Economic assessment mangrove ecosystems' goods services of India

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Abstract

Mangroves are a group of trees and shrubs that live in the coastal intertidal zone. Mangroves have been distributed in low-energy, tidal shorelines between latitudes in tropical and subtropical areas. Mangroves are important productive ecosystems in coastal areas. Mangrove ecosystems are rich in biodiversity and provide a wide range of goods and services to human communities living in coastal areas including wood and non-wood forest products, fisheries, medicines, tannins, apiculture, wildlife resources, fishery, recreation, ecotourism, bio-filtration, nursery grounds, coastal protection, and carbon sequestration. Mangroves are bio shields of the coast and protect people from disasters like tsunamis, and cyclones. Mangroves support shoreline protection, sediment accretion, and, other functions. Mangrove cover in coastal areas of India is 559098.62 ha. They have been discontinuously distributed in 42859 patches of the coastal areas. India's coastal States and UTs are distributed with mangrove ecosystems except the UT of Lakshadweep. Benefits from mangroves are often ignored by industry and local inhabitants since the values of goods and services and their equivalent economic benefits are derived from the mangroves of India. This study aims to analyse various benefits of mangroves and estimate their equivalent economic benefit to inform the conservation benefits of mangroves. This study has followed the Millennium Ecosystem Assessment framework. The average total economic benefit of mangroves' goods and services is the equivalent economic values of India's mangroves range between Rs. 92662/-/ha/yr., = US$1985.17 ha/yr (minimum) and Rs. 3361144 = US$72008.47/-/ha/yr. (maximum) with an average total economic benefit of Rs. 958766/ha-/yr = US$ 20540.41/ha-/yr. The mangrove ecosystems of India are contributing equivalent economic benefit of Rs. 53604 crore Rs./yr., = US$1148.40 Rs./yr (Average) to the welfare of coastal communities. The ecosystem value shall support policy decisions and awareness creation on conservation benefits and sustainable utilisation of goods and services of the mangrove ecosystem.

Keywords: mangrove, economic valuation, benefit transfer, India

1. Introduction

Mangroves are a group of trees and shrubs that live in the coastal intertidal zone. The word 'mangrove' is usually referred to both vegetation and habitat. Mangroves have been called coastal forests, swamps, wetlands, and mangal (FAO, 2007; Spalding *et al*., 2010) [1, 2]. Mangrove ecosystems are rich in biodiversity and provide a wide range of goods and services to human communities living in coastal areas including wood and non-wood forest products, fisheries, medicines, tannins, apiculture, wildlife resources, fishery, recreation, ecotourism, bio-filtration, nursery grounds, coastal protection, and carbon sequestration. Mangroves are bio shields of the coast and protect people from disasters like tsunamis, and cyclones. Mangroves support shoreline protection, sediment accretion, and other functions (James Spurgeon., 2002) [3]. Man-made activities such as reclamation, agriculture, aquaculture, fuelwood, timber, damming, oil pollution, mining operation, etc., degrade the ecosystem function. Mangrove products and services are often undervalued or even ignored in the economy by industry and local inhabitants (Ong and Gong. 2013)[4]. Mangrove ecosystem destructions are mainly because; the conservation benefits of mangroves do not receive adequate importance and there is very little understanding of the role of mangroves in economic systems. This has led to mangroves being considered wastelands with little use, and no value (IUCN. 2006) [5]. Express the environmental goods and services used from the mangrove ecosystem shall enhance conservation thoughts and participation of stakeholders in the conservation of the sustainable function of mangroves. Economic valuation of various benefits of mangroves is a useful tool to support conservation and the decisions of mangrove ecosystem management and governance (Laurans et.al. 2013) [6]. This research study has estimated the equivalent economic value of various goods and services of the mangrove ecosystem that to make awareness about the conservation benefits, supporting policy decisions for risk management, cost-benefit analysis, and compensation decisions etc.

2. Study area and methodology

India has 9 coastal States and 4 UTs (Union Territories) in its political boundary. All coastal States and UTs of India have mangrove ecosystems in the coastal areas for except in Lakshadweep UT. Mangrove cover in coastal areas of India is 559098.62 ha and they have been discontinuously distributed in 42859 patches of the coastal areas. The Indian mangroves comprise approximately 59 species in 41 genera and 29 families. The species composition varies between east coast, west coast and island mangroves. However, the uses and benefits of mangroves are equal. India's mangroves provide a range of non-market as well as marketed goods and services, both on and off-site. Various economic valuation methods were

applied to the various mangrove patches towards a comprehensive assessment of many goods and services of mangrove ecosystems of India and the same has been explained in the following chapters. Mangrove ecosystems areas distributed in the coastal states and UTs have been digitised and areas have been calculated by applying RS and GIS techniques (Map-1). The mangrove patches have been listed under the administrative boundaries (District level) of the States / UTs.

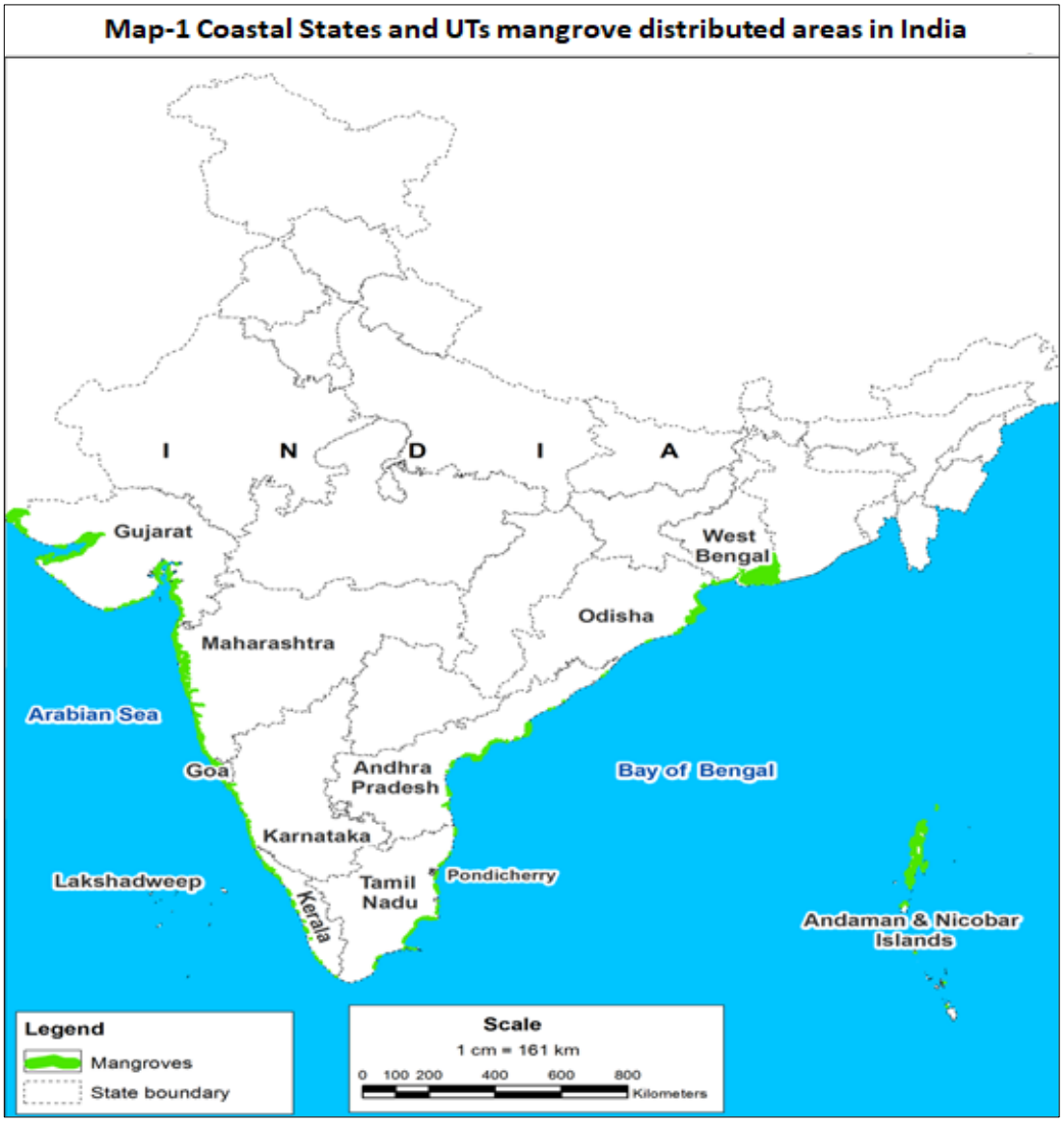

Fig 1

There are many economic analyses to value the goods and services of the mangrove ecosystem of the world (Vo, Q.T., et.al. 2013) [7]. Meta-analysis is a method of synthesising the results of multiple studies to examine the phenomenon, which is then 'explained' using regression techniques (Stanley, 2001) [8]. Meta-analysis shall also be applied to identify the common goods and services of the mangrove ecosystem and their value by using the benefits transfer method (Navrud and Ready, 2007) [9]. Using the benefit-cost transfer method, the values (existing values) have been applied to estimate the economic benefits of India's mangrove patches (policy site). These values can be applied to estimate the economic loss of the damages caused to the mangrove ecosystems (Brouwer, 2000) [10]. This study collected all the published economic values of various goods and services from mangroves and selected suitable services, which is existing in India, and transferred them to Indian mangroves. The maximum, minimum, and average values of services also have been estimated to support decision-makers to select suitable values based on the application including compensation, cost-benefit analysis, risk assessment etc. Average physical quantities of goods and services or values from mangrove areas have been analysed using 73 studies encompassing 352 observations followed by Marwa etal (2012) [11]. To get the TEV of mangroves, the goods and services have been classified as provisional, regulation, cultural, and supporting services followed by Millennium Ecosystem Assessment (MEA, 2005) [12].

3. Results and Discussion

3.1 Provisioning services of mangrove

Provisioning services are the goods that can be extracted from mangroves for human requirements (Ruitenbeek, 1994) [13]. Coastal communities, especially fishermen depend on mangrove forests to fulfil their needs for food and raw materials (Van Oudenhoven et.al. 2014) [14]. Fishery, aquaculture support, timber, fuelwood, honey, pharmaceuticals, fodder etc.

(Nibedita Mukherjee et.al. 2014) [15] are the important provisional services provided by the mangroves.

It was also reported that 1ha of mangroves generates 1,100 kg to 11,800 kg of fisheries catch, which in developing countries corresponds to a market value of $900 to $12,400 annually (Ronnback, 2000) [16]. In another study, Ronnback (2001) [17] estimated the annual market value of fisheries supported by mangroves in developing countries to be US$ 3,400/ha/year. In addition to general fisheries-related valuation estimates, there are estimations for individual groups such as molluscs, shrimps, crabs and echinoderms that are associated with mangroves. Giselle and Alan (2007) [18] estimated the mangrove-associated mollusks and echinoderms (sea cucumber, sea urchin, etc.) for US$33/ha/yr. On-site crustacean and mollusc harvests from mangroves of Vietnam were estimated for US $ 126/ha/yr. (Nielsen *et al*., 1998) [19]. Cabahug *et al*. (1986) [20] estimated the mollusks harvested from mangroves in the Philippines for US $675 /ha/year. Shrimps belonging to the genus *Penaeus* have a life cycle where they spawn at sea and, after a few weeks, the post-larval shrimps settle in inshore and estuarine waters, which they use as nurseries during their critical early life stages. The wild shrimp post larvae (seed) that are stocked in grow-out ponds are either allowed to enter traditional ponds with incoming tidal waters or caught by seed fishers and subsequently stocked in ponds. Shrimp post larvae can also be produced in hatcheries, which depend upon continual inputs of wild-caught brood stock. The shrimp hatchery industry is heavily dependent on the continuous input of wild-caught Penaeus monodon spawners generated by mangrove ecosystems (Ronnback et.al. 2000) [16].

Dead parts of mangrove trees have been the source of firewood in India (Bandarnayake, WM., 1999) [21]. Because of the high specific gravity, the species of *Rhizophora, Kandelia, Ceriops* and *Bruguiera* are preferred for firewood by the local communities for secondary uses other than cooking. The value of mangroves for fuel can be determined based on the cost of alternative supplies of fuel (i.e. substitute price). Khalil (1999) [22] estimated that the daily household use of mangrove wood in Indus Delta, Karachi, Pakistan was 4.5 kg/household/day. At an average price of RS 1.45 per kg, it was estimated that the overall value of mangrove fuel wood in the Indus Delta was estimated to be Rs 22.5 million per year (approximately US$ 385,000/yr). Similarly, in Sri Lanka, the household's dependent firewood was estimated as 20.5 kg/week which was equivalent to 982 kg/year. In the local markets, the equivalent firewood sold for 1.2 Rs/kg was interpreted for the annual value of the harvest and it was estimated at US$24 /ha/year (Gunawardena, M and J. S. Rowan., 2005) [23]. Mangrove forest produces construction materials and supports the subsistence economies of coastal communities (Fredrik Moberg and Patrik Ronnback., 2003) [24]. In addition, they have been used to construct local canoes (Wilson, J.S., 1858) [25]. Strength and durability including pest and rot resistance make the mangrove wood suited for use in construction (Kairo *et al*. 2002) [26]. The economic value of building materials extracted from MEDA creek, Kenya mangrove ecosystem was valued at US$16/ha/yr., whereas, in Tana creek, Kenya, mangrove timber was estimated at US$15/ha/yr. (UoN & UNEP., 2016) [27]. Export price of mangrove wood in Indonesia cost about US$67/ha/yr. (Ruitenbeek. 1992) [28]. Mangroves grazing ground for many cattle.

Mangrove leaves are used for camel fodder in Gujarat. Similarly, mangroves are used as camel fodder throughout northeast Africa, the Middle East and Pakistan. Khalil (1999) [22] estimated that mangrove leaves of the Indus, Pakistan are very nutritious, and it helps food support to 16,000 camels and 11,000 cattle. Faya (1993) [29] studied the nutritional value of *Avicennia marina* for browsing animals and indicated that it has poor nutritional value when it was given as a lone feed while, it was also given with alternative fodder, and it is a nutritious source of cattle food. The most suitable valuation technique would be based on the volume of leaves eaten and the market price of providing an equivalent amount of fodder (i.e. substitute product price) (James Spurgeon., 2002) [3]. Based on data from a household survey it was estimated that the Indus delta yielded 2 million kg of fodder per year worth RS 2.56 million per year, based on a price of RS 1.25 per kg of mangrove fodder. Memon reports that the area of mangrove forests was 263,000 hectares in 1977 and 158,500 ha (392,000 acres) in 1990. This will value the use of mangroves as fodder at US$16.15 ha/yr.

The links between bees and mangroves are inextricable and have been exploited by humans for thousands of years. Since the mangroves naturally provide a safe habitat by providing a year-round supply of nectar, and pollen, unlimited water source, stability of trees, resilience against forest fires, and deters termites and ants (Jonathan Baines and Manon Whittaker., 2016) [30]. Honey collection from the mangrove forest is a traditional activity in India. It has been estimated that the Sundarbans mangrove alone produces 111 tons of honey annually http://www.niobioinformatics.in/mangroves/MANGCD/fact.htm (visited on 13/03/2017). Honey and bee wax contribute around Rs. 4500 = 96.40 US$ (3.5%) on average to the average annual household income in the Sunderban villages (Anshu Singh et.al. 2010) [31]. About 35,000 tonnes of honey was collected from the India part of Sundarbans mangrove forests last year and sold through the State's Forest Development Corporation. Sundarbans tiger reserve of India has estimated that honey collection during 2014-15 was 47,412 kg and it was sold for Rs. 47, 41,200/- = 101574.51 US$ (http://sundarbantigerreserve.org/urls/non-timber-forest-produce.html# visited on 14/03/2017). India's part of Sundarbans mangrove covers an area of about 426200 ha and the honey potential in this area can be estimated for Rs. 11/ha = 0.23 US$/ha. According to Tri *et al* (1998) [32] around 0.2 kg/ha/yr. of honey can be collected from mangroves in Vietnam. The value was based on potential volumes of honey produced and the market price (US$ 4 to 5 per kg in Cairo) of honey. After deducting the production cost, the value was estimated at US$ 0.8 to 1/ha/yr. Economic value of honey collection from MEDA creek of Kenya mangrove was estimated at US$22/ha/yr., whereas, in Tana creek mangroves of Kenya it was estimated at US$2/ha/yr. (UoN & UNEP., 2016) [27]. The values have been applied to the total mangrove areas of India and have been incorporated in Table – 1.

Extracts and chemicals from mangroves are used mainly in folkloric medicine (e.g. bush medicine), as insecticides and pesticides and these practices continue to this day (Bandaranayake, 1998) [21]. Ethno-botanical studies revealed the therapeutic potential of nearly 17 applications from eleven

plant species of mangrove and associated species including medicinal properties to treat different diseases and ailments. The important traditional therapeutic applications of mangrove in Pitchavaram fishing community are; cure for snakebite, Smallpox, ulcer, detoxification, birth control, urinary disorders, stomach disorders, tumor inhibitors, jaundice, malaria, toothache, skin diseases, diarrhea, nausea, vomiting, cholera, etc. (Ravindran et.al. 2005) [33]. *Rhizophora sp.*, bark has been found to be important as a source of tannins, used in leatherwork and for curing and dyeing fishing nets made of natural fibre (FAO, 1994) [34]. Traditionally mangroves have been used for the treatment of diabetes (Revathi etal. 2013) [35]. Kathiresan *et al*. (2006) [36] found biochemical components related to medicines of cancer and other diseases. Extracts from mangroves and mangrove-dependencies have proven effective against human, animal, and plant pathogens, but only limited investigations have been carried out to identify the metabolites responsible for their bioactivities (Roome *et al*., 2011) [37] Pharmaceutical values of mangroves were suggested for US$ 0.1 to US$ 60/ ha, using values of similar components of other studies (Bann, 1997) [38].

3.2 Regulation services

Mangroves protect life and livelihoods of coastal communities since they border the shoreline. They protect the coastal communities from coastal extreme events such as floods, storms and tsunamis (Ong and Gong, 2013) [4]. Regulating services that have been analysed in most detail include water quality maintenance, storm, flood and erosion control and climate regulation (Saenger 2002) [39]. Mangrove forests reduce risk from coastal hazards, such as waves, storm surges, and tsunamis. They reduce flood depths and wave heights, lessening damage to the property behind mangrove forests. The level of risk reduction depends on the type of hazard, as well as mangrove characteristics (World Bank. 2016) [40]. McIvor *et al*. (2012) [41] analysed several recordings of Louisiana during the Rita hurricane and found that the mangroves reduce the water level by 15.8 cm per km. The protection service of mangroves are particularly important to poor communities since they are less resilient to flooding and other damages (BCA, FORES, FORWET. 2013) [42]. The mangroves protect the coastal communities from extreme coastal events such as tsunamis. Evidence from the 12 Indian Ocean countries affected by the tsunami disaster, suggests that those coastal areas that had dense and healthy mangrove forests suffered fewer losses and less damage to property than those areas in which mangroves had been degraded or converted to other land uses (Wetlands International, 2005) [43].

While calculating the NPV of mangroves forest of India, it was estimated that 1 ha of mangrove forests shall save 0.0148 lives (Verma., *et al*., 2013) [44]. It was estimated that the average opportunity cost of saving a life by retaining mangrove forests was 11.7 million rupees per life saved during the Orissa super cyclone (Das and Vincent. 2009) [45]. In Bhitarkanika of India, storm abatement function of mangroves was estimated at 116.28 US$/household using damage cost avoided method (Ruchi Badola and S A Hussain., 2003) [46]. The value of the mangrove buffer in Srilanka was estimated at 21,000 Rs/ha/year or US$ 300/ha/year (Gunawardena, M and J. S. Rowan., 2005) [23]. Constanza etal., (1997) [47] estimated the disturbance regulation function of mangroves at US$ 1800/ha/yr. In southern Thailand, Sathirathai (1998) [48] estimated the coastline protection service of mangroves and valued it for US$3,000/ha/yr. However, Barbier *et al*. (2007) [49] estimated an average value for the storm protection value of mangroves of Thailand at $1879/ha/yr. The protection function of Ngoc Hien, Vietnam mangrove forests was valued between the range of 742 and 756 USD/ha/yr. (UNEP. 2015) [50]. Protection service of mangroves during extreme events in south of Viet Nam was estimated at USD 5,000/km2/yr. (Tri *et al*. 1998) [32]. Economic value of flood control protection service of MEDA creek, Kenya mangrove was estimated at US$154/ha/yr. Strom surge protection using seawalls in Bamburi, Kenya to protect property against the high sea storm surges cost around US$952/mtr., with 1% maintenance cost as equal to the mangrove protection service in the natural coast (UoN & UNEP., 2016) [27]. Further, the shoreline protection value from severe weather events in Gazi mangroves, Kenya was estimated at US$ 91.7/ha/yr. (Janis Hoberg., 2011) [51]. While estimating restoration benefits of mangroves, Barbier (2009) [52]. estimated flood protection at $11000 per/ha. and suggested that restoration was profitable. Salem and Mercer (2012) [53] used meta-analysis to value the protection service of mangroves to be 10.45-8044 USD/ha/yr.

Shoreline erosion and deterioration have been reduced by mangrove by its ability to retain soil and stabilize the sediment (BCA, FORES, and FORWET. 2013)[42]. Erosion protection function of mangrove of Philippines was estimated at US$672/ha/yr. (Giselle and Alan. 2007)[18]. Ruitenbeek (1992)[28] estimated the value of damage cost avoided for agriculture farming by the erosion protection function of mangroves of Bintuni Bay, Indonesia at US$ 240/ha. In Indonesia, the prevention of coastline erosion service of mangroves was valued within the range 1192 kUSD to 6475 kUSD or 694 USD/ha to 3767 USD/ha (Abdul Malik etal., 2015)[54] for both erosion and seawater intrusion function. Similarly, Christensen (1982) [55] estimated erosion protection function of Asia–Pacific region mangroves at $165/ha/year. Sathirathai and Barbier (2001)[56] have estimated the cost of constructing breakwaters to prevent coastal erosion in Southern Thailand and equated the potential economic service of mangroves for US$3679/ha (coastline protection). The unit cost of constructing artificial breakwaters to prevent coastal erosion and damages from storm surges was US$1011/mtr (1996 price). Based on the estimate, Barbier (2007)[49] estimated the erosion prevention service of mangroves of Thailand for protecting the shoreline with a 75-meter width stand of mangrove to be approximately US$13.48 per m^2, or US$134800/ha (1996 prices). Shoreline loss after mangrove removal and hard structures establishment and maintenance to protect Kenya coast was estimated at US$ 20.81 m^2/yr., US$ 395/ ha (Mark Huxham *et al*. 2015)[57].

Mangroves help to purify and maintain freshwater sources in coastal areas. Further, it acts as a barrier against siltation and pollution from land based sources, which protects coral reefs, sea grass beds and the coastal wetlands (BCA, FORES, FORWET, 2013)[42]. Lal (1990)[58] estimated the nutrient (waste) filtering service derived from Fiji mangroves worth of US$5,820/ha / year using alternative cost approach. Harahab (2010)[59], estimated the mangrove service of prevention of seawater intrusion in to the coastal aquifers of Probolinggo district, East Java for USD 7 kUSD/ha/year. In Indonesia

protection of aquifers and prevention of seawater service of mangroves were estimated at 476 kUSD or 277 USD/ha, (Abdul Malik etal., 2015) [54].

Mangroves are the most productive and bio-geochemically active ecosystems and important sinks of carbon in the biosphere (Ong 1993; Walters *et al*. 2008) [60,61]. The carbon stock per unit area of mangrove forest are high since the photosynthesis rates of mangrove trees and top layers of mangrove sediments store large amounts of organic carbon (Alongi 2012; Bouillon *et al*., 2008)[62,63]. This carbon sequestration and storage service by mangroves provides global benefits by removing the harmful greenhouse gas carbon dioxide from the atmosphere (Meenakshi Jerath etal., 2012)[64]. Ong (1993)[60], reported that mangroves could store 100 to 200 ton C/ha above ground, whereas below ground carbon can reach 700 ton C/1 m soil thickness/ha (with an estimated carbon sink rate of 1.5 ton C/ha/year). A 20-year old plantation of Rhizophora mangroves stores 11.6 kg m2 of carbon with a C burial rate of 580 g m2 /yr. (Fujimoto 2000)[65]. It has been reported that the carbon sequestration potential of India mangrove was estimated at 2.27 tC/ha/yr and the functioning of avoided emission was estimated at 1.61 tC/ ha/yr (Lucy Emerton., 2014)[66]. The market price for carbon ranges from $6.86/tC in the Regional Greenhouse Gas Initiative (RGGI) market in the United States to $75.24/tC in the European Union's Emissions Trading System (Meenakshi Jerath *et al*., 2012)[64]. It has been estimated that the carbon sequestration potential of all mangroves of the globe were valued at $30.50ha/yr (Chmura *et al*. 2003)[67]. Economic value of carbon sequestration service of the mangroves of MEDA creek, Kenya was estimated at US$177/ha/yr (UoN & UNEP., 2016)[27]. The economic value of carbon sequestration from mangroves in Ngoc Hien District, Vietnam was about 325 USD/ha/year (UNEP.,2015)[50]. In southern Thailand, carbon sequestration potential of mangroves was estimated at US$100/ha/yr (Sathirathai, 1998)[48]. In Indonesia, carbon sequestration services were estimated at 945 kUSD to 1891 kUSD or 550 USD/ha to 1100 USD/ha. (Abdul Malik etal., 2015)[54]. A study assumes a carbon price of US$ 7/ tonne, and estimated the Gazi mangroves, Kenya 'carbon sequestration potential to be US$ 126 ha/ yr (Janis Hoberg., 2011)[51]. In India, Hirway and Goswami (2007)[68] assumed the carbon value as $ 150/ton C. The value of carbon sequestration provided by mangroves in India has been estimated using direct market pricing average value 1.21 billion Rs for 4,62,763 ha or 2614 Rs/ha/yr in 2013 price (Kavi Kumar et.al. 2016)[69]. Mangrove soils play an important role in the uptake of N and P (Robertson and Phillips., 1995)[70]. The waters around mangroves are generally rich in nutrients, as a result of the organic matter produced by the trees and plants themselves, and also from the sediment that is trapped around the roots. Mangroves produce about 1 kg litter/m2 annually, which forms the basis of a complex food chain and some of which is exported with the tide (Mumby *et al*., 2004)[71]. In Bhitakanika mangroves of India, the nutrient retention function was valued at US$350 /acre/year (Ruchi Badola and S A Hussain., 2003)[46]. Oyster reefs are located inside mangroves and counteract increases of nitrogen loading by promoting bacterially mediated denitrification induced by concentrated bottom deposits of feces and pseudofeces. It has been estimated that the economic value of oyster reef services in nutrient cycling was estimated at $5500 and $99,000 per hectare per year with an average of 10,325 US $/ha/yr. (Jonathan etal., 2012) [72].

3.3 Cultural services

Cultural services of mangroves include economic benefits through aesthetic, spiritual, recreational, educational, and other cultural values. Mangroves are traditionally and culturally important habitats for many coastal communities and maritime peoples (Polunin 1983)[73]. Coast communities traditionally use the mangroves for firewood, constructions, furniture, boats, fishing gear, folk medicine (e.g. bush medicine), and tannins. In addition, mangrove ecosystems are attractive for recreation purposes especially, for eco-tourists, hunters, and birdwatchers. The traditional uses of mangroves have little information since they have not been documented (Bandaranayake. W.M., 1999)[21] except for recreation and tourism. Mangroves were viewed as dangerous as they were seen to be the refuge or hiding place of 'dangerous' indigenous communities. In addition, Mangrove forests lands were used as graveyard or burial ground among coastal communities especially aboriginals (MacDonald, J.D., 1857; Wake, C.S., 1866; James, G.K., 2013)[74, 75, 76].

The mangrove species *Excoecaria agallocha* is worshipped as a 'sacred grove' in the Lord Nataraja temple in Chidambaram town. The rock carvings depicting mangrove as "Thillai" are very much present in the temple. There was a belief that a dip in the temple's pond water lined with the mangrove species cures many incurable human diseases. A group of fishermen in Andhra Pradesh, India worship a mangrove tree (*Excoecaria agallocha*) before they venture into the sea for fishing. In Kenya, Shrines built in the mangrove forests are worshipped by the local people, who believe that the spirits of the shrine will bring death to those who cut the surrounding trees. In Solomon Island, the dead bodies are disposed of and special rites are performed in the mangrove waters. Bennet and Reynolds (1993) [77] estimated the tourism value of mangroves of Sarawak mangrove reserve forest, Malaysia at US$ 424 /ha. The mangrove reserve of Ras Mohammed, Egypt was estimated at US$ 130,000/ha/year (James Spurgeon., 2002)[3]. The mangroves of Ngoc Hien District, Vietnam were estimated at 25 USD/ha/year (UNEP. 2015)[50]. The income from eco-tourism in Gazi mangroves, Kenya in 2010 was estimated at Ksh 334700/yr or Ksh 540/ha/yr, which is equivalent to US$ 6.5 ha/yr (Janis Hoberg., 2010)[51]. The above tourism estimate is very near (US$ 9.3/ha/yr) to the similar economic valuation exercise carried out in the same mangrove area by Kairo *et al*., (2009) [78]. Ecotourism value for Pitchavaram mangrove, India was estimated for Rs. 157500000 /- or Rs.143182/yr/ha. (Piyashi DebRoy and R. Jayaraman., 2012)[79]. Tourism and recreation benefit of MEDA creek, Kenya mangrove were estimated at US$155/ha/yr, whereas, in Tana creek, Kenya, it was estimated at US$84/ha/yr. (UoN & UNEP., 2016)[27]. The mangroves are valuable asset for education to students and environmental awareness to general public. The benefits derived relate to expenditures within the local and national economy (i.e. economic impact) and from the additional knowledge and enjoyment gained. It was estimated that the contribution of Gazi mangroves, Kenya to research value per year is US$ 114,000 or US$ 184.4 ha-1y-1 (Janis Hoberg., 2011)[51]. Economic value of education and research service of

MEDA creek mangroves, Kenya was estimated to be US$22/ha/yr (UoN & UNEP., 2016) [27].

3.4 Supporting service

Supporting services: ecosystem services that are necessary for the production of all other ecosystem services such as biomass production, soil formation and retention, nutrient cycling, etc (Verma etal., 2013)[44]. In this study, supporting services of mangroves are classified under two heads viz., (1) biodiversity and nursery ground support (2) nutrient and soil formation support. Mangroves are home to many uniquely adapted biodiversity. In Bintuni Bay, Indonesia, a value of $US 15 /ha/yr was estimated for biodiversity benefit from mangroves (Ruitenbeek., H.J. 1992)[28]. A similar study to value mangrove biodiversity in Bohol Marine Triangle, Philippines estimated for US$19/ha/yr (Giselle and Alan., 2007)[18]. The economic value of the biodiversity service of MEDA creek mangroves of Kenya was estimated at US$40/ha/yr (UoN & UNEP., 2016) [27]. It serves as a nursery and feeding ground for juvenile fish and prawns (Sasekumar *et al*., 1992) [80]. Extracts from different mangrove plants have been reported to possess diverse medicinal properties (FAO 1985)[81]. It has been estimated that in Indonesia, the provision of nursery ground service of mangroves were estimated for 1403 kUSD or 2292 USD/ha./ yr. (Abdul Malik etal., 2015)[54]. In Bohol Marine Triangle, Philippines, supporting nursery services of mangrove were estimated at US$243/ha/year (Giselle and Alan., 2007)[18]. The economic value of the fish breeding and nursery service in MEDA creek, Kenya mangrove ecosystem service was estimated at US$585/ha/yr, whereas, in Tana creek, Kenya, it was estimated at US$626/ha/yr. (UoN and UNEP., 2016) [27].

3.5 Economic values of India mangroves

This study has applied maximum and minimum values fixed by the studies conducted all over the world. Accordingly, the aggregated economic value of India's mangroves ranges between Rs.92662 /- / ha/yr. = US$1985.17 (minimum) and Rs. 3361144/-/ha /yr = US$ 72008.47 ha/yr (maximum). In the meta-analysis, averages of various services have been used to value total economic value per ha. /year. consequently, the average total economic benefit out of goods and services of mangroves amounts to Rs.9,58,766/- ha/yr. = US$20540.41 ha/yr. This value is very close to the similar TEV study on mangroves conducted by global meta-analysis estimate by Salem & Mercer (2012) [53] 13,07,568 Rs / ha/ yr. = UD$ 28013.07 / ha/yr. Similarly net present value of global mangroves estimated by Abdul Malik etal (2015)[54] (10,80,286 Rs/ ha/ yr. = UD$ 23143.83 ha/yr) amounts to 23,252 Rs/ha/yr. = US$ 498.15 (value converted for 2011). Also compared with Southeast Asian country (Thailand) net present value ranges from 27,400$ to 37500$/ ha/ yr as estimated by Sathirathai & Barbier (2001)[56]. Similarly the maximum value of Rs.33,61,144 /ha /yr = US$ 72008.47 ha/yr. is close to TEV study on mangroves conducted by Costanza (2014)[82]. His estimated TEV value of mangroves is Rs. 194,000 (US$ 4156.22/ha/yr). Mangrove's economic benefits through various services and functions of India are given in Table-1. Accordingly, the regulatory service contribute maximum (Avg. Rs. 602074/- / ha/yr. = US$ 12898.71/ ha/yr) followed by support service (Rs. 287401/- / ha/yr., = US$ 6157.22), provisional service (Avg.Rs. 36908 / yr/ha. = US$ 790.71/ ha/yr.) and cultural service (Avg. Rs32383 /ha/yr. = US$ 693.77/ ha/yr).

Table 1: Mangroves ecosystem service values-minimum, maximum, average, and total ha/ yr./ Rs

Services	Minimum	Maximum	Average	No. of Referenced
I. Provisioning service				49/52
Fishery	790	88042	18177	a29/32r
Aquaculture	7619	7619	7619	1
Fuel and timber	418	36518	8531	13
Fodder	929	929	929	1
Honey collection	8	511	188	3
Medicinal uses	1022	1905	1464	2
II. Regulating service				34/35
Protection function	4260	1994013	310437	18
Erosion prevention & soil accretion	15378	33126	19578	a4/5r
Water quality maintenance	12080	418372	254136	3
Carbon sequestration	116	61400	17923	9
III. Cultural service				10/11
Tourism	307	130462	27623	a7/6r
Bird nesting ground	Patch wise	Patch wise	Patch wise	1
Education	952	8567	4760	2
IV. Supporting service				8
Biodiversity & nursery ground support	929	99982	23625	6
Nutrient & soil formation support	47854	479698	263776	2
Total	92,662	33,61,144	9,58,766	101

Economic values of mangroves using global average estimate (Costanza. 2014) [82], India's mangroves total value is Rs.5062067723508 (Rs. 506206 crore)/yr. = US$10844.85)/yr. Application of the maximum value estimated by this present study for India mangroves is Rs.1879210972021(187921 crore) / yr. = US$4025.98/yr Average value estimated from this study values India's mangroves at Rs. 536044746143 (53604 crore) /yr., = US$11484114224.90/yr., Among the coastal States and UTs, West Bengal has huge area (218209 ha.) of mangroves which shares Rs. 209211573934 (20921 crore) =US$ 4482106446.37 / yr. which is 39 % of total mangroves benefit out of National Green Account. State / UTs mangroves economic share in National Green Account is given in Table 2.

Table 2: Total economic value of mangroves services in states & UTs of India Rs. / Yr.

S. No	State /State / Union Territories Union Territories	Mangroves distribution - ha	Total Economic Value of Mangroves	Total Economic Value of Mangroves US$
1.	Gujarat	142133.23	136272508720	2919474665.34
2.	Maharashtra	31724.29	30416180101	651630090.73
3.	Goa	3288.07	3152498728	67538495.15
4.	Karnataka	1646.87	1578969328	33827519.53
5.	Kerala	2111.65	2024585519	43374310.68
6.	Diu & Daman	522.18	500650163	10725827.83
7.	Tamil Nadu	11909.55	11418474666	244627091.83
8.	Andhra Pradesh	50729	48637249507	1041994596.43
9.	Odisha	26463	25371835947	543561081.81
10.	West Bengal	218209.21	209211573934	4482106446.37
11.	Pondicherry	435.96	417981288	8954746.58
12.	Andaman & Nicobar Island	69925.55	67042238243	1436299352.65
Total		559098.62	536044746143 (53604 crore)	11484114224.90

4. Conclusion

The status of mangroves has been influenced by natural processes including climate change and manmade activities. Man-made activities such as reclamation, agriculture, aquaculture, fuelwood, timber, damming, oil pollution and mining operation, etc., degrade the ecosystem function. India's mangroves provide a range of non-market as well as marketed goods and services, both on and off-site. Mangrove products and services are often undervalued or even ignored in the economy by industry and local inhabitants. Mangrove ecosystem destructions are mainly because; the conservation benefits of mangroves do not receive adequate importance and there is very little understanding of the role of mangroves in economic systems. Economic valuation of various benefits of mangroves is a useful tool to support conservation and the decisions of mangrove ecosystem management and governance. The monetary values of mangrove ecosystem goods and services shall be a tool to raise awareness and convey the (relative) importance of ecosystems and biodiversity to the general public and policymakers. This awareness shall create markets for the conservation of biodiversity and mangrove ecosystem services. In addition, the monetary values of mangrove ecosystem goods and services shall support decision-making on the allocation of resources for competing uses. Estimated values of the mangrove ecosystems allow policymakers to quantitatively assess the economic benefits and apply that to court cases to compensate and recover the ecosystem damages.

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