Sand Dunes National Park and Preserve (GSD) in Colorado, USA was estimated at $89/visitor/yr or U.S. $54/visitor/24-recreational day (in 2002 U.S. $) using the individual travel cost model [37]. Similarly, in Tramore, Ireland, the recreational benefits of sand dunes were estimated at USD 290,000 including maintaining access and use of the coastal waters [31].

3.4 Supporting service of sand dunes

Coastal sand dunes serve as essential habitats for many plants, invertebrates, and vertebrates (NSW DLWC, 2001). In addition, the sand dune acts as a feeding and nesting site for birds and sea turtles [39]. Many plants living in the coastal sand dune have been used incessantly in the traditional health care sector. Some coastal sand dune legumes are edible, endowed with medicinal properties; generate a variety of bioactive compounds of health and industrial importance. Mostly, they have been used to treat skin diseases, skin injuries, wounds, snake bites, and spider bites. They have been also been used to treat muscle sprain, and gynecological problems and to improve the immunological response. It has been estimated that the coastal sand dune legumes are contributing a significant share ofUS$400-US$500 million in India's herbal and traditional medicine global market [39, 13]. However, there is no sufficient information about the economic share of the sand dune plants in traditional medicinal support in India. To get all services from the sand dunes, a sand dune project was undertaken in Monterey, California, USA, to re-vegetate 17.8 ha of

coastal dune at a cost US$ 295,000. This represents US$18,800/ha and involved placing over 150,000 seedlings of 26 native dune plants [40].

4. BENEFIT TRANSFER AND META-ANALYSIS OF SAND DUNES ECOSYSTEM

Accordingly, the provisioning service contribute maximum (Avg. Rs.3318335/ yr. /ha. =US$ 71091.34) followed by Regulating service (Avg. Rs. 2872067/yr. /ha. =US$61530.58), Cultural service (Avg. Rs. 11, 56,898/-/ yr. /ha. =US$ 24785.15) and supportive service (Avg. Rs. 8, 72,702/yr. /ha. = US$ 18696.59). The aggregate economic value of India's sand dunes ranges between Rs.4593242 /ha/yr.=US$ 98404.69 (minimum) and Rs. 11293765 /ha/yr. (maximum)=US$ 241955.34. In a meta-analysis, averages of various services have been used to value total economic value per ha. /year. Consequently, the average total economic benefit out of goods and services of sand dunes is Rs.8220002 /ha. / Yr.=US$ 176103.66. This value is very close to the similar TEV study on sand dunes conducted by global meta-analysis estimate Mendoza(2012-Mexico) $80459/ha/Yr., as standardized for 2011Indian Rs. 40, 73,126. Similarly, meta-analysis value of sand dunes was estimated in Spain [29] at US$104,146 /ha/Yr. is standardized for 2011 Indian Rs. 56, 09,100. India's sand dunes' minimum value is Rs. 149029348671(14902 crore) /yr. =US$ 3192774624.35. Application of the maximum value estimated by this present study (NCSCM) for India sand dune is Rs. 366430168929 (36643 crore) /yr.=US$ 7850325827.66 Average value estimated from this study value India's sand dune for Rs. 266700849669 (26670 crore) /yr. =US$ 5713745062.36 Sand dune's economic benefits through various services and functions of India are given in table 2.

Among the coastal States and UTs, Andhra Pradesh has a huge area (11594 ha.) of sand dunes which shares Rs. 95306236262 (9530 crore) /yr. =US$ 2041745837.88 which is 36% of total sand dunes benefit out of National Green Account. State / UTs sand dunes' economic share in National Green Account is given in Table 3.

Table 2 - Sand Dunes service and function values - ha / Yr.

Sl. No.	Valuation Methods	Value estimation study	Year& Estimated value	Value In $ 2011	Value in Rs. 2011	Average value / ha	TE value of sand dunes, India (32445 ha)
I	**Provisioning service**						
I.1	**Water (drinking water)**						
1.	Substitute cost pricing method	[16]	2011 74268 $	74268	3318335	3318335	107664543632
II	**Regulation service**						
II 1.	**Disturbance regulation**						
1.	Benefit transfer	[28]	2012 67874 $	66646	3096390	2869729	93109364526
2.	Spatial value transfer analysis	[29]	2010 67400 $	68792	3196061		
3.	Contingent	[30]	1999	109249	5075715		

	valuation		84667 $				
4.	Benefit – cost analysis	[31]	1997 1800 $	2384	110748		
II.1	**Carbon sequestration**						
1.	Mitigation cost	[34]	2014 30.30 $	29	1336	2338	75857231
2.	Mitigation cost	[34]	2014 75.70 $	72	3339		
III	**Cultural service**						
III.1	**Recreation**						
1.	Spatial value transfer analysis	[29]	2010 36687	37445	1739672	1156898	37535961619
2.	Benefit transfer method	[28]	2012 12585	12357	574124		
IV	**Supportive service**						
IV.1	**Medicinal value**						
1.	Market Price	[39]	2009 12265	12671	588699	872702	28315122661
2.	Market Price	[40]	1997 18800	24897	1156704		

Table 3 - Sand dunes ecosystem service values - minimum, maximum and average ha/ yr./ Rs.

Service	Minimum	Maximum	Average
I. Provisioning service			
Water (Drinking water)	3318335	3318335	3318335
II. Regulating service			
Disturbance regulation	110748	5075715	2869729
Carbon sequestration	1336	3339	2338
III. Cultural service			
Recreation	574124	1739672	1156898
IV. Supporting service			
Medicinal value	588699	1156704	872702
Total	**4593242 (45 lakhs)**	**11293765 (1 crore)**	**8220002 (82 lakhs)**

5 CONCLUSION

A coastal sand dune is a transitional zone between sea and land that forms a unique ecosystem. They are providing habitat for fish, shellfish, birds, rodents, and ungulates. They serve as sediment reserves, stabilize coastlines, provide areas for recreation and provide breeding and feeding sites for seabirds, turtles, and other coastal species. They have been used for coastal defense, water catchment areas, agriculture purposes, mining, and housing. Though there are many ecosystem services for human well-being, estimates of the value of sand dunes are scarce. Using the Benefit Transfer method, aggregated economic value of India's sanddunes with an average economic value of Rs.8220002/ha./yr. =US$ 176103.66 Accordingly, India's sand dunes estimated from this study, arriveat Rs. 26670 crore/yr. =US$ 5713683259.43. Among the coastal States and UTs, Andhra Pradesh has a huge area (11594 ha.) of sand dunes which share Rs. 9530 crore/yr.=US$ 2041745837.88. which occupies 36% of the total sand dunes benefit of the National Green Account. Sand dune benefits in various coastal States in India have been given in table 4. The monetary values could be used in National, State, and regional policies to integrate the environment and economics.

Table 4 - Total economic value of sand dunes services Rs. / Yr.

S. No	State / Union Territories	Sand dunes distribution - ha	Total Value of sand dunes (ha/yr 8220002)	Total Value of sand dunes (US$/yr.)
1.	Gujarat	6650.16	54663013300	1171089341.20
2.	Maharashtra	411.38	3378420822	72378604.40
3.	Goa	293.59	2416680588	51774476.14
4.	Karnataka	46.87	386340094	8276872.04
5.	Diu & Daman	382.03	3140040764	67271598.25
6.	Tamil Nadu	3093.19	25424466186	544688621.40
7.	Andhra Pradesh	11594.43	95302703188	2041745837.88
8.	Odisha	9681.92	79586059364	1705035639.32
9.	West Bengal	263.97	2170080528	46491366.33
10.	Pondicherry	27.82	230160056	4930902.49
Total		**32445.35**	**266697964890 (26669.80 crores)**	**5713683259.43**

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