Goods and Services and Equivalent Economic Benefits of Sand Dunes of India

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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. Many of the goods and services produced by the sand dunes are not easily quantified and accounted for since they are not being traded in the formal market. Hence, many of the environmental benefits have been often neglected or even ignored by the economy, industry, coastal communities, and other stakeholders. Systematic accounting of the benefits shall enlighten the relationship between environmental function, human dependency, and economics. Though there are many goods and services, economic assessment of sand dune landforms is scarce.

Estimated values of sand dune landforms allow policymakers to assess the benefits that society gains from the environmental feature. The monetary value of sand dune landforms goods and services shall be a tool to raise awareness and convey the (relative) importance of the environmental feature to the general public and policymakers. In addition, the monetary value shall support decision-making on the allocation of resources for competing uses. This policy paper analysis assesses the economic value of sand dune landforms to wise use of the sand dune and sustainable management of the coastal environment.

This policy paper used the Benefit Transfer method to estimate the equivalent economic benefit of the sand dune landforms. 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; landforms; environmental economics; goods and services; India.

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 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 [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. Sand distributed patches along the mainland coast of India have been shown in Fig. 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.     | Devbhumi Dwarka          | 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                | Uttarak nad      | 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.    | Kanniyakumari            | 8                | 53.14                                       |
| 20.    | Tamil Nadu               | Nagappattinam    | 21                                          | 233.76                       |
| 21.    | Ramanathapuram           | 108              | 693.74                                      |
| 22.    | Thanjavur                | 1                | 0.13                                        |
| 23.    | Tirunelveli              | 11               | 116.44                                      |
| 24.    | Tiruvarur                | 23               | 216.70                                      |
| 25.    | Thoothukudi              | 18               | 869.19                                      |
| 26.    | Villupuram               | 21               | 297.21                                      |
|        | **Sub Total**            | **298**          | **3093.19**                                 |
| Sl. No | State / Union Territory | District          | Number of Sand Dune patches in coastal areas | Sand Dune distribution - ha. |
|-------|--------------------------|-------------------|---------------------------------------------|-----------------------------|
| 27.   | Andhra Pradesh           | Krishna           | 1                                           | 21.02                       |
| 28.   | Andhra Pradesh           | Nellore           | 120                                         | 7547.72                     |
| 29.   | Andhra Pradesh           | Prakasam          | 44                                          | 1047.31                     |
| 30.   | Andhra Pradesh           | Srikakulam        | 36                                          | 2640.11                     |
| 31.   | Andhra Pradesh           | Vishakhapatnam    | 18                                          | 311.93                      |
| 32.   | Andhra Pradesh           | Vizianagaram      | 4                                           | 26.33                       |
|       | **Sub Total**            |                   | **223**                                     | **11594.43**                |
| 33.   | Odisha                   | Baleshwar         | 47                                          | 744.55                      |
| 34.   | Odisha                   | Ganjam            | 48                                          | 1359.73                     |
| 35.   | Odisha                   | Jagatsinghapur    | 53                                          | 1024.30                     |
| 36.   | Odisha                   | Kendraparha       | 10                                          | 343.29                      |
| 37.   | Odisha                   | Puri              | 57                                          | 6210.05                     |
|       | **Sub Total**            |                   | **215**                                     | **9681.92**                 |
| 38.   | West Bengal              | North 24 parganas | 2                                           | 4.90                        |
| 39.   | West Bengal              | Purbamedinipur    | 109                                         | 210.43                      |
| 40.   | West Bengal              | 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 dunes is washed and used in the construction industry [13]. However, sand mining from sand has 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].
Fig. 1. Sand dune distribution in mainland coastal States of India
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 $67,874/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 (tCO₂/ha/yr) was estimated for sand dune [33]. Accordingly, CO₂ 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-developing places for common people, academicians, and researchers. Since the 19th century, 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, beach combing, 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 $125,855/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 [38,39]. 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 of US$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 revegetate 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. 149029348671 (14902 crore) / yr. = US$3192774624.35. Application of the maximum value estimated by this present study (NCSCM) for India sand dune is Rs. 366430168929 (36643 crore) / yr. =US$ 7850354827.66 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.

| 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.1    | Provisioning service | I.1 Water (drinking water) | 1. Substitute cost pricing method [16] | 2011 | 74268 $ | 3318335 | 107664543632 |
| II.1   | Regulation service | II.1 Disturbance regulation | 1. Benefit transfer analysis [28] | 2012 | 66646 | 3096390 | 2869729 | 93109364526 |
|        |                   |                         | 2. Spatial value transfer analysis [29] | 2010 | 68792 | 3196061 |
|        |                   |                         | 3. Contingent valuation [30] | 1999 | 109249 | 5075715 |
|        |                   |                         | 4. Benefit – cost analysis [31] | 1997 | 2384 | 110748 |
| II.2   | Carbon sequestration | 1. Mitigation cost [34] | 2014 | 29 | 1336 | 2338 | 75857231 |
|        |                   | 2. Mitigation [34] | 2014 | 72 | 3339 |
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         | 11293765        | 8220002         |
| (45 lakhs)                  | (1 crore)       | (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 sand dunes with an average economic value of Rs.8220002/ha./yr. =US$ 176103.66. Accordingly, India’s sand dunes estimated from this study, arrive at 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. These would offer new opportunities for investment and employment and improve the environmental quality and welfare developments for human living. The values can be used for the cost-benefit analysis for decision making, and indicative value to collect compensation for the violations made by stakeholders of the coastal areas.
Table 4. Total economic value of sand dunes services Rs. / Yr. & US$/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                             | 5713683259.43                      |

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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