Resource Nexus Perspectives in the Blue Economy of India - The case of sand mining in Kerala

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Abstract

The spotlight on sand mining in coastal zones and marine activities has increased, and for good reason. Since the 2000s, sand has become a scarce but essential natural resource for development; albeit sand extraction has been dotted with myriad socio-economic and ecological costs. In coastal communities of Kerala, the costs of sand extraction have proliferated the scarcity of livelihood assets such as food, and water among coastal communities, and the attainment of Sustainable Development Goals (SDGs) and targets. This is worsened by the lack of a comprehensive framework to manage sand mining and trade sustainably and integrate the multiple natural resources from the land and the sea. In Kerala, current sand mining policies are either less integrated, less enforced, lacking, or exploitative to the marine and coastal resources (read Blue Economy resources) that sustain coastal communities, and thus the resource nexus approach to sustainable resource management. This gap formed the foundation of this study to gain an understanding of the state of sand mining in Kerala state in India, the resource nexus perspectives of sand mining, the existing pathways being advanced to promote sustainable sand mining in different case studies and identify the best framework based on Ecosystem Service Assessments (ESAs) and Environmentally Extended Cost-Benefit Analysis (CBA) to test and identify feasible pathways for sustainable sand mining, and Blue Economy governance. The study used a non-systematic literature review method and based on the reviewed literature, there is evidence that there are myriad abiotic and biotic effects of sand mining which increase threats to coastal communities such as access to water, coastal recreation, and food (fish). Based on the literature on sustainable Blue Governance, a comprehensive framework on how to test and adopt the best methods and steps using the ESA Framework in Kerala which could help identify and balance ecosystem health, and socioeconomic development and integrate the coastal resource nexus is developed.

Keywords: Sand, Sand Mining, Blue Economy, Nexus, Resource Nexus Concept, Coastal Zone, Ecosystem Service Assessment, Kerala, India.

1.0 Introduction

The demand for marine sand has sporadically reached unsustainable limits ruining the terrestrial and marine ecosystems in sand production zones [36]. Several studies have projected that sand mining will reach unsustainable levels in the next few decades; a precursor to marine ecosystem damage and a loss of coastal livelihoods [94; 39]. Today, marine sand emanating from the ocean beds and threshold coastal zones is the 3rd most important natural resource after air and water; with increasing global annual consumption due to construction [45]. The 2021 International Resource Panel Report critically documented the negative effects of sand mining and related human activities such as over-urbanization including overexploitation of ecosystem resources, pollution, and human-induced climate change on biodiversity and coastal livelihoods [97]. For instance, by 2100 it is estimated that 67 percent of California beaches will be history due to the high demand for coastal sand for coastal urbanization running tourism and recreation [45]. This is worsened by the lack of comprehensive tariffs related to sand trade; especially in developing countries such as among others Mozambique [61]. By 2018, only 2.9 percent of sand trade had tariffs based on the HS4 Product Classification [61]. Our report uses this emerging debate to assess the case of sand mining in Kerala. The relevance of this case stems from the increasing evidence of the effects of sand mining along the coast of Kerala and India which is threatening socioeconomic livelihood security. In addition, an increase in coastal and offshore sand mining is threatening Blue Economy (BE) resources, and sectors such as recreation and tourism, and coastal fishing [94]. BE resources comprising of all coastal and marine resources emanating from marine activities such as fishing and aquaculture, coastal and marine tourism, mining, marine transport, renewable energy, and marine biotechnology [103]. In addition, the report proposes to assess this case through the lenses of a resource nexus concept and a blue economy. Sand mining illustrates the nexus dimensions of such material with food, water, and land use (land-sea interaction). The report will explain why and how an underpinning with coastal ecosystem services will be essential. Furthermore, sand mining illustrates the necessity to look at entire value chains and take a life-cycle perspective due to the demand for sand from downstream cement factories and construction purposes, often taking place in other countries. To understand this debate, it is imperative to contextualize the BE concept and its value (both globally and in India).

1.1 Meaning and extent of the Blue Economy in India

Of the many terminologies that marine environment studies have become accustomed to since 2012, '*Blue Economy*' (BE) is perhaps one of the more ominous ones [97]. Although the idea was initially mooted and dismissed as little more than a conspiracy theory by Small Island Developing States (SIDS) and coastal communities to profit from maritime resources [93; 94], myriad stakeholders now believe that 'sustainable ecosystem management and inclusive sharing of marine ecosystem benefits by vulnerable communities and countries for sustainable development is a reasonable prerequisite for participating in the sustainable Blue

Economy (BE) future [39; 53]. Insights into new approaches of the BE bring into perspective an avenue to develop new paradigms for the sustainable coastal zone management of the BE resources [71]. The 2021 International Resource Panel defines the BE as '*an ocean-based economy that provides equitably distributed social and economic benefits for current and future generations; while restoring and protecting the intrinsic value and functionality of coastal and marine ecosystems and is based on clean technologies and circular material flows*' [36]. Thus, BE resources that are crucial in understanding the land-sea interactions include fisheries resources (food), mineral resources, water resources, and renewable energy resources [50; 37].

In India, the BE has been projected as core to India's Maritime Vision 2030 and thus, the Government launched a flagship program-*Sagarmala* in 2015 to partly streamline the potential of India's Blue Economy [53]. Efforts to tap the potentials of the BE have been advanced through the formulation of the 2021 draft Blue Economy Policy Framework for India has created benchmarks for increased employment of historically marginalized people in India in the BE sectors, and a pathway for increasing the potential of India's *Blue Chakra;* through inter alia, the development of the shipping industry, ports, and gendered strategies for employment and inclusive leadership in the maritime sectors [53; 39]. The Government of India's Vision of New India 2030 envisions the BE as a crucial sector in increasing labor force participation and promoting social equity, and security in the Indian Ocean [53]. Under the current business-as-usual scenario, the potential of India's BE is estimated at 700 billion USD; and if socioeconomic barriers are bridged, projections show that India could reap about 1-2 trillion USD under a best-case scenario by 2025 [53; 39]. The definition of the BE in India involves the inclusive and sustainable harnessing of the myriad BE activities "focusing on sustainable resource development and assets management of oceans, rivers, water bodies, and coastal regions to promote equity, inclusion, innovation, and technological advancement" [39]. In other words, the BE of India focuses on national priorities encompassing marine resources systems and anthropogenic infrastructure developments within India's maritime jurisdiction and along coastal onshore zones with a need for socio-economic development, environmental sustainability, and increased national security [53]. Thus, the BE of India is a subset of the national economy that focuses on the tapping of ocean resources in coastal and offshore zones to aid in the production of goods and services that enhance socioeconomic growth, environmental sustainability, and national security.

A paucity of studies shows that coastal zones are crucial nodal points in the functioning of human-ecological systems [74]. Based on the Millennium Ecosystem Assessment definition of a coastal zone, about 40 percent of the global population is sedentary within the 100-kilometer coastal buffer zones [104; 105; 50]. Coastal zones are habitats for inestimable rich natural resources and marine ecosystem habitats concentrated in intertidal zones and continental shelves [41]. Furthermore, coastal zones are a beehive to a paucity of livelihood activities such as fishing, coastal mining, and tourism, especially in the global south that sustain their economies [3]. Unfortunately on a geospatial level, more than a billion people, especially in Asia live in highly vulnerable low-lying coastal zones and their livelihoods are threatened; especially due to exacerbated climate change effects thence requiring coping and adaptation strategies (e.g., coping with floods) [104]. This is worsened by a lack of comprehensive coastal zone management and governance approaches which creates unsustainable exploitation of BE resources and natural resource user conflicts [97; 16]. Most coastal zone management frameworks mainly lacked the sustainability perspective and were mainly linear, and focus on single resource categorization and valuation [81; 16]. Traditional approaches further lacked conceptual clarity on how to design synergies and ecosystem trade-offs relating to coastal resource use and management in the BE [31] as in India where there is an overt lack of an integrated and extensive shoreline management plan in most Indian coastal regions and the Sand Mining Framework released in 2018 and the Draft Sustainable Sand Mining Management Guidelines being issued by the Ministry of Mines are yet to be formulated in sand producing states [34; 59; 67; 71; 40]. To leverage the potential of the BE resources, spatial and temporal pathways need to be developed in different contexts to design synergies in the valuation of BE resources, assessment of ecosystem services, and the integration of system dynamics relating to BE resource use [39]. In other words, the sustainability of the BE depends on (a) such resources being sustainably managed and (b) ecosystem services being fully acknowledged and maintained.

However, how to develop a sustainable coastal zone management approach to sustainable sand mining which is further related to the resource nexus concept in vulnerable coastal zones and a methodology to aid in the understanding of the cumulative effects arising from land-based activities and the vulnerability of the BE resources in India and Kerala has proved elusive! [40]. In addition, a lack of knowledge of the impact pathways that connect land-based activities to coastal resources in coastal zones of Kerala coupled with gaps in multi-level coastal resource governance jurisdictions create complexities in coastal resource access against the services derived from ecosystems for local communities [59; 69]. This conundrum forms the gist of this paper that aims to:

(i) Profile the trends of sand mining and how the resource nexus perspectives help in analyzing it relating to the BE

(ii) Explore the governance approaches related to sand mining and coastal zone management using case studies.

(iii) To propose methods based on Ecosystem Service Assessments (ESAs) and Environmentally Extended Cost-Benefit Analysis (CBA) to identify a feasible framework for sustainable sand mining in the BE in Kerala

1.2 Research Questions

- How can sand mining help in the understanding of the coastal resource nexus perspectives and its impact on livelihoods?
- Do the current sand mining governance pathways address the risks emanating from sand mining on the environment and livelihoods?
- How to propose methods and tools based on Ecosystem Service Assessments (ESAs) and Environmentally Extended Cost-Benefit Analysis (CBA) to identify feasible pathways for sustainable coastal sand mining in the BE in Kerala?

2.0 Method used for data collection

A non-systematic literature review was used to obtain, and analyze peer-reviewed articles and reports related to sand mining and the Blue Economy such as the International Resource Panel Reports. The primary approach used was to gather studies related to the Blue Economy and sand mining at a global and local level in India and Kerala which was done through electronic retrieval from multidisciplinary databases: Web of Science, PubMed, Scopus, Google Scholar, Wiley Online Library, ProQuest, and Springer Link to obtain references. An additional Google Search was done to obtain and screen reports related to sand mining and the BE from global organizations such as the International Resource Panel, regional, and national agencies.

The results obtained were screened using their titles, abstracts, and keywords to accommodate the various combination of the key terms within the sand mining perspective as “Blue Economy”, “Blue Economy sectors”,” sand”, “ecosystem concept”, “resource nexus”, “resource nexus concept”, “Sand Mining“, Trends and implications of sand mining”, “sand governance challenges”, “sand and livelihood”, “sand mining and India”, “sand mining and Kerala.” Only articles and reports containing information related to the key terms above were considered. The articles and reports considered in the study were dated until July 2022 and were entirely in English. In general **250 articles** were retrieved for full-text screening and after identifying duplicates and conducting an eligibility assessment based on the study area context**, 90 studies** were included in this review. Further analysis of international sand trade statistics was obtained from global databases such as the Atlas of Economic Complexity, and the Chatham House Resource Trade Database.

3.0 Kerala Study Area Profile

Kerala is one of the nine (9) coastal states in India with a coastline extending to 590 kilometers; which ranks as the 5th longest coastline among the mainland coastal states of India (53). Owing to Kerala’s natural beauty, abundant natural resource endowments, and rich ecosystem diversity especially along the Arabian Sea coastline and the Western Ghats, Kerala is popularly known as the ‘*God’s own country’* (56; 55. Geographically, Kerala is located in the South-Western part of India covering about 1.18 percent of the total land area of India (www.ficci.in). To the North and North-East, Kerala is bordered by Karnataka, Tamil Nadu in the East and South, and Lakshadweep and the Arabian Sea to the west [(53).] The location of Kerala astride the Western Ghats has led to a radial drainage pattern leading to several deltas with alluvial sediments, and backwaters that sustain livelihoods (www.keralatourism.org).

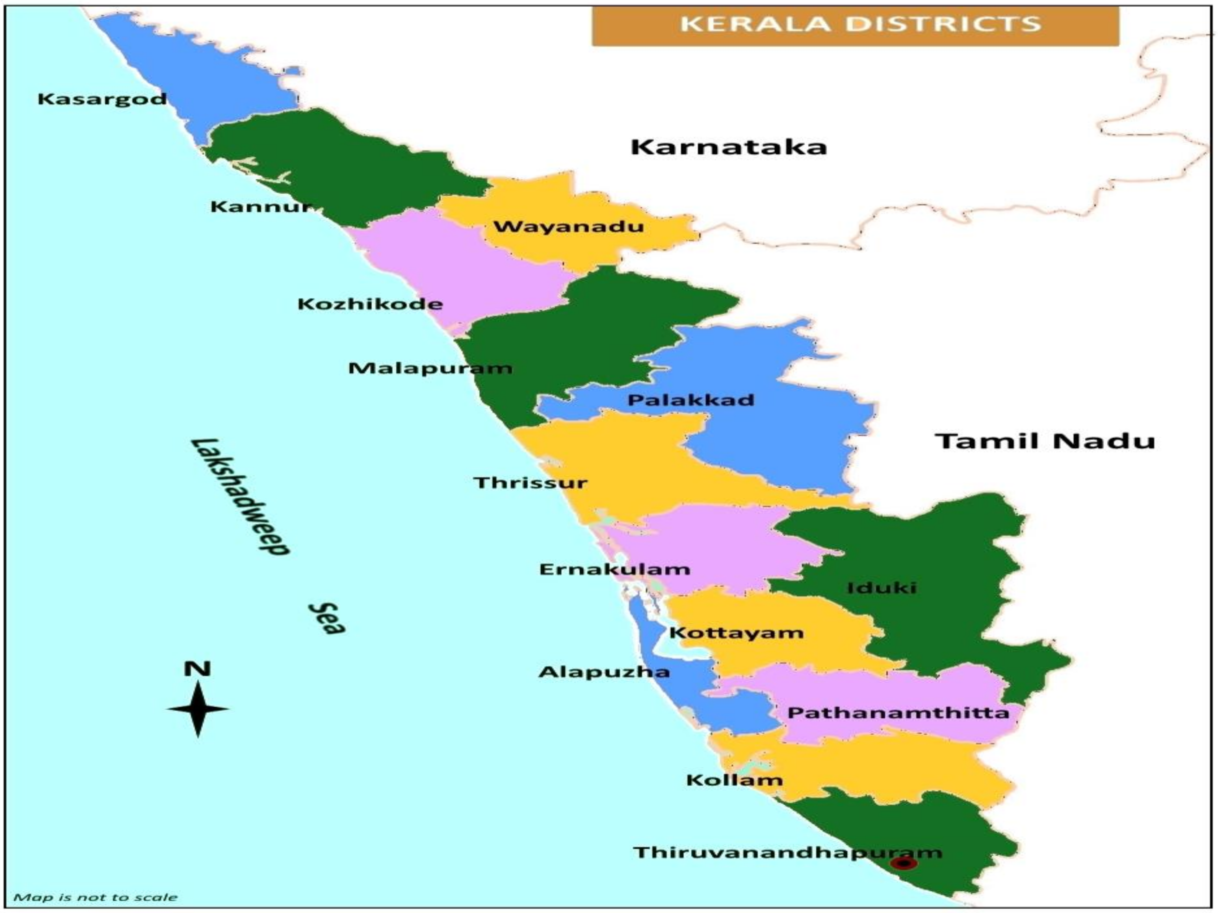

Figure 1: Map of Kerala (https://www.googlemaps.com/)

Demographically, Kerala's population constitutes about 2.76 percent of the total share of India's population; estimated at 33.41 million persons (India National Census Report, 2011); spread in the 14 state districts. According to the 2022 demographic estimates of Kerala, this population has increased to about 34,698,873 million people (www.indiacensus.net/states/kerala); indicating a spike in demand for construction materials and infrastructural development to cater to the increasing population [(106).] (See *Fig 2* below):

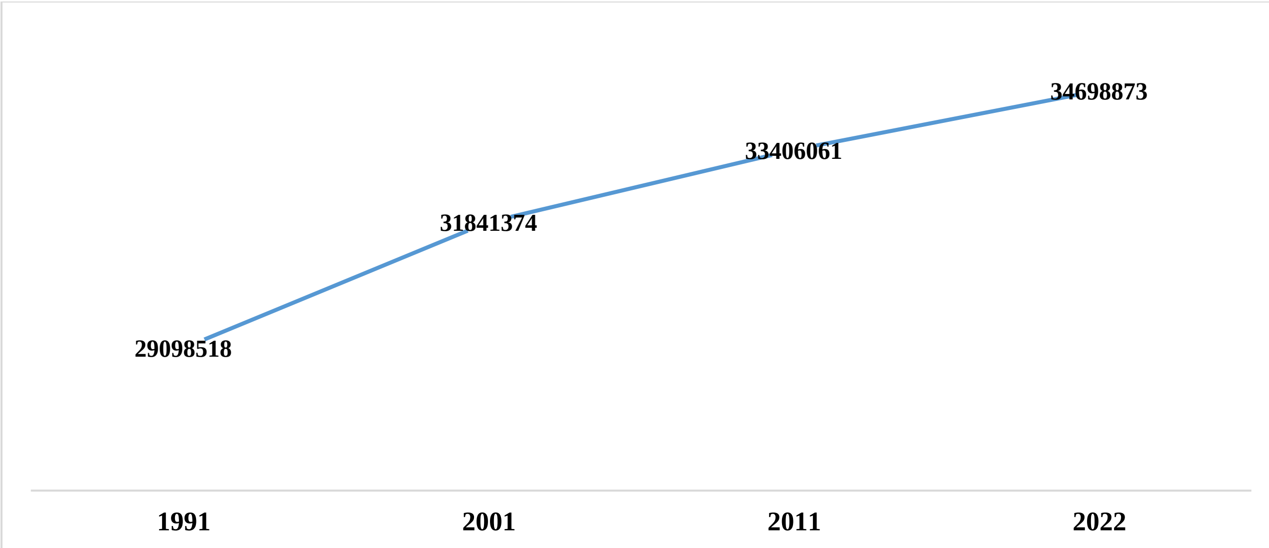

Figure 2: Inter-decadal population change in Kerala (Kerala Tourism Statistics Report, 2019/www.indiacensus.net/states/kerala)

3.1 Main resource endowments of Kerala (including sand)

In relation to India's context, sand mining has been dominant in the West and Southeast coastal regions such as in Kerala, Pondicherry, and Tamil Nadu [59; 40]. To understand the extent of sand mining, a preamble on mining activities in Kerala gives an entire perspective on the state of sand mining in India [69].

Kerala is endowed with a paucity of biotic and abiotic natural resources with great potential for socio-economic development (www.opensdi.kerala.gov.in). The coastlines of Kerala are dotted with unique beach sand deposits between the Lakshadweep Sea and the Arabian Sea coasts that contain unique minerals such as ilmenite and monazite [89; 82]. Increased sand mining however is posing ecological threats to the coastal environment in coastal India and Kerala [83].

The total quantity of natural sand in Kerala is unknown though a mapping survey study off the Kerala coast around Lakshadweep Sea estimated that about 288 million tonnes of calcareous sand deposits exist in and around the lagoons and offshore areas of Lakshadweep and Kerala [75; 77]. The territorial sea of the Kerala coast contains ferromanganese nodules and lime mud suitable for cement manufacturing and construction [89; 53]. Along the Chavara coastline stretching 22 kilometers through Kollam, Kayamkulam, and Alappuzha, abundant deposits of black sand deposits with heavy rich minerals exist [1; 68]. The west coast of Kerala further contains one of the largest deposits of thorium in the world which are crucial in the production of nuclear even though exploration research to determine the thorium quantities and their origin is in infancy [46].

Other abiotic mineral endowments along coasts, rivers, and highland zones of Kerala include heavy mineral placer sands which include inter alia opaques, zircon, and garnet that could have been deposited by the monsoon, river action, volcanic action, and long-shore drift [(47).] It is estimated that about 96 percent of Kerala's abiotic mineral endowments have heavy mineral concentrates of opaques that give Kerala sand a distinct black color [(47; 49).] In near-shore zones of Kerala especially around Alappuzha, exponential deposits of mud bank sediments comprising huge concentrations of iron, phosphorus, and lime mud exist [(49).] The initiation of sand audit reports in the last decade has compelled the Government of Kerala is restrict the mining of sand within a radius of one kilometer in ecologically sensitive zones, especially along the main rivers such as Chaliyar and Bharathapuzha [(55).] The Center for Water Resources Development and Management (CWRDM) estimated that rivers in Kerala annually lose huge amounts of sand against the average natural replenishment rate. This is partly meant to maintain the natural flow and supply of water, safeguard cultural services of the rivers, and sustain the production functions of rivers and water bodies such as the provision of fish to local communities [(75).]

The biotic resource endowments in Kerala especially marine living organisms are immense [(77).] The marine space of Kerala is a fisheries mecca of India contributing about 4.14 lakh tons to the total marine fish production in India (www.fisheries.kerala.gov.in). The coastal backwaters of Kerala are a beehive for the sprawl of unique coastal plants and ecosystems that have ballooned tourist revenues, eco-goods, and eco-services(www.opensdi.kerala.gov.in). It is estimated that the Total Economic Value of wetland resources in Kerala; especially in Ashtamudi is 424 million USD equivalent to 820 USD of economic output for every hundred square meters (Nayana and Saikat, 2020). In other words, an increase in sand mining under the Business As Usual scenario could lead to a loss of more ecosystem/natural resource values and threatened BE services to livelihoods than benefits; if there is a low focus on sustainable governance and target communities' inclusion in management. To clearly understand the level of significance of the BE sectors and marine resources in Kerala, insights on the monetary value and population depending on some BE sectors and coastal resources are shown in *Table 2* below.

Table 1: Significance of the various BE sectors and resources in Kerala (in comparison to Sand Mining)

BE Activity/Resource	**Estimated/current volume/production**	**Dependent Population**	**Monetary/Economic value**	**Source**
Sand mining	2,88,000 loads	n.a	150 million USD (illegal mining) (National level)	Maiti, 2014; India Rivers Forum, 2020

Fishing (both marine and inland)	6.16 lakh tonnes	1044361	1.2 billion USD (18% of India's revenue)	Kerala Fisheries Handbook, 2020
Wetland Ecosystem Services		Around Ashtamudi wetland	424,873,525 (USD)	Nayana and Saikat, 2020
Tourism	19.48 million tourists	23.5 percent of Kerala Population	2 million USD	Kerala Tourism Statistics, 2019/Centre for Public Policy Research, 2020, IBEF, 2020

***Lakh=100,000 and Crores=10,000,000**

4.0 Why, and where is sand mining and its nexus implications?

Sand (especially marine sand found along coasts, seabed, riverbeds, lakes, and ocean beds) is a crucial common-pool resource (Ludacer, 2018); that contributes to a large volume of natural resources used as primary material inputs for anthropogenic infrastructural developments (Torres, et al, 2021). Sand is the second leading consumption resource and the increasing appetite for sand and non-metallic minerals is projected to increase to about 86 Gt (Gigatons) by 2060 (OECD, 2019); surpassing the rate at which sand replenishes (Marschke and Rousseau, 2022; Lamb et al, 2019). Today, sand accounts for about 85 percent of the annual volume of minerals mined globally (UNEP, 2019; Filho et al, 2021). Studies, especially those focusing on sand mining in Asia attribute the spike to a typology of factors: population explosion, urban sprawl, and increased consumerism due to technological advancement and environmental changes/risks such as climate change that creates a need to set up coastal defense systems/infrastructure mitigate disasters (Hubler 2021; Won et al, 2017). Urban sprawl and population explosion in the Pearl River Delta made China use more concrete and cement in the first quarter of this decade than the USA did in the last century (Ludacer, 2018). With an estimated increase in global population to 11.2 billion people by 2100; the global estimated value of sales from sand is projected to reach 481 billion USD in the next eight decades (Bendixen et al, 2019). The pivotal role of sand in the manufacture of borosilicate glass used to make vials, especially during the COVID-19 pandemic in leading pharmaceutical companies in Europe and North America, computer chips, and soaps (Baraniuk, 2021; Blais, 2020; Beiser, 2018); continues to skyrocket the need for sand mining, especially from cheap sources in the developing world such as India and Indonesia (Marschke and Rousseau, 2022; Ludacer, 2018). In India, the sand market is booming partly due to the increase in the real estate business, and the value is expected to shoot up by 2030 though with immense socio-ecological risks (Indian Minerals Yearbook, 2015).

Recent studies have documented spatial and temporal variations in the production, exportation, and importation of sand extracted both legally and illegally; with varying trends (Atlas of Economic Complexity, 2020). For instance, China has emerged as the leading user of sand resources (concrete) since the turn of the last decade (Beiser, 2019; Ludacer, 2018); and some African countries such as Mozambique are increasingly exporting sand (Gavriletea, 2017), with the USA emerging as the leading exporter of sand (Atlas of Economic Complexity, 2020). The volume of sand imports in Canada has reduced from 15.35 percent in 2018 to 10.48 percent in 2020 (Atlas of Economic Complexity, 2018) (See *Table 1* below).

Table 2: Some of the leading sand importing and exporting countries by 2020

Country	**Share/Volume of Sand (%)**		**Gross Monetary Value (Million US Dollars)**	
	Imports	**Exports**	**Imports**	**Exports**
Canada	*10.48*	*1.88*	*183*	*32.8*
USA	*3.33*	***20.23****	*58.1*	***353***
Germany	*4.83*	*8.77*	*84.3*	*153*
Netherlands	*4.98*	*9.64*	*87.0*	*168*
France	*2.58*	*2.98*	*44.9*	*52.1*
Belgium	*8.30*	*6.30*	*145*	*110*
Singapore	*2.54*	*0.03*	*44.3*	*0.559*
China	***13.60****	*4.67*	***237***	*81.5*
India	*0.53*	*0.32*	*9.20*	*5.65*
Japan	*5.35*	*0.47*	*93.3*	*8.19*
Saudi Arabia	*0.22*	*2.13*	*3.90*	*37.2*
Mozambique	*0.02*	*1.65*	*0.369*	*28.7*
Egypt	*0.10*	*2.24*	*1.7*	*39.1*
Australia	*0.11*	*8.59*	*2.0*	*150*
Brazil	*0.19*	*0.25*	*3.25*	*4.45*

**Leading Sand exporting or importing country*

Source: Atlas of Economic Complexity (2020), Accessed 8th August 2022 via www.atlas.cid.harvard.edu

Table 2 above shows that though all countries partly rely on sand imports (Filho et al, 2021); it is evident that top sand consumers and producers are mainly from developed countries (Marschke and Rousseau, 2022). Based on the categorization of sand mining activities, Category 6 countries that mine in excess of 55 million tons of sand per year include China, Australia, the USA, and Canada (Filho et al, 2021). The Chatham House Resource Trade Database shows that even though the import value of sand mining in some countries such as India seems marginal, the internal demand for sand has been rising in India scaling up to 1.8 percent of the global sand and gravel trade with a monetary worth 96.7 million USD as of 2020 (www.resourcetrade.earth). Thus, the spiral in sand demand in India is likely to proliferate environmental pressures on sand extraction for infrastructure development (Saveer, 2017). For instance, since 1999, the average annual consumption of sand in Kerala has increased to over 32 million metric tons (Nandakumaran et al., 2016; CWRDM, 1999). The 2022 Chatham House Resource Trade Database further shows that India's sand exports have exponentially increased to countries experiencing infrastructural construction booms such as Vietnam, Norway, United Arab Emirates, and China. The increase in the trans-boundary sand trade cycle partly implies that states with huge sand deposits in India are likely to experience increased sand mining (both legally and illegally) which could devastate local systems related to the provision of food, water, energy, and increase land conflicts; exacerbating livelihood threats already affected by climate change.

4.1 Effects, Trade-offs between sand mining and other BE environmental resources and dependent activities in Kerala

The scramble for the extraction of sand in Kerala has increasingly sprawled into a wicked paradox (Mathew et al, 2022). On the one hand, corporate lobbies and sand mining mafias are reaping revenues from less regulated coastal resource extraction, and at the same time, local communities' livelihoods and coastal ecosystem sustainability are threatened (Ludacer, 2018). Evidence shows that the increase in sand mining has been dotted with a plethora of implications on livelihoods, the local economy, and the environment, especially in the backwaters, estuaries, riverbanks, and coastal zones (Prasad et al, 2016). The social micro benefits of sand mining in most coastal areas such as the provision of low-skilled work emerge due to a lack of sustainable and alternative employment opportunities among vulnerable coastal people and are dotted with adverse health impacts (Marschke and Rousseau, 2022). In some places in Asia such as India, sand mining has hardly translated into local benefits since most mining activities are run by corporate lobbies and use bonded labor (Lamb et al, 2019; Padmalal and Maya, 2014; Singh and Tripathi, 2010). In other words, the abundance of marine sand has increased complexity in access to resources such as land, water, energy, and marine resources that promote livelihood empowerment due to monopolization and preference for black sand mining to fisheries in Kerala (Sharon, 2021; Jansatya, 2011). Excessive mining along the Kerala coast has led to saltwater intrusion into water aquifers, lowering of the water table, river degradation, and ecosystem damage (Sathya, Thampi, and Chithra, 2021; Siddique et al, 2020). Unsustainable sand mining in Kerala has also led to drastic coastal morphological changes including caving-in of coastlands by about 300 meters which affects coastal infrastructure (Prasad et al, 2020). Studies further project that an increase in unsustainable sand mining in Kerala is likely to damage coastal infrastructure, sprawl food scarcity, degrade coastal fish breeding sites and increase land conflicts in coastal India (Prasad et al, 2020; Bhattacharya et al, 2019; Bisht and Gerber, 2017). It is estimated that about 30 percent of the main fish breeding sites along the West coast of India have been irreversibly damaged by illegal and over-exploitation of coastal sand affecting fishing-dependent communities (Ramachandra et al, 2018).

A systematic review of the impacts of sand work on livelihoods indicates a mix of impacts including; the provision of work with spin-off benefits, negative health effects such as respiratory and radioactive exposure, social conflicts due to land grabs and social infrastructure damage, and negative impacts on non-sand livelihoods such as fishers, farmers, tourist operators (Marschke and Rousseau, 2022; Prasad et al, 2016; Mohapatra, 2017).

The most impacts of sand mining have been visible on the environment through ecological changes in both biotic and abiotic resources (Satish and Geetha, 2021). The biotic impacts include a change in coastal biomass mainly dotted with a decline in rich coastal biodiversity of vertebrate species such as fishes (Sathya et al, 2021); and a loss of micro-benthic and plankton biomass of invertebrate species (Shiji et al, 2016). A decline and/or loss of biodiversity affects coastal livelihoods that heavily rely on coastal ecosystems for food, income, and aesthetics (Hubler, 2021). A study in Kerala linked the decline of coastal bird species to an increase in sand mining (Aarif et al, 2014). Around the Ithikkara River in Kerala, the unique assemblages of aquatic fauna and flora are threatened by indiscriminate mining affecting local tourism and flood plain zones (Sheeba, 2009). Research by Mohammad and Jalal (2018) identified a correlation between coastal biotic species reduction and increased sand mining, especially in estuaries.

The ripple effects of sand mining extend to abiotic consequences including increased pollution, hydrological impacts, coastal geomorphological impacts, and bathymetric changes involving water level changes that could lead to droughts or floods (Sreekumari et al, 2016; Prasad et al, 2016). A study in coastal Kerala documented a negative depletion in the Chavara coastal morphology due to placer mining which increases the vulnerability of coastal people to environmental disasters such as Tsunamis (Satish and Geetha, 2021; Prakash et al, 2016). Sand mining has further affected water turbidity especially due to dredging and the creation of sand depots that partly lead to water eutrophication (Shiji et al, 2016). A study in Northern Kerala found a poor water quality index around Lake Kavvayi ranging from 43.99-44.77 partly due to sand mining affecting access to clean water (Shiji et al, 2016). This finding correlated with a finding in Sri Lanka that documented an acute decline in safe drinking water due to illegal sand mining (Torres et al., 2017).

In addition, sand mining has accelerated an increase in chemical pollutants in water increasing the risk of exposure to health complications and affecting land-use practices of local communities (Anand and Reddy, 2014). A Physiochemical study around Lake Vembanad in Kerala observed an increase in organic pollution due to lime-shell and sediment mining (Sebastian et al. 2012). The increase in chemical pollution stems from externalities associated with sand mining that require changing the topography to expose sand deposits, especially along riverbeds (Padmalal et al., 2008). A study around Sasthamkotta in Kerala documented that the indiscriminate use of high jet pumps affected aquifers leading to the drying up of flood plains covering 3.57 km2 (Sreekumari et al, 2016). It is evident that coastal zones and communities are increasingly becoming vulnerable to multiple risks emanating from sand mining (Torres et al, 2021); which calls for a reevaluation of the current sand mining approaches if sustainable coastal resource use and development are to be attained (Hubler et al, 2021; IRP, 2020).

5.0 The resource nexus implications related to sand mining and its relevance to the BE in coastal zones

One of the pivotal concepts and perspectives that have been recommended in ensuring a sustainable BE is the resource nexus concept. The resource nexus concept focuses on multi-systems thinking and assessment of the inter-relationships between the resources systems of water-energy-food-land and climate change to offset trade-offs and boost sustainable synergies (Dargin et al, 2019). In other words, the resource nexus tries to account for the interactions in resource systems in a given area while evaluating the implication or efficiency of a given scenario or activity from a sustainability perspective (Brouwer et al. 2018). The focus on resource interactions implies that the resource nexus concept is increasingly being advanced as a crucial tenet in leveraging the coastal zone eco-human interlinkages and interdependencies on how BE resources could be managed (Ramos et al. 2022). This is because it helps in understanding the interlinkages between water-energy-land resources that are crucial in sustainable development in coastal zones (World Ocean Assessment II, 2021). The resource nexus further promotes a low-carbon economy which brings to the fore an international lifecycle perspective on the regulation of global marine and coastal activities including sand mining (Papadopoulou et al, 2020; IRP, 2020); through the integration of the water-energy-land nexus with climate services for the co-production of micro and macro-integrated assessments (Cremades et al; 2019). Using this perspective, it can be feasible to avail situational information on the effect of climate change adaptation and mitigation decisions related to various coastal sectors and livelihoods using BE resources (Bleischwitz et al, 2018). A Study conducted in Greece observed that the resource nexus integrates system thinking and modeling that helps understand trade-offs and synergies to improve resource efficiency and policy decisions on water-energy-land-focus resources (Papadopoulou et al, 2020); and how the use of a given scarce BE resource affects the other (Brears, et al, 2017). This creates a synergetic pathway that can be used to integrate abiotic coastal activities such as sand mining into local systems related to livelihood sustainability involving the sustainable provision of water, food (fisheries and coastal farming), and energy. For instance, in Germany, cooperative agreements related to resource use along the rivers have promoted the development of integrated resource management and governance policies related to water quality and food provision (Brouwer et al, 2003). This means that this approach can be extended to areas threatened by unsustainable resource use such as sand mining in Asia (Cremades et al., 2019). For instance, in India, several studies found that sand mining along rivers led to a reduction in wetland functioning in Ashtamudi through a reduction in the water table affecting rice fields in lowlands, and water pollution thus a reduction in water quality affecting the provision of ecosystem services and livelihood welfare (Prakash et al, 2020; Lamb et al, 2019; Nayana and Saikat, 2020). In other words, the complexities associated with the exponential increase in sand mining along food, water, and other natural resource-rich zones that sustain local communities necessitate the designing of sound coastal management approaches (Filho, et al. 2021).

5.1 Exploration of the current global, regional, and national governance approaches related to sand mining; the resource nexus, and coastal management (Case studies) that could be relevant to Kerala

This conundrum related to the disruption of the resource nexus due to sand mining in Kerala underscores the need for designing inclusive pathways, and regulations at micro, meso, and macro levels, especially in countries heavily engaged in sand mining (Bendixen et al, 2021; Filho et al, 2021); but how can holistic governance approaches be designed? Policy recommendations postulate that sustainable sand mining frameworks could provide natural barriers to vulnerable coastal communities decimated by floods, erosion, and typhoons, especially in regions with catastrophic levels of sand mining such as Asia, and also reduce the cost of providing and sustaining local food, energy, water resources systems (Gavriletea, 2017; UN Environment, 2019). However, the development of comprehensive and global pathways for sustainable sand mining that integrates the resource nexus has proved elusive; piecemeal and in some regions lacking affecting the sustainable future for the aggregate resources and communities where sand is extracted (Bendixen et al, 2021; UNEP, 2019; Marschke and Rousseau, 2022).

The 2019 report on *Sand and Sustainability: Finding New Solutions for Environmental Governance of Global Sand Resources* recommends strategies engulfing socio-ecological, and political pathways such as *inter alia* reducing coastal poverty and unemployment, aligning sustainable development to environment protection by evaluating the relationship between coastal ecological disasters to illegal and legal sand mining and designing soft and hard laws relating to environmental non-compliance by sand miners (UNEP, 2019; Filho et al, 2021; Qi et al, 2018). A literature review scoping study on the best pathways to reduce the resource nexus effects of sand mining recommended a quadruplet of measures including (i) increasing coastal communities' awareness of the negative impacts of sand mining, (ii) transparent stakeholder engagement in sand mining monitoring and surveillance, designing a legal framework to reduce and control illegal sand mining, and encouraging innovations that encourage the substitution of natural sand used with different construction materials (Filho et al, 2021). To understand how sustainable sand governance approaches could be formulated to integrate the resource nexus and promote a sustainable BE such as Kerala, it is pertinent to dive into some case studies on how some countries/regions are trying to promote governance in sand mining (Marschke and Rousseau, 2022).

5.1.1 Case study one: The African governance pathways

The coastline of Africa is dotted with marine ecosystems and resources especially in the West Indian Ocean (WIO) rim (Oulmane and Sberna, 2022). The value of marine resources in the region are valued in excess of 333 billion USD and support over 70 million people through tourism, carbon sequestration, fishing, and mining (UNECA, 2016). However, with mounting pressures emanating from *inter alia* coastal development, less regulated marine activities such as coastal mining are increasingly threatening marine ecosystems that threaten to cripple the coastal livelihoods and ecosystems (UNECA, 2016). The insatiable illegal sand dune raiding in Morocco, Senegal, South Africa, and Uganda is threatening coastal beaches and pristine ecosystems (UNEP, 2019). A DW report documented that in Zanzibar, it is estimated that about three million tons of sand were mined both legally and illegally; decimating the coastal beaches and unique ecosystems in the archipelago (DW, 2020).

Owing to the low legislation on sand mining and the limited enforcement of national policies on sand mining, through the 2022 Africa Regional Forum on Sustainable Development, there has been the launching of the 'Great Blue Wall' (GBW) initiative (Oulmane and Sberna, 2022). The initiative hinges on interconnecting and integrating '*seascapes*' and local community stakeholders to mitigate current environmental disasters and risks and harness the potential of the African BE (Salamanca, 2022). The GBW initiative aims to halt reverse coastal resource loss by 2030 using locally feasible regenerative practices and sustainable use of marine resources using local people as core drivers (Oulmane and Sberna, 2022). By 2030, it is projected that the GBW would protect 30 percent of marine zones, and restore 2 million hectares of endemic and endangered marine ecosystems; thus increasing the net gain of critical blue ecosystems that provide coastal regenerative BE activities (IUCN, 2021; UNEP, 2019).

5.1.2 Case study Two: The European governance pathways

European countries have historically been among the leading sand-producing and exporting countries (Atlas of Economic Complexity, 2018). For instance, the value of imported natural sands by Germany equated to 102 million USD-equivalent to 5.23 percent of the global share and in the Netherlands, the global share is 5.42 percent (Filho et al, 2021). However, the recent shift in the sand markets, illegal mining, and the depletion of some natural reserves such as in Portugal has led to calls for clear mechanisms to regulate sand mining and marine resource use (UNEP, 2019; Borges et al, 2002). The 2020 International Resource Panel report concluded that developing a governance approach for sand mining could yield immense benefits towards achieving sustainable development. Unfortunately, due to a lack of a regional or international convention to regulate sand extraction, its use, and trade, specific European countries have come up with relatively sustainable pathways; though they hardly operate in a sufficiently coordinated manner (IRP, 2020; Melissa, 2021). Some of the current pathways in different Europe include:

The European Green Deal: This mainly focuses on restrictions on deep-sea mining to reduce impacts on marine ecosystems (Leotaud, 2022). Through this initiative, the European Union (EU) calls for collaborative support to restrict mining in coastal and offshore zones. This is being advanced under the 30initiativetive that aims at turning 30 percent of coastal and marine zones into conservation zones by the next decade. To aid the financing of relatively poor economies, the EU countries including the G7 are proposing a Natural Restoration Law where about 1 billion Euros is devoted to sustainable marine resources management and environmental disaster risk reduction (IRP, 2020). This pathway is aligned with the Nature Restoration Law being proposed by the EU to restore land and seascapes scathed by anthropogenic activities (UNEP, 2022).

A new feasible pathway for Europe could be designing smart innovations involving building solid infrastructure now to reduce future environmental and social risks and focus on recycling (Hubler and Pothen, 2021). The International Resource Panel report on sustainable sand mining governance advocates for the refinement of a new '*Sand Extraction Allowances Trading Scheme*' (SEATS) to balance the importer-exporter economic growth and development respectively or advancing a new '*Social Development License to Operate'* (SDLO) that focuses on improving the net societal benefits of mining through integrated stakeholder actions that cover the nexus of sustainability issues within the remit of the SDGs and their targets (IRP, 2020).

In countries such as the UK, there has been an *introduction of environmental taxes*, reliefs, and schemes for businesses where the government imposes aggregates level on sand that is either imported, directly extracted from the ground, or dredged from the sea (https://www.gov.uk/green-taxes-and-reliefs/aggregates-levy). This national policy specifically aims at aligning global sand markets and standards with local development imperatives, needs, standards, and enforcement realities to provide a clear environment, and economic and social accounting system advocated for by UNEP (Hubler and Pothen, 2021). In the Netherlands, the *negotiated environmental governance pathway* has been used as it integrates cooperation, competition, and authority in achieving robust and legitimate policy results though its performance is more or less similar to the European average (Arentsen, 2001). In Greenland, the Self-Rule Act of 2009 guarantees the right to use and manage all metallic and non-metallic natural resources (Bendixen et al, 2019).

5.1.3 Case study three: The Asian governance pathways

Asian countries contain some of the largest sand mines globally and are one of the leading importers and consumers of sand due to the spike in infrastructural projects such as in Singapore (Hubler and Pothen, 2021; Filho et al, 2021). For instance, China's Lake Poyang mine is the largest sand mining site in the world with an estimated extraction rate of 236 million cubic meters per year (Bendixen et al, 2021; Beiser, 2018). With the exploding population and urban sprawl in Asia, there is a projected strain in efforts to address environmental concerns such as climate change and natural resource exploitation including coastal and marine resources (Marschke and Rousseau, 2022; Won et al, 2017). This conundrum calls for the development of strong governance and integrated pathways for sustainable management of threatened resources and livelihood empowerment (Gavriletea, 2017).

In relation to sand mining, studies document gaps in sand governance frameworks in Asia, and where they exist, governance policies are often weak and manipulated by illegal sand mining mafias across the leading sand mining countries in Asia such as India, China, Indonesia, and Cambodia (Lamb et al, 2019; Ludacer, 2018). In China and Cambodia, spatial governance measures have revolved around sand mining bans, especially on sand exportation (Marschke and Rousseau, 2022). Sand mining bans in some Asian countries such as India have proliferated illegal and less regulated sand mining with less concern for ecosystems, a lack of environmental licenses, and restrictions on sand mining quotas (Pathania and Singh, 2017). Most sand governance licenses and operations are regulated by state and regional corporate lobbies and sand mining mafias that reap mass revenues albeit with low tax remittances and suspect under-reporting from less regulated coastal resource extraction threatening local communities' livelihoods and coastal ecosystem sustainability are threatened as in Myanmar, India, and Cambodia (Marschke and Rousseau, 2022; Prasad et al. 2020; Ludacer, 2018). For instance, it is estimated that about 90 percent of sand mining operations in India are either run by sand mafias or some form of criminal activity (Bisht and Gerber, 2017).

In many countries, there has been a focus on designing national systems and pathways mainly focusing on reducing environmental damage from sand mining (Bendixen et al, 2021). In Malaysia, digital solutions involving the use of satellite technology to identify illegal sand mining are being done in conjunction with sand mining permits in line with environmental guidelines (Ashraf et al., 2011). In India, the government has issued the Sand Mining Framework released in 2018 and the Draft Sustainable Sand Mining Management Guidelines to guide sustainable sand mining and regional states are trying to develop sustainable solutions such as in Maharashtra (India Rivers Forum, 2020). The other sand governance pathways have revolved around the restriction of in-stream mining, the developing of new national sand mining accounting, auditing, and reporting systems (Sathya, 2021), and the issuance of long dredger lease with strict guidelines on sustainable sand extraction such as in Singapore and China (Meng, et al. 2018), setting up restoration and restricted sand mining zones such as in India (Bhattacharya, Dolui, and Chatterjee, 2019), integrated and collaborative community stakeholder engagements (Bendixen, 2021), sustainable coastal sand mining activism (Mathew et al. 2022), sustainable infrastructural development initiatives such as the use of treated saw dust in concrete in India (Siddique et al, 2020), integrated coastal planning and developing of new Environment and Social Impact Assessments (ESIA) to identify best and suitable options for sand mining (Marschke and Rousseau, 2022; Aparna, 2019; Singh and Kumar, 2018).

5.2 Global case studies and Lessons learned from the case studies and their implications related to sustainable sand mining and governance

The discussion and observations related to prospects and policies related to sand mining and governance provide new insights. The cardinal observation is that though the implications are crucial, they are rather broad, and thus a need to compartmentalize them into locally feasible solutions that could serve as benchmarks for developing sustainable sand mining starting points to reduce the impact on local resources that sustain communities. Some of the new lessons from the case studies include:

In the European scenario, policy results and focus envision the integration of similar governance regulations related to natural resource management, uniformity in sand value chains, and aligning sand trading schemes to the level of effect on the resources that might affect dependent communities such as along extraction zones of main rivers. This partly aligns with the current SEATS that try to reduce the externalities of sand mining and extraction on food production, and water quality (Hubler and Pothen, 2021; Brouwer et al, 2003). In either case, the implementation of an integrated governance pathway poses challenges as observed with the implementation of the voluntary cooperative agreements for sustainable resource provision in Germany, Netherlands, and Italy (Brouwer et al; 2003).). For instance, the use of the standard command-and-control approach has been met with limited success, and thus a focus has been on the total integration of environmental protection requirements into all local communities involving all stakeholders through voluntary cooperative agreements is a necessity for the next decade through the Water Framework Directive (WFD) (6th EU Environmental Action Programme Report, 2002). This has been reinforced with the development of cost-effective resource management strategies that supplement traditional options such as environmental taxes such as on resource mining, and subsidies for sustainable environment management activities/projects related to food, water, and renewable energy (UNEP, 2016). Some of these strategies have proved crucial in the development and implementation of the European Union Common Agricultural Policy (CAP), Sustainable Energy, and Water Policy (EU, 2016). The challenge however remains that the implementation of cooperative agreements in some countries and communities is still met with resistance and ineffectiveness (Brouwer, et al, 2003). However, in countries where cooperative agreements have been implemented such as Germany, France, and the Netherlands, they have proved crucial in promoting environmental effectiveness vis-à-vis sustainable socioeconomic returns related to sustainable water and resource use management (Schans, 2001). For instance, in several German states such as North-Rhine/-Westphalia, voluntary agreements have reduced human-induced pressures on the Rhine such as farming, and mining leading to solving several foods and water-related problems (Heinz, 2003). In economic terms, the estimated net benefit of cooperative agreements in the UK in the GRID Catchment of Yorkshire is 1 million Euros per year making it an effective cost-effective solution to water and environment management (Brouwer and Zabel, 2003). This has been achieved through self-regulation of the key actors, establishing of self-interest among all users, robust negotiations amongst all stakeholders related to financial resources, and the designing of specific programs targeting a specific area with given natural resources such as a water catchment or protected zone (Brouwer et al, 2003). This implies that the use of voluntary cooperative agreements by local communities and sand mining companies can be developed in threatened sand mining zones in order to improve the environmental resource quality and partnership in regulating mining zones and protected zones among sand mining contracted companies and local communities.

In Africa and Asia, fragmented approaches related to sand mining, and trade are rampant which has led to a rethink on how to regulate sand mining activities to reduce the damage to ecosystems, and environmental resources that are crucial in the provision of food, water, and energy (Ahmed, 2013). For instance, The African Development Bank's experience report under the 'Ten Year Strategy' (2013-2022) on implementing the resource nexus approach in fragile zones observed that the restoration of watersheds affected by activities such as sand mining, and urbanization proved crucial in improving livelihoods and environmental management (Hulsmann et al, 2013). To achieve such breakthroughs, the principle of legitimacy related to the use of a given resource can be considered where all parties bargain and reach acceptable resource extraction/use limits using the social network perspective, bargaining approach, and community-based management alternative options (Hulsmann et al, 2013). In the EU, this principle is being advanced to the Common Fisheries Policy through the development of 'target-based contracts' between the local communities, government institutions, and contracted resource users (CEC, 2002). This helps in restraining multiple resource users from exploitative actions that might affect the sustainable use of a resource; hence facilitating the development of a specific community-based resource management solution.

This can effectively be achieved among communities that are relatively small and less heterogeneous to promote socioeconomic agreement on resource use through legislation and restrictive extraction in some zones (Singleton and Taylor, 1992).

To practicalize the GBW initiative, the focus is turned towards up-scaling the relevance of *regional ecological corridors* focusing on critical marine ecosystems and abiotic activities that threaten ocean functioning. This is intended to be done through the direct and indirect mobilization of impact investors for instance in sand mining and financing of network conservation projects (Oulmane and Sberna, 2022). To achieve this, Central governments and Ministries, Departments, and Agencies (MDAs) need to coordinate and collaborate in designing feasible frameworks for their local communities and zones that dedicate efforts to Blue programs, incubation initiatives, and acceleration mechanisms (UNEP, 2019). In other words, the GBW could provide an integrated and holistic approach through which multi-stakeholders can become stewards in reversing marine and coastal resource loss via integrated conservation efforts that focus on collaboration, coordination, financing, and designing leverage points for ecological connectivity and regenerative sustainable resource use possibilities (IUCN, 2021).

In addition, since most countries lack effective monitoring systems and effective enforcement of environmental legislation relating to resource use, soft approaches related to voluntary cooperative agreements could help in establishing locally feasible options to tackle human-environmental pressures such as coastal sand mining that affect the provision of food, quality water, and ecosystem resources to local communities and the designing of sustainable environmental laws (Heinz et al, 2002). This can be achieved through cross-compliance that supersedes legislation, setting up regulatory interventions on environmental standards, and the development of specific-area environmental schemes (Brouwer et al, 2003). In addition, they can be integrated into other environmental policy regulatory frameworks in targeted areas to guide how sustainable environmental governance can be achieved (Brouwer and Zabel, 2003).

The observations in the three case studies show that it is still important to increase awareness about the nexus approach, especially among coastal communities, integrated planning for specific areas affected by sand mining is crucial and this can be achieved through multi-stakeholders driven community-based planning and management to achieve the best outcome of the nexus approach in soil use, food, water, and waste. This integrated planning needs to further consider the recommendations and best case examples that can be replicated even in marginalized and poor communities. This can be through giving economic incentives to communities to recover the losses from unsustainable sand mining and also develop partnerships on management (EEA Report No 2/2008). This new perspective can help understand the crucial ecosystem assets in a given community and how sand mining threatens the ecosystems that sustain a given community.

Therefore, based on the mounting evidence of the impact of sand mining in Kerala, understanding the existing land-sea activities especially sand mining, and its direct and indirect impact on coastal resources and the extent of vulnerability of coasts to natural and human-induced disasters is crucial in developing synergies for sustainable decision-making that can be incorporated into the BE policy Framework (Ministry of Earth Sciences, 2021; Prakash et al. 2016). This can include understanding the value of coastal ecosystems such as mangroves, and fisheries resources and how increased coastal sand extraction affects coastal livelihoods and the provision of ecosystem services (Hema and Devi, 2015). Attainment of feasible options calls for the exploration of case study scenarios and examples of how some coastal zones and communities have tried to integrate livelihood approaches with natural resource extraction for sustainable development (Filho et al.2021).

Summarizing the above case studies/main lessons in relation to the resource nexus concept; particularly in coastal areas and the BE, its crucial to explicitly generate analyses that identify and test terrestrial and marine pressures that affect food systems, water availability, energy, and related coastal resources (such as coastal forests and wetlands) that highly provide resources/goods/services that communities depend on. This brings to the fore an avenue to design pathways for ecosystem services assessments that can probably promote sustainable livelihoods and ecosystem protection. A number of regional and local community pathways have been adopted (See Case studies above) though explicit guidelines that analyze the spatial and temporal land-sea pressures are non-existent in some regions. The following section shows a systematic approach and an in-depth description of how to test methods based on ESA to help in the identification of synergies and trade-offs associated with unsustainable sand mining practices on BE resources and local communities. In addition, the developed framework focuses on how such a process can be aligned to a given Sustainable Development Goal, natural resource component, and livelihood components of a given coastal community.

6.0 How to test methods based on Ecosystem Service Assessments (ESAs) and Environmentally Extended Cost-Benefit Analysis (CBA) to identify feasible pathways for sustainable coastal sand mining in the BE in Kerala

The emerging threat of increased sand mining coupled with a lack of a holistic global framework to regulate sand mining activities is a conundrum that increases the need to assess coastal ecosystems and their services to sustain and yield socioeconomic and environmental benefits (Flachenecker et al, 2016). The 2021 International Resource Panel categorically pointed out that a comprehensive decision support tool is urgently needed to support land-sea governance focused on impact pathways at various spatial and temporal scales (UNEP, 2021). This is partly because all parts of the BE are vulnerable to coastal changes emanating from *inter alia* sand mining; and existing governance approaches hardly cope with the anthropogenicinduced impacts on coastal resources (Raimund, 2019). Developing governance pathways for sustainable sand mining can help identify risks of self-reinforcing feedback that can disrupt ecosystems, coastal communities' values, assets, and economies (Steffen et al, 2018); thus promoting adaptation and resilience options and perspectives toward sustainable development (Turra, 2021). However, questions remain: how to develop sustainable sand mining pathways, and what are the best methods for the assessment of sand mining impacts at the land-sea interface?

A foresight based on the 2021 International Resource Panel Report is that Ecosystem-Based management principles should be the epitome of any governance pathway including sand mining regulation (UNEP, 2021); as they focus on all the drivers and influences on coastal resource change that underpins the safeguarding of natural capital and assets for sustainable development and livelihoods sustainability (Van der Voet and Guinee, 2018). The most common gaps in most pathways on sand mining and resource governance include a focus on single resource categories related to the socioeconomic dimension to increase extraction efficiency with less regard to environmental resource nexus interconnections and there is room for more integrated management policies (IRP, 2021; IRP, 2020; Sharmina et al, 2016). In addition, most governance instruments hardly succeed in shifting from the '*extractivist*' model to the creation of sustainable linkages between users, local communities, and the environment (IRP, 2020). A summary of some of the existing pathways is shown below

Table 3: A snapshot of some of the global/regional approaches on sustainable sand mining and governance

Framework/Approach	Main Focus	Recommendation	Region	Source
Ecosystem Service Framework	Natural capitals (land, water, climate change, energy)	Integration of resource Nexus components	UK	*Sharmina et al, 2016*
Voluntary Cooperative Agreements	Water and Agriculture	A sustainable model for financing the partnership (ecosystem service user levies)	Germany, USA, Colombia, Pakistan, Nepal, Indonesia	*Richerzhagen and Scheumann, 2016*
ENGAGE-Materials Model	resources extraction efficiency and circular economy	Need for material macro-economic modeling	Global	*Winning et al, 2017*

Systems Approach	Systemic risk assessment, knock-on effects, and interdependences	Need to understand system boundaries, nexus, actor networks and leverage points	Global	*Dawson et al. 2018*
Sand Extraction Allowances Trading Scheme (SEATS)	Tax imposition on sand trade (imports and exports) to reduce demand	Certification and creation of guarantees on sand trade outside eco-protected zones	Global	*Hubler, 2021*
Social License to Operate (SLO)	Enabling actors in extractive decisions	New Sustainable Development License to operate needed/Creation of the International Minerals Agency	Global	*IRP, 2020*
Sustainable Development License to Operate (SDLO)	Improving net societal benefits	Need for new metrics measured based on sustainable economic development, environmental management, and social values	Global	*IRP, 2020*

The single resource focus and linear nature of the traditional sand extraction approach along supply chains soil the thinking for sustainable BE resource governance (IRP, 2021). At a global level, a focus on the integration and interlinking of BE resources and activities such as sand mining to address trade-offs, synergies, and feedback loops are increasingly envisaged (IRP, 2020; Bleischwitz, 2018). The 2021 World Ocean Assessment Report recommends for an integrated and comprehensive Regular Process for the Reporting and Assessment of the State of the Marine Environment that focuses on the evaluation of trends and identifying gaps in the marine environment and socioeconomic interactions along coastal interfaces to develop integrated assessment pathways (UN, 2021). This can inform robust decision-making at micro and macro levels in evaluating the sustainability of Ecosystem Services and availing of baseline information that can boost sustainability and responsible sand mining (UN, 2017).

The designing of the ESA might help balance sand mining with a sustainable livelihood approach and ecosystem resilience outcomes. An integrated Ecosystem Services Assessment (ESA) pathway can be developed to appraise the economic value of sand mining in relation to ecosystem services and identify possible restoration scenarios in coastal zones threatened by sand mining (Sinclair et al, 2021; Turra, 2021). For instance in Kerala, developing a framework tuned towards ESA could help identify the critical threats of sand mining on coastal zones and communities, identify trade-offs and synergies for the sustainable management of natural capital and ecosystem goods and services for sustainable development (Valdes, 2017). To develop an integrated ESA governance pathway, understanding the level of resilience based on the interdependencies of both anthropogenic activities and natural capitals or goods and services which are the direct drivers of change is paramount (Stamford and Azapagic, 2014). This benchmark is crucial in the compartmentalizing of the interaction of the resources and the nexus therein with the different SDGs in a given coastal system (Brouwer, 2018).

The 2021 International Resource Panel recommends seven (7) interlinked steps that inform the guidance for integrated ESA in coastal regions threatened by activities such as sand mining that has been a mainstay in states of India such as Kerala- (i) Focus on interlinkages and connections between coastal/terrestrial activities and coastal resources, (ii) Regulatory frameworks that take into account the impact of human activities on coastal resources, (iii) Safeguarding of natural capital at the land and sea interface, (iv) Mapping and the integrated protection of coastal natural capital needs, (v) Developing of a stakeholder community to replace area-based stakeholder partnerships, (vi) Effective monitoring and evaluation with a focus on Impact pathways than the state of coastal resources, (vii) An integrated spatial and temporal decision support tool for a specific geographical context to governance based on impact pathways (IRP, 2021). The inclusion of the land interface in the ESA is crucial in understanding the crucial marine inputs, environmental functions, and services such as coastal nutrient recycling, water-related ecosystem services, and sedimentation ((Bleischwitz, 2018). The use of the ESA helps in the identification of multiple resource stressors and management of a single resource that has multiple livelihoods and natural functions such as coastal sand which is both crucial for biodiversity and coastal livelihoods. Thus, in Kerala, the profiling of natural capital assets could streamline the alignment of sand mining regulations and guidelines to local governance frameworks on resource use and sustainability (Prasad et al, 2020). For instance, ESA has been used to provide guidelines for Natural Capital Accounting (NCA) involving the identification of natural capital assets in a given coastal zone and how coastal users or activities affect them and a holistic landscape approach including balancing coastal and marine conservation efforts, sustainable production, and inclusive community-based management in Madagascar and Liberia (Neugarten et al, 2016)

This avenue provides critical nodes in understanding resource nexus complexities which can be crucial in coastal governance and decision-making (Conservation International, 2016). Developing coordinated and cooperative pathways and action plans related to coastal resources offset trade-offs and enhance the gross value of the extractive sector to sustainable development (IRP, 2020). This requires coherent systems and prioritization of complex issues and intricate dynamics that may impede the myriad opportunities and livelihood benefits availed by natural capitals, and ecosystem services (IRP, 2021). In the case of Kerala therefore, a sustainable process to promote sustainable sand mining and coastal resource management could integrate the main components of the land and sea activities. This could serve as a target-area-based framework to consider in creating and processing coherent steps for an ESA governance pathway that promotes sustainable sand mining and the attainment of efficient global resource use targets (UNEP, 2019; Steffen et al, 2018). Thus, considering the seven (7) assessment procedures identified above could help (a) in selecting suitable extraction sites and (b) making any sand mining activity as sustainable as possible; leaving space for other BE activities such as tourism, and fishing. The main aspects to test can include:

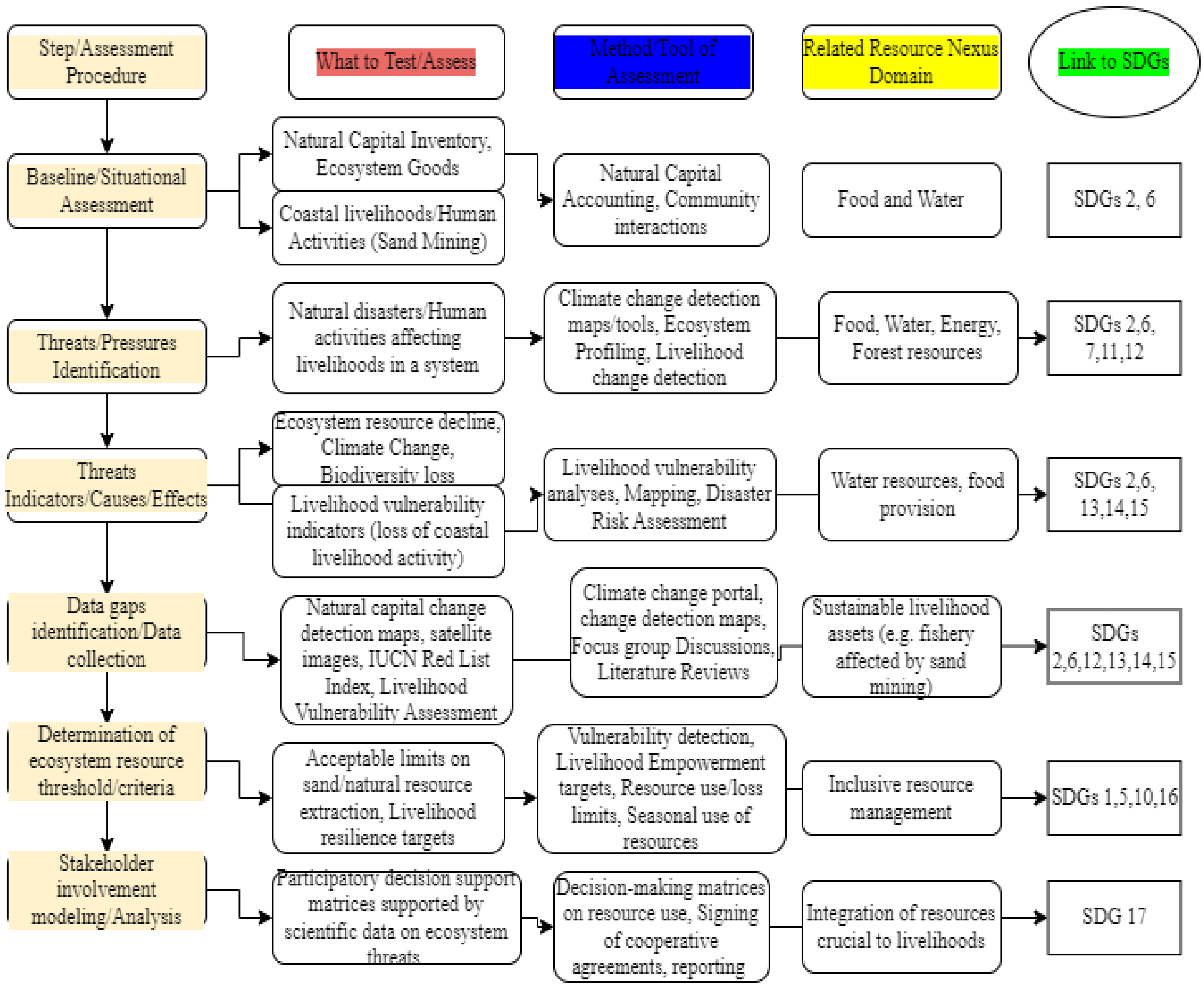

Fig. 3: Proposed framework based on ESA and Environmentally Extended Cost-Benefit Analysis (CBA) to identify feasible pathways for sustainable coastal sand mining in the BE in Kerala (Developed by the author).

The proposed framework in *Fig.2* can be developed as a guiding pathway that focuses on assessing the trade-offs of coastal sand mining activities and micro and macro identification of synergies and multidisciplinary actions for sustainable development. These perspectives can be used in generating new perspectives for climate adaptation and mitigation, livelihood vulnerability assessments and coherent evaluation and valuation of sand trade resource flows that directly impact coastal livelihoods and coastal resources related to the BE (United Nations, 2017).

The primary aspect of this assessment procedure of ESA related to sand mining is conducting and profiling baseline and situational assessment of the natural capital and ecosystem assets in a given coastal zone as coastal livelihoods and economies directly rely on nature, ocean issues, and biodiversity (IPCC, 2019). The profiling of natural capital can help document the value-per-unit-area equivalence scale and the spatiotemporal evolution of ecological services which are affected by sand mining (Liu et al, 2017; Zhao et al., 2013). In China, for instance, this has been done using a new index for ecosystem goods and service accounting known as the Gross Ecosystem Product (GEP) to measure the value (monetary) of ecological benefits to a given coastal society in relation to a given anthropogenic activity such as mining (NBS China, 2021). In Europe, natural capital assessments have been done using the National Ecosystem Assessments (NEA) based on the guidelines of the EU Mapping and Assessment of Ecosystems and their Services (MAES); which can be provisioning, regulating, and cultural services (GBS, 2021; Schroter, et al, 2016). Integrating these assessments in sand mining zones such as in Kerala can help in providing new workstreams for the compilation of ecosystem accounts, application of the developed accounts in scenario analysis in line with local and national priorities, development of guidelines and methodology for Natural Capital Accounting (NCA) and ecosystem accounting (Obst et al, 2016), and alignment of such methodologies to livelihood empowerment indicators, and sustainability reporting on the Final Ecosystem Services that sustain livelihoods, and developing of pilot studies for the designation of the key Ecological Function zones (EFZ) for eco-compensation scheme s (Ouyang et al, 2020; Zhao et al., 2013). This aligns with the planned Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) which aims to avail practical guidelines for developing baseline information on NEA in countries lacking clear frameworks for comprehensive, systematic, and comparable assessments (UN, 2021). In coastal zones experiencing sand mining in Kerala therefore, crucial data to determine GEP can include (i) physical capital assets, (ii) water quality levels, and (iii) coastal species lost/maintained among others (GBS, 2021).

The next assessment procedure is the identification of land-sea threats, pressures, and their drivers are paramount (Bleischwitz, 2018); as it helps in the understanding of the resource nexus challenges and emerging coastal resource scarcities that affect livelihoods and coastal ecosystems. This is done using footprints and indicators of ecosystem outlook both under current and future scenarios due to coastal operations such as sand mining (Liu et al., 2017). The best methods to achieve this include environmentally extended input-output analyses (Tukker et al, 2016), ecological redline list indexes, and annuity capitalization method to assess interdependencies and vulnerabilities or shocks in supply, and value assets according to a proper rate of return on investment (in this case sand mining investments) in relation to the attainment of sustainable livelihoods (NBS China, 2021). This helps in capturing local stresses and shocks of sand mining on local ecosystems and livelihoods and this can be complemented with new approaches such as Life-Cycle-Sustainability Analysis and GEP to explore direct threats and opportunities on livelihoods (Van der Voet and Guinee, 2018; Ouyang et al, 2020). The 2021 World Ocean Assessment II identified five main drivers that increase pressure on coastal ecosystems and threaten livelihoods including population growth and demographic changes, economic activity (mainly mining, manufacturing, and trade), technological advances, changing governance structures, and climate change. These drivers have proliferated sand demand leading to negative trade-offs on coastal resources, ecosystem stock, and flow accounts (Ouyang et al, 2020; UNCTAD, 2021; Ludacer, 2018); such as fish as it affects fish spawning zones and zooplankton affecting local fisheries communities (Prasad et al. 2020). The increase in population further intensifies domestic and global material consumption, food requirements, and the increased need to use the sand for related BE activities notably port construction threatening SDGs 2, 11, 13, and 14 as it balloons pressure on natural capital and assets. For instance, the increase in coastal sand mining has sprawled out anthropogenic pollution affecting marine taxa (World Ocean Assessment II, 2021). This validates this assessment procedure in Kerala to build capacity related to developing new methods to standardize and monitor coastal threats including the development of datasets is needed to design and evaluate the best priorities (IRP, 2021). This can be through the use of digital technologies to monitor threats, cleaner sand production methods, quieter technologies, and pollution control processing technologies (UN, 2017).

The understanding of the key threats, their drivers, and their effects forms a crucial part of the ESA (IRP, 2020). A paucity of methods and tools are being recommended to inform decisions on sustainable coastal resource governance in the BE (IRP, 2021). Notably, natural capital and ecosystem damage emanating from sand mining has been documented through natural capital detection maps using both satellite images and land use change maps (Schroter et al, 2016). New advances encourage leveraging the benefits of new methods such as the use of ecological redlines in sand-mining-affected zones, sensors, and autonomous observation platforms to detect the impact of sand mining on ecosystems that sustain a given coastal community (Ouyang et al, 2020; UN, 2017). To integrate the climate change dimension into ESA, a focus on climate vulnerability assessment in coastlands that have been caved-in due to coastal sand mining and scenario modeling is advanced to project the effect of a given coastal or marine activity on social systems and economic sustainability (Turra, 2021).

Such information can be used to determine acceptable thresholds for the use or extraction of a given resource (Dargin et al., 2019; Torres et al, 2017); especially in illegal sand mining zones of Kerala (India Rivers Forum, 2020). For instance, the World Business Council on Sustainable Development is focusing on new initiatives in cement manufacturing to develop low-carbon concrete and alternative fuel and energy by using dry-kiln with a precalciner-a precursor for low water use in cement manufacturing in developing economies. In Kerala, the focus is on seasonal sand mining along riverbanks, conducting sand audits, identification of zones threatened by sand mining, and development of guidelines on sand mining as stipulated in the Draft Sand Mining Guidelines of 2018 (India Rivers Forum, 2020). In addition, a focus has been on developing natural capital/resources balance sheets in consultation with all stakeholders to generate statistical databases that value sand mining activities and their effect on ecosystem service provision and livelihood sustainability (GBS, 2021). These criteria further help in creating assessment plans on how to manage invaluable cultural assets and resources that may be threatened by sand mining and the creation of land-use and land-cover accounts that specifically document the spatiotemporal classification of ecosystem types in a given area and their values (Liu et al, 2017). This could help in designing inventories to evaluate and compare trends in ecosystem assets, services, their values, and how coastal sand mining activities are affecting them over a given period of time (Schroter et al, 2016).

Again, such inventories help stakeholders in extending their scope related to sand mining patterns, demand, and supply flows (UNEP, 2019). The involvement of all stakeholders in ESA is thus a crucial aspect in optimizing the land-sea systems' interactions and designing inclusive synergies for positive transformation (IRP, 2021). The best strategy for participatory stakeholder involvement should progress above baseline surveys and expert interviews or recommendations; but should base on sound and evidence-based data and best-livelihood options on what works best for a given coastal community (IRP, 2021); to reduce the risks of recurring natural resource user conflicts and livelihood vulnerabilities to coastal threats mainly climate change which are exacerbated by the negative effects of sand mining (Richerzhagen, and Scheumann, 2016). In other words, participatory stakeholder involvement should not be based on the '*winner takes it all*' principle but on the blending of local community interests and perspectives with prospective natural resource users or benefactors (UN, 2021). This can be complemented with livelihood vulnerability matrices and ecological resources datasets and compilations to highlight synergies and feedback loops of a given resource to a local community (GBS, 2019). For instance, if a local fisheries community prefers to setup key Ecological Function Zones (EFZ); even though it has vast deposits of sand resources or natural resources, policymakers and political actors should respect such a social perspective since the local knowledge of such a zone could explain for the sustainable harvesting of such fisheries with less over-exploitation which might be decimated with the initiation of sand mining excavations. Such local decisions and bottom-up decisions can be integrated into National Action Plans (NAPs) and aligned toward global targets based on Agenda 2030 of the United Nations Sustainable Development Goals (UN, 2021). For instance, if local communities are focusing on climate risk reduction, their insights can form a national knowledge portal that can be integrated into the national climate change disaster risk reduction framework (Dawson et al, 2018); which can be integrated into the United Nations Climate and Disaster Risk Screening Knowledge Portal for simulating mitigation and adaptation scenarios and decision making at the national and global level (www.climateknowledgeportal.worldbank.org).

7.0 Conclusion

Owing to the gross evidence that sand mining is increasingly ruining ecosystem health and livelihoods of poor communities; especially in the coastal regions of Asia in general and Kerala in particular, it can immensely be concluded that the importance of designing new sand mining and sand governance perspectives is urgently needed to not only streamline and regulate the demand-supply flows but also create integrated synergies for sustainable management of the land, soils, and water resources at the land-sea interface. Though ‘no one size fits all’ solution has been advanced, the research perspective presented in this paper relating to the ESA provides an initial ‘full package’ of workable solutions that integrate both natural capital resources and coastal livelihood synergies that are prevalent at micro and macro levels along coastal systems. Understanding the state of natural capital can catapult society’s capacity to understand current and future multiple stressors that can determine how local communities can generate knowledge, and innovations, and develop or identify tangible solutions to optimize the role of coastal resources that can contribute to the sustainable development of the BE under changing environmental and socio-economic conditions.

One of the best assessment guidelines that the ESA can bring to the fore in the context of sand governance in Kerala is the focus on integrated and bottom-up participatory planning and geospatial governance processes that promote the prioritization of interlinkages across all BE sectors and coastal landscapes. This can help in the identification of sand mining trends, trade-offs, and costs on both the ecosystems and livelihoods which can bolster socioeconomic and environmental governance and foresight in decision-making on the best options for promoting sustainable mining. With such a perspective increased monitoring of the relationship and the effect between sand mining on BE resources that sustain coastal livelihoods can systematically be attained hence boosting resilience, mitigation, and accruing of co-benefits among different stakeholders. Therefore, with the integration of ESA assessment guidelines into local and state guidelines related to sand mining, inclusive and integrated pathways on sustainable sand mining, BE activities and livelihood welfare could be tapped.

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9.0 Conflict of Interest

The authors declare no conflict of interest in the production of this work.

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