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REVIEW ARTICLE

# Advances in Ecosystem Services Valuation Studies in India: Learnings from a Systematic Review

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## Abstract

Ecosystem services (ES) concept has gained global momentum as they hold immense importance for human well-being. On the other hand, direct and indirect drivers of biodiversity loss have led to deterioration of ecosystem health and their capacity to deliver ecosystem services. Worldwide, ES assessments have been increasingly used by administrators to formulate sustainable and environment centric policies. Similarly, there has been continuous expansion of ES related work in India to capture the material and non-material benefits derived from diverse ecosystems in the country. In the current paper, 105 research articles/reports have been reviewed to assess the growing trajectory of ES research and also to map their methodological approaches. The lacunae in the studies and literature have been critically examined. Analysis of the study shows that ES derived from forests have been captured widely while marine ecosystems have not received appropriate scholarly attention. Similarly, dearth of studies focusing on long- and short-term implications of climate change and other environmental challenges on the ES delivery was also evident. A strong need is felt to integrate interdisciplinary approaches for holistic ES assessment. Also, future ES assessments must assimilate traditional as well as indigenous knowledge systems within ES assessment framework to ensure formulation of tangible, sustainable policies.

**Keywords** Ecosystem services · Provisioning services · Regulating services · Supporting services · Cultural services · Economic valuation

## 1 Introduction

Globally, the ecosystems are degrading at an unprecedented rate and biodiversity loss has come to be the order of the day (IPBES 2019). In this milieu, it is imperative and prudent to articulate the benefits of the ecosystems to the policy-makers, administrators and general public so that veracious management and conservation-related tools can be used to mainstream conservation in decision-making to ensure a sustainable future. The conceptual framework of ecosystem services (ES) provides that apposite pedestal to accomplish this exercise (TEEB 2010; Masiero et al. 2019). The Millennium Ecosystem Assessment (MEA) (2005) marked the watershed moment in transcending the boundaries of traditional perception regarding ecosystems and the goods and services derived from them. Ecosystems services are the benefits derived from ecosystems that are quintessentially linked to human well-being and sustenance (Constanza et al. 1997; MEA 2005; TEEB 2010). In other words, they are the goods (food, fiber, medicinal plants, genetic resources, etc.) and services (pollution control, soil formation, pollination, recreation, disease control, etc.) that are directly or indirectly allied to human welfare (Leviston et al. 2018). Humans continuously interact with ecosystems through various processes to derive these benefits (Fedele et al. 2017).

The MEA (2005) framework was laid down under four broad categories of ES: Provisioning Services (food, fiber, medicines, fresh water, etc.), Regulating Services (climate regulation, erosion control, etc.), Supporting Services (primary production, soil formation, etc.) and Cultural services (recreation, spiritual values, etc.). Holistic valuation

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approach is a prerequisite to capture and integrate the multifaceted, heterogeneous and entwined aspects of various ecosystem services (Masiero et al. 2019; Tinch et al. 2019). The conceptual framework of total economic value (TEV) is an indicative of sum total of two values- use value and non-use value. Use values can be explicit, when resources derived from ecosystems are consumed directly (direct-use value) while they can also be indirect (indirect-use value) when they are non-consumptive and non-extractive in nature and derived from some of the regulating aspects of the ecosystems such as pollution control, climate regulation etc. or recreational value of nature (e.g. tranquility of forests, hillsides). There are various methodologies to divulge and quantify the veiled and unperceived dimensions of ecosystem services (Kornatowska and Sienkiewicz 2018; Tinch et al. 2019). They range from market price-based approaches to revealed preference methods and stated preference methods (Barbier et al. 2011; TEEB 2011; UNEP 2013; Kornatowska and Sienkiewicz 2018). There are various methodologies to divulge and quantify the veiled and unperceived dimensions of ecosystem services (Tinch et al. 2019; Kornatowska and Sienkiewicz 2018). These include direct market valuation, revealed preference methods and stated preference methods. Direct market valuation methods are based on market derived data indicating cost, price and quantity of various vendible ecosystem goods and services. They can be further segregated into three types viz. Market price-based approaches, revealed preference methods and stated preference methods. The market price-based approaches which deal with market value of commodities i.e. the price on which they are traded. Cost-based approaches indicate the cost incurred if the natural ecosystem service has to be deputize with artificial ones, and production functions based approaches that uses the relationship between ecosystem service and marketable good production (TEEB 2010, 2011; UNEP 2013). Revealed preference methods are based on individual revelation of their picks or preferences, revealed preference techniques can be of two types. Travel cost method (TC) which is used to determine recreational value of the ecosystems by including amount consumers are willing to spend for accessing ecosystems/biodiversity of recreational significance. Hedonic Pricing (HP) which decomposes the values attached by consumers to the specific attributes of certain commodities, especially this method bears high application in case of determining property pricing which are located in vicinity of forests or other serene landscapes (TEEB 2011; Barbier et al. 2011). Stated preference methods are especially useful in deriving the non-use values. Surveys are extensively employed in these methods where respondents are asked to rate or rank trade-offs. They can be further subdivided into first contingent valuation (CV) in which people with the help of questionnaire and other elicitation methods are asked to state their willingness to pay (WTP) to access a particular ecosystem attribute or service or willingness to accept (WTA) the disservice. Second is Choice Modelling in which people are made to select the alternatives linked with shared aspects of ecosystem services under evaluation. Third and last is Group valuation that involves integration of premeditated processes to find out value pluralism, non-human values etc. (TEEB 2010; Masiero et al. 2019; Barbier et al. 2011).

Multiple studies have eulogized mainstreaming ecosystem services valuation or assessment in conservation policies and evidence based decision-making (Daily et al. 2009; Martinez-Harms et al. 2015). Integration of ecosystem services in decision-making can act as a potent tool for framing conservation and restoration strategies and in accomplishing the sustainable development goals (SDGs) 2015 by 2030 (Huq 2015; Dangles and Casas 2019). Carbon sequestration, habitat for biodiversity and provisioning of food and water are pivotal ecosystem services that can contribute noticeably towards attaining seven or even more SDGs—viz. SDG 1(No Poverty), SDG 2 (Zero Hunger), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), SDG 14 (Life Below Water) and SDG 15 (Life on Land) (Woods et al. 2018). Moreover, sustainable utilization of ES can have positive implications on all the SDGs, as all of them are directly or indirectly linked with each other (Yin et al. 2021). Conservation, preservation, restoration of forests and investments in ecological infrastructure (EI) can help nations to ensure sustained flow of ES at regional and national scale and also expedite the localisation of SDGs (Dandabathula et al. 2021; Hawkens et al. 2021).

India is one of the mega-diverse nations of the world with more than 1.3 billion population (17.7% of the world) and 7–8% of global biodiversity with 3 important biodiversity hotspots (MoEFCC and GIZ 2014). The direct and indirect drivers of biodiversity and ecosystem loss have resulted in the degradation of land causing 557, 666 $km^2$ to become wasteland while 305 species of vertebrate species are threatened (NSO EnviStats-India 2020). In wake of increased environmental challenges, it is being increasingly realized to accentuate on the ES assessment studies in the country. Also, it is important to analyze how ES assessment and changes at global scale correlates with the ES literature at national and regional scale. The present study was designed to review the qualitative and quantitative ES assessment studies taken up in India during the period 2010–2021. Our work was focused on three research questions: (1) Which type of ecosystem services are well researched as compared to others? (2) What is the regional distribution of ES-based literature in the country? (3) What are the type of ecosystems that are well covered in ES literature? Further, the gaps are identified especially that are there at regional scale and also in ES mapping strategies.

## 2 Materials and Methodology

In the present study we have reviewed journals and publications published in between the period of 2010–2021. An extensive search was carried out on digital repositories-Google Scholar and Scopus (accessed between March, 27th and May, 28th 2022) using keywords- "Ecosystems Services AND India" followed by "Provisioning Ecosystem Services AND India", "Regulating Ecosystem Services AND India", "Supporting Ecosystem Services AND India" and "Cultural Ecosystem Services AND India". In case of regulating and cultural services, individual ecosystem services such as "pollination"; "air pollution control"; "ecotourism", "sacred groves", etc. were also used as keywords to get specific studies for these services. We also further reviewed relevant review papers and list of references they have used in their publication. We cross-checked these references and obtained some quantitative ES research work. Grey literature was also sought from Google (http://www.google.com/). PRISMA guidelines were followed for the selection and exclusion of literature (Page et al. 2020).

The design of the research methodology used is detailed out in Fig. 1. In the primary stage of data collection, 186 studies were derived. As the concept of ecosystem services is broad, multi-faceted, and multi-dimensional, a large number of duplicates along with studies from neighbouring counties viz. Nepal, Bangladesh, Pakistan, etc. were also derived in the search results as they share common physiographic features and transboundary locations in the region such as Himalayas, Sundarbans, etc. with India. We restricted ourselves to the geographical boundaries of India and thus studies exclusive to neighbouring countries along with the duplicates ($n = 26$) were excluded. In the second step, studies ($n = 160$) were thoroughly scrutinized and those with a clear methodological approach and added significantly towards ES valuation literature were chosen while opinion papers and subjective studies were further removed. This yielded around 127 studies. In the final stage of scrutiny, we fine-tuned our research to suit our review framework and gave preference to quantitative studies focussing on emerging trends, novel technology usage including GIS and models, landscape-based ES studies, comparative analysis, etc. Some important case studies and reports were also included in the current framework as they contain substantial, in-depth ES-related research work carried out in the country that bears considerable relevance in policy-making process. Few review papers carrying pan country analysis of important studies

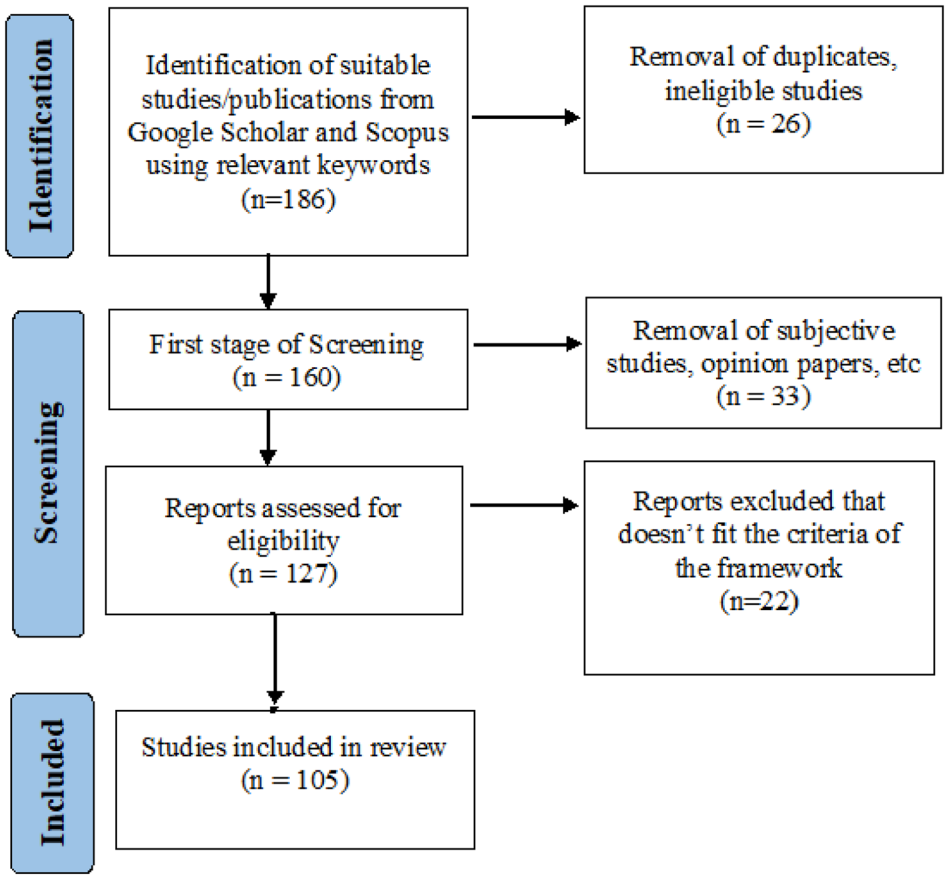


**Fig. 1** Flow chart of the methodology used for identification of studies for systematic review

or under-researched vital ecosystems (for e.g.—wetlands) have also been given space in this paper. On the basis of this, we further narrowed down our study to 105 suitable research papers and other relevant published material specific to India (Supplementary File 1).

For simplified and systematic classification of multiple studies, we arranged the material in accordance to the broader ES categories as specified by Millennium Ecosystem Assessment (MEA 2005), viz. Provisioning Services, Regulating Services, Supporting Services and Cultural Services. We also linked the publications to their sources to find out the number of publications from Central and State Universities, reputed scientific and academic organizations of India including deemed and autonomous institutes; along with those sourced from other institutes (including private universities, non-profit organizations, foreign universities, etc.). The studies were segregated on a regional basis.

## 3 Results and Discussions

### 3.1 Ecosystem Service Valuation Approaches in Indian Context

In India, scholarly interest is steadily growing towards valuation of ecosystem services for various ecosystems in the country with a focus on forests, grasslands, mangroves, wetlands, coral reefs among others. On the basis of ecosystem-wise studies available in the country, valuation studies are majorly focused on forest ecosystem services followed by wetlands (Verma 2018). A slew of methodologies is incorporated to derive the ecosystem service values in the country such as Contingent Valuation approach (Sinha and Mishra 2015; Mohamed et al. 2016; Venkatachalam and Jayanthi 2016; Kadaverugu et al. 2021), Benefit Transfer method (Singh and Thadani 2013; Bahuguna and Bisht 2013; Chaudhry et al. 2016), Travel cost method (Gopal and Marothia 2016; Dixit et al. 2016) and Market price method (Jain et al. 2011; Ramachandra et al. 2011; Murali et al. 2017). There is also a growing trend of incorporation of modelling tools in ecosystem evaluation studies. Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) has been used widely by Verma et al. (2019) in their iconic study related to valuation of ecosystem services derived from tiger reserves in the country. The use of GIS in evaluation process has also been undertaken in several recent works estimating the changes in the ecosystem services at regional level (Das and Das 2019; Sannigrahi et al. 2019; Tripathi et al. 2019; Talukdar et al. 2020; Sharma et al. 2020, 2021; Shakya et al. 2021).

Total economic value (TEV) of the entire Indian region or important landscapes have been investigated in detail by several authors. Kubiszewski et al. (2016) reported that the total value of ecosystem services for India in 2011 was USD $1.8 trillion/year. Studies are also available that find TEV at regional and state level. In a study by Ghosh et al. (2016), the value of nine ecosystem services evaluated from Terai Arc landscape was estimated to be ₹390 billion (US$6 billion) in 2015–2016. The maintenance cost of the Jim Corbett Tiger Reserve was estimated US $2,153,174.3 per year by Badola et al. (2010). Similarly, TEV studies on the forest of the state of Arunachal Pradesh by Kumar and Chaudhary (2015) has estimated the value at ₹ 1518 billion (USD 19,583,186.70) per year.

### 3.2 Provisioning Services

Provisioning services indicate the direct, tangible benefits/resources derived/obtained from the ecosystems for human welfare which can be either directly consumed or traded as a commodity in the markets (Dhyani and Dhyani 2016). They can be easily monetized and range from food, fodder, fuel wood, Non timber forest products (NTFPs) such as honey, tendu leaves, medicinal plants to thatching material, lac, nuts, gums, resins, fibers, genetic resources, to freshwater (MEA 2005; TEEB 2011). Provisioning ecosystem services from various ecosystems along with comparative analytical studies in their subtypes have been widely covered in literary works (Subba et al. 2015; Uniyal and Rawat 2018; Pala et al. 2019; Sachin et al. 2020; Sinclair et al. 2021). Joshi and Negi (2011) in a comparative study carried out in Western Himalayas on ecosystem services provided by Oak and Pine forests reported that oak forests provide provisioning services worth of ₹5676 (73.22 USD) per person per year in the form of fodder and fuel wood which is greater than compared to pine forests i.e. ₹4640 (59.85 USD) per person per year. Similarly, Naudiyal and Schmerbeck (2018) studied the relationship between provisional ecosystem services and five different vegetation types found in Central Himalayas.

Non timber forest products or NTFPs provisions significantly towards food security and income generation among the underprivileged socio-economic groups in developing countries especially India (Lakerveld et al. 2015). This relationship has been analyzed by Islam and Quli (2017) which reported that the average income earned per household per year from NTFPs in villages located in Bundu Block, Ranchi district, Jharkhand stands at ₹4791.16 (61.36 USD). Similarly, Kumar (2015) has reported that 42 species of plants are used as NTFPs while their collection helps in generation of 31.67% employment in the Dang District, Gujarat. Dash et al. (2016) reported that NTFP collection plays a substantial role in the income of tribal communities present inside and in the periphery region of Simlipal Tiger Reserve, Odisha.

Agriculture plays a vital role in the subsistence of the Indian economy. The role of ecosystem services derived

from rice farms in Odisha was studied by Nayak et al. (2019). Rice farms provide provisioning services in form of food and by-products such as straw, supporting services in form of soil formation, hydrological flow and nutrient cycling, and regulating services (bio-pest control, carbon flow, nitrogen fixation) which ranged from ₹90,533 to ₹1,23,441 (1159.37–1580.79 USD) per hectare per year. Collection of leaf litter for forest dependent agriculture in Western Himalayas was quantified by Dhyani (2018).

Fodder production by forest and grasslands along with agro-ecosystems in the country ensured supplementary income of farmers through livestock rearing. Evidently, multiple studies have focused on quantitative assessment of fodder production (Dhyani et al. 2011; Pandey 2011), fodder species and fodder consumption patterns (Dhyani and Dhyani 2016) and overall fodder-related benefits derived by local communities living in the vicinity of protected forested areas (Ninan and Kontoleon 2016; Ramachandra et al. 2017).

Fuel wood is a dominant energy source, especially in rural settings in India. A large section of urban poor and those living in rural and tribal areas heavily rely upon fuel wood and other forms of biomass for meeting their energy needs. Most fuelwood-related studies ranged from investigation of fuelwood consumption patterns and suitable fuelwood species identification to the potential impact of biomass extraction on forest and grassland ecosystems. Kumar and Kumar (2016) investigated the altitudinal variations in fuelwood consumption patterns in the Himalayas while Hussain et al. (2017) investigated the impact of fuelwood extraction on forests by Van Gujjar community in Uttarakhand.

In case of freshwater provisioning, we came across studies focusing on calculations of overall drinking water or fresh water supply benefits derived from ecosystems to spatial variations in water yielding capacity of ecosystems at regional and subregional level (Khan et al. 2019). Bhoj wetland in Bhopal is known to yield drinking water supply benefits worth of ₹15,50,58,920 (1,985,414.73 USD) (Verma and Negandhi 2011). A spatial study from Periyar Tiger Reserve established that the evergreen forests found in the reserve have maximum water yielding capacity followed by semi-evergreen forests while plantations have the least water yielding capacity. The same study revealed that total estimated water yielding capacity of Periyar Tiger Reserve stands at 2.33E + 09 $m^3$ per year which was calculated using InVEST (Chacko et al. 2019).

### 3.3 Regulating Services

Regulating services depict the benefits ensued by the regulation of one or more ecosystem processes (MEA 2005). Robust, fully functional ecosystems tend to influence and standardize air, water, soil and climate and provides a myriad of non-material benefits in form of air purification, flood control carbon sequestration, storm protection, water purification, pollination etc. (Science for Environmental Policy 2015). The present study has revealed that alike the global scenario, there is dearth of studies exclusively focusing on regulating services in India with major focus on air pollution regulation and carbon sequestration while pollination and storm protection has not been appropriately captured (Pannure 2016).

The problem of air pollution is aggravating all over the world with an intensification of scenario in India. Several Indian cities are ranked among top most polluted cities of the world. Pollution bears a significant effect on the health of city residents (Manojkumar and Srimuruganandam 2021). The topic of air pollution and its disease burden aspects along with policy implications are extensively researched (Patankar and Trivedi 2011; Maji et al. 2017). The pollution regulating aspect of ecosystems is also catching attention of researchers. Several studies are now available that provide substantial evidence to underline the role of vegetation in ameliorating air quality in urban settings (Kumar et al. 2019; Banerjee et al. 2021). In one such study, Chaturvedi et al. (2013) has reported that out of five zones of the Nagpur city, the two zones having less greenery have more concentration of $SO_2$, $NO_2$ and RSPM as compared to other three zones which have more greenery. Urban trees play a major role in entrapping dust and controlling particulate pollution (Vailshery et al. 2013). *Ficus religiosa*, *Azadirachta indica* and *Pongamia glabra* tree species are found to be highly tolerant to air pollution and heavy metals concentration in industrial areas of Bengaluru city (Begum and Harikrishna 2010).

India is highly vulnerable to floods, especially during the four months of monsoon from June to September. India's 12% land area which is equivalent to 40 million hectares is prone to flooding (Alam and Muzzammil 2011). According to Tripathi (2015) the economic loss incurred by floods was nearly 2% of the country's GDP from the period of 2005–2015 and around 71,426 people lost their lives. Vegetation present in floodplains and watersheds plays a critical role in flood regulation by limiting the speed of water and increasing its percolation (Crossman et al. 2019). The total benefit derived from natural hazard mitigation and flood prevention from the forests of Uttara Kannada is ₹217,872 (2790.15 USD) per hectare (Ramachandra et al. 2017). On the other hand, it was found that deforestation increases chance of flooding because of reduction in moisture holding capacity of soil along with soil organic content (Chomitz 2007).

In the wake of unrestrained human activities, the concentration of GHGs especially that of $CO_2$ is on rise in the atmosphere (Bruhwiler et al. 2021). In terrestrial ecosystems, vegetation and soil plays a pivotal role in capturing and storing carbon (Singh et al. 2015). In Indian

context, the current study has revealed that there is plenty of scholarly evidence to illustrate the role of forests in carbon sequestration. According to India's State of Forest Report by FSI (2021), the estimated carbon stock in India's forests stands out at 7204 million tonnes million tons, out of which the largest share comes from soil organic carbon (56.18%). This is followed by the share from above-ground biomass, below-ground biomass, litter and deadwood, which stands at 32.50%, 10.07, 1.50%, and 0.67% respectively. Salunkhe et al. (2014) in a study in Madhya Pradesh, have reported that the tropical deciduous forest found in four districts of Damoh, Raisen, Katni and Sagar have above-ground biomass ranging between 3.99 and 53.90 tons per hectare while carbon stock in between 1.89 to 25.6 tons per hectare. Dhyani and Joshi (2018) reported total tree carbon density for Central India that varied from 48.97 to 214.97 Mg C per hectare. This study has also found the process of carbon sequestration has also been well covered in case of agroforestry systems (Tanwar et al. 2019) and urban landscapes (Chavan and Rasal 2010; Suryawanshi et al. 2014; Lahoti et al. 2020; Dhyani et al. 2021). The last three studies have used allometric method and non-destructive sampling to estimate the value of carbon sequestration among various species of trees growing in cities.

Pollination is an imperative ecosystem service that is vital for food production and thus helps in sustaining food security in humans (IPBES 2016). An estimated 85% of all flowering species found globally are pollinated by biotic agents (Ollerton et al. 2011). More than 80 percent of the crop plants found in India entirely depend or derive benefit from insect-assisted pollination (Thakur 2012). The estimated value from insect pollination of major fruit species grown in India is ₹17,095.45 crores (2,146,333,283.29 USD) while that from vegetables, oilseeds and condiments & spices is ₹19,498.20 crores (2,447,765,259.56 USD), ₹43,993.08 crores (5,522,600,418.07 USD) and ₹ 10,109.43 crores (1,269,136,803.73 USD) respectively (Chaudhary and Chand 2017).

Globally, a drastic decrease in the population of pollinators especially honey bees has become a major point of concern in recent years (IPBES 2016). Fruits, vegetables and stimulants are more susceptible to a reduction in pollinator population as compared to other crops (Gallai et al. 2009). In India, there is a lack of awareness among small-scale farmers regarding the value of pollination services for the crops cultivated by them secondly, there is also lack of studies to ascertain the effect of bee decline on agriculture production in the country (Pannure 2016). However, a lack of enough literary evidence to cause-effect relationship related to decline of bees and other pollinators on crops and ecosystems in India was clearly observed during the review process.

Wetlands are the most productive ecosystems of the Earth that provides various ecological services such as ground water recharge, flood control, sustenance of biodiversity, water purification etc. (TEEB 2010; Kumar et al. 2017; Kumari et al. 2020). Wetlands play an essential role in maintaining water quality and act as kidneys of the natural world (Padmavathi and Srinu 2017; Mandal et al. 2020). During review, we observed some relevant studies focusing on the role played by wetlands in water purification. The riparian vegetation of the wetlands helps in reducing the nutrient load from flowing water and help in cleaning it (Verhoeven et al. 2006; Bassi et al. 2014). Everard et al. (2019) used Rapid Assessment of Wetland Ecosystem Services (RAWES) approach to review 36 ecosystem services including water purification provided by East Kolkata Wetland. The role of Himalayan forests in providing various ecosystem serviced water purification was also investigated by Joshi and Joshi (2019).

### 3.4 Supporting Services

Supporting services are quintessential for the delivery of the other ecosystem services however; their impact on human well-being can be indirect or gets manifested over a long period on the time scale (MEA 2005). The major supporting services include primary production, soil formation, nutrient cycling and production of oxygen. In context of India, the total Net Primary Productivity (NPP) is estimated at 1.42 Peta grams of carbon for the period of 1981–2006 while Net Ecosystem Productivity (NEP) for the same period is 20 Tera grams of carbon. Strong seasonal and inter-annual variations were observed in NPP and NEP budget values for the country (Nayak et al. 2016). In a region-specific study, Leaf Area Index (LAI) and meteorological variables have been employed in Kaziranga National Park, Assam to derive the Gross Primary Productivity (GPP) which is estimated to be at 2.11 kg C $m^{-2}$ per year (Burman et al. 2017).

Nutrient cycling, soil formation and maintenance of soil fertility play an integral part in ecosystem processes mainly ecological succession that is essential for the ecosystem stability. In managed ecosystems, human interference extensively influences the soil nutrient regime. In a major assessment on ecosystem services provided by the rice fields in Eastern India, it was found that the mean economic value of soil formation was $₹0.20 \times 10^{-5}$ per hectare per year while the value for nitrogen fixation stands at ₹402.50 (5.053 USD) per hectare per year (Nayak et al. 2019). In studies we observed that nutrient cycling ecosystem services in agri-ecosystems (agricultural fields and agroforestry) have got strong wide scholarly coverage (Singh et al. 2010; Sharma and Rana 2014; Gogoi et al. 2021). Das and Das (2010) discussed the role of traditional home gardens in nutrient cycling in Barak Valley of Assam. In another study carried

out on the bamboo plantation established on three major ravine systems of India, it has been observed that bamboo plantations bring in the soil carbon enhancement benefits in the range of ₹365.90 (4.68 USD) and ₹2927.24 (37.48 USD) per ton of carbon while value of nutrient saved in the soil was estimated at ₹2126–5555 (27.22–71.12 USD) per hectare (Pande et al. 2012).

### 3.5 Cultural Services

Cultural services indicate the non-material benefits derived from ecosystems which have been the cornerstone of human culture, society, knowledge, philosophy and heritage (MEA 2005). Human interactions with ecosystems have manifested in the form of various cultural practices that are essentially linked to human well-being. Moreover, ecosystems have played an inspirational role in science and arts and also provide infinite prospects for environmental education and nature-centric research (de Groot et al. 2002). It recognizes the role of culture in outlining the relationship between man and nature. In a study by Dasgupta et al. (2021a, b) six non-material landscape values (i.e. spiritual, recreational, heritage, aesthetic, educational, and negative values) were mapped in a total of 65 locations, depicting all the six landscape values in Sundarbans delta. We observed that cultural ecosystem studies in Indian context are dominated by studies investigating the recreational value, ecotourism and traditional livelihoods based on forests, however, only some recent studies have focused on role of green spaces on well-being of urban residents (Gandherva et al. 2019). Place-based attachment and psychological benefits from natural spaces is another area of cultural services that was explored by Sen and Suchhait (2021). This was seriously studied during COVID-19 when stay at home enhanced psychological issues and nature provided benefits to handle the stress (Basu et al. 2021). Additionally, it was found that there exists substantial empirical evidence to underline the role of sacred groves in providing cultural and other ecosystem services along with the conservation of biodiversity (Trivedi et al. 2018).

India is a land of cultural heterogeneity, where veneration for nature and biodiversity conservation is intrinsically rooted within the traditional ethos. We found that there is consistent piece of literary work available to correlate the intricacies linked with traditional forest-based livelihoods in India and their role in conservation of forest resources including biodiversity. In a study on Adi tribe from Arunachal Pradesh, it was revealed that through their local specific survival practices and community approaches such as managing community forest resources through institution called 'Kebang' and gender-based harvest strategies, Adi tribals played a pivotal role in sustainable management and conservation of forests resources (Singh et al. 2018). Exploration of Indigenous and Local Knowledge and Practices (ILKPs) in Traditional Jhum Cultivation in Zunheboto District of Nagaland, India helped understand that ILKPs hold strong potential for the local implementation of several Sustainable Development Goals (SDGs), particularly, SDG-1(No poverty), SDG-2 (Zero hunger), and SDG-15 (Life on land) (Dasgupta et al. 2021a, b). Likewise, Baiga tribe of Madhya Pradesh with their extensive indigenous knowledge and rituals play integral role in biodiversity conservation and forest resource management (Singh and Deewan 2018). Extensive literary evidence is available for other traditional groups as well such as the Gond tribe (Heda 2012), Aka tribe (Nimasow et al. 2011), Tangkhul community (Shimrah et al. 2018), Soliga and Kattunayaka tribal (Balasubramanian and Sangha 2021) etc.

There is wide coverage of recreational value from both natural and human dominated ecosystems in the country. Using travel cost method, the estimated recreational value of Rajaji National Park was assessed to be ₹24,86,36,900 (3,333,251 USD) in 2011 (Gupta et al. 2015). Similar method was used to find recreational value of other national parks, tiger reserves, biological parks etc. in the country including Mahatma Gandhi Marine National Park, Andaman & Nicobar Islands—₹1646 (22.07 USD) per hectare per year (Chaudhry and Tewari 2016), Kaziranga National Park, Assam—₹21 million per year (Verma et al. 2015), Biological Park, Itanagar—₹38,758,105 (519,595.03 USD) per hectare per year (Kumar et al. 2015) and Dachigam National Park—₹33,88,91,932 (4,543,219.13 USD) per year (Bhat and Bhatt 2018). There is a growing interest to study the role of recreational value of urban green spaces. Urban green spaces in India provide both tangible and intangible benefits to the residents ranging from ecological benefits to health and social benefits. In Nagpur city, the average per capita availability of recreational urban green spaces to the city dwellers stands at 3.65 $m^2$, however, the value varies in different zones of the city (Lahoti et al 2019). Vellayani Lake located in the Thiruvananthapuram district of Kerala state estimated recreational value of ₹55.83 lakh (74,846.26 USD) per year (Vijayan and Job 2015). In a study regarding the emotional perception of visitors towards the experience of nature in an urban park located in Jammu, 39% of respondents answered happiness closely followed by "freedom" and "closer to nature" (Duggal and Chib 2012).

Ecotourism is nature-based tourism that incorporates social, environmental, cultural and economic sustainability criteria (UNEP 2002). It sustains the well-being of local people along with ensuring conservation of biodiversity. The concept of ecotourism has gained momentum in India in last few decades (Chaudhary et al. 2022). There are several scholarly investigations that ratify immense economic and social benefits of eco-tourism in the country (Goodwin and Chaudhury 2017). In a questionnaire-based survey carried

out in famous hill station of Ooty in Tamil Nadu, 95% of respondents opined that tourism in the region be conducted along with ecotourism so that local communities stay benefitted (Veeramani et al. 2018). Correspondingly, the people living in the periphery villages of the Kaziranga National Park perceived positively towards ecotourism (Das and Hussain 2016).

The concept of sacred groves is innately entrenched in Indian traditional belief system. They are the patches of vegetation that are dedicated to the local folk deities or ancestral spirits and generally range from 5 to 50 hectares in size (Amirthalingam 2016). They provide myriad of ecosystem services from conservation of biodiversity harbouring mainly endemic and endangered species to microclimate regulation, soil conservation, watershed management etc. (Blicharska 2013; Laxmi 2014; Rawat 2014; Agarwal 2016; Singh et al. 2017; Gadgil et al. 2021; Jana et al. 2021). In a study from sacred groves located in Central Western Ghats, 144 species of trees of which 15 are endemic have been reported along with the highest value of carbon sequestration (196.43 tons per hectare) reported among the forests in India (Devakumar et al. 2018). Similarly, a biodiversity assessment technique has been designed for the study of biodiversity in 13 sacred groves of Pune district in Maharashtra (Trivedi et al. 2018). Attrition and disintegration of traditional tenets is proving to be a major roadblock for the existence and sustainable management of sacred groves in India (Kandari et al. 2014; Chaudhry and Murtem 2015). Ballullaya et al. 2019 studied the perception of local people towards conservation of sacred groves located in Kasargod and Kodagu areas of Kerala.

### 3.6 Critical analysis and Gap Identification

Present review identifies and underlines the major scholastic works in the field of ecosystem services in India published between 2010 and 2021. The year-wise analysis of publications between 2010 and 2021 is shown in Fig. 2. The major chunk of studies is are those which have focused on all the four ecosystem services (37 studies) with more tilt towards provisioning services (Fig. 3). In terms of individual ecosystem services, cultural ecosystem services (30 studies) have major percentage followed by studies exclusively focusing on provisioning services (17 studies), regulating services (14 studies), while least number of papers were found solely focusing on supporting services (7 studies). In terms of individual ecosystems (Fig. 4), ES derived from natural forests have been widely studied (45 studies), followed by

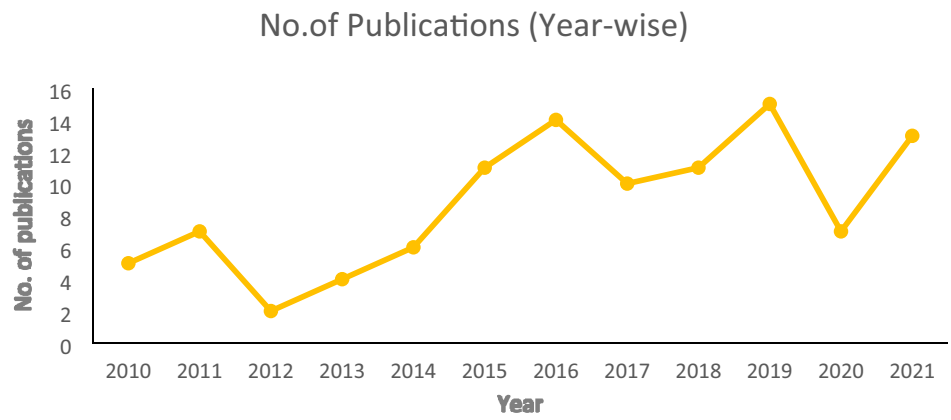


**Fig. 2** ES studies published between 2010 and 2021 ($n = 105$)

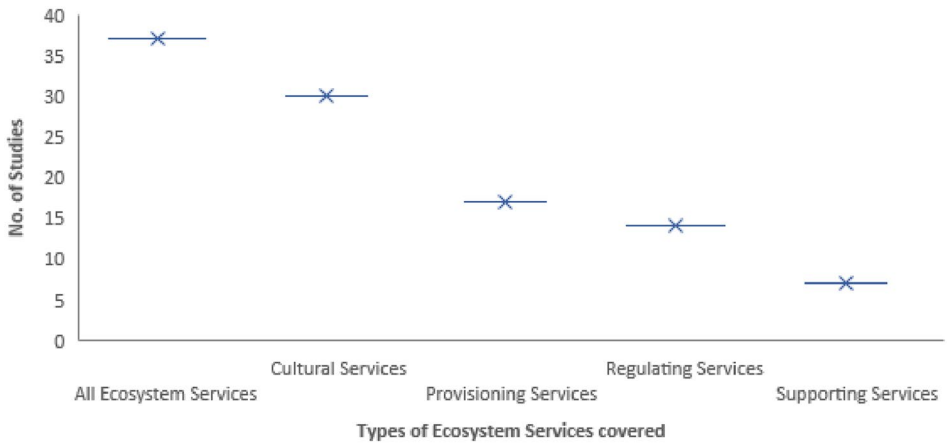


**Fig. 3** Distribution of studies used in present review according to ES types

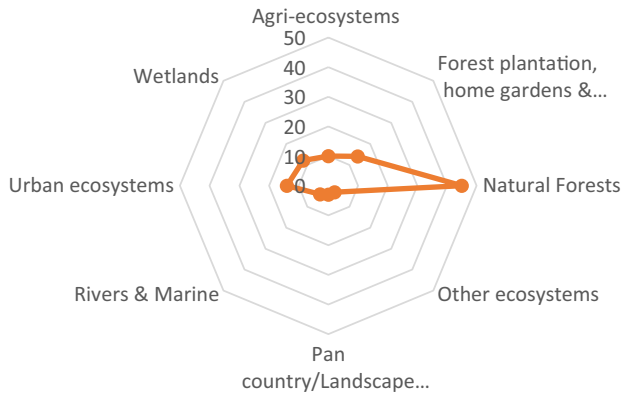


**Fig. 4** Distribution of ES studies according to ecosystem types

forest plantations, sacred groves and home gardens (14 studies), urban ecosystems (14 studies), wetlands (12 studies), agri-ecosystems (10 studies). This is in agreement with the review work undertaken by Verma (2018). Only three relevant studies focused on evaluation of ES at pan country and landscape level and four studies were found related to rivers and marine ecosystems.

At regional level, 18 studies from Eastern India (Fig. 5) show that this region has got extensive ES literature coverage closely followed by Western Himalayas and Southern India with 16 studies each. The North-eastern states with 13 studies have also been fairly covered in ES assessment literature. Further, region-wise analysis shows that there are 12 Pan-India and miscellaneous studies followed by Northern India (11 studies), Central India (10 studies) and Western India (8 studies) regions. Only one suitable ES assessment study was found covering the Andaman and Nicobar Islands, which underpins the urgency to carry out extensive ES assessment in this region.

The source-wise analysis of ES literature in the country (Fig. 6), maximum studies have been sourced from Central and State government research institutes/departments/

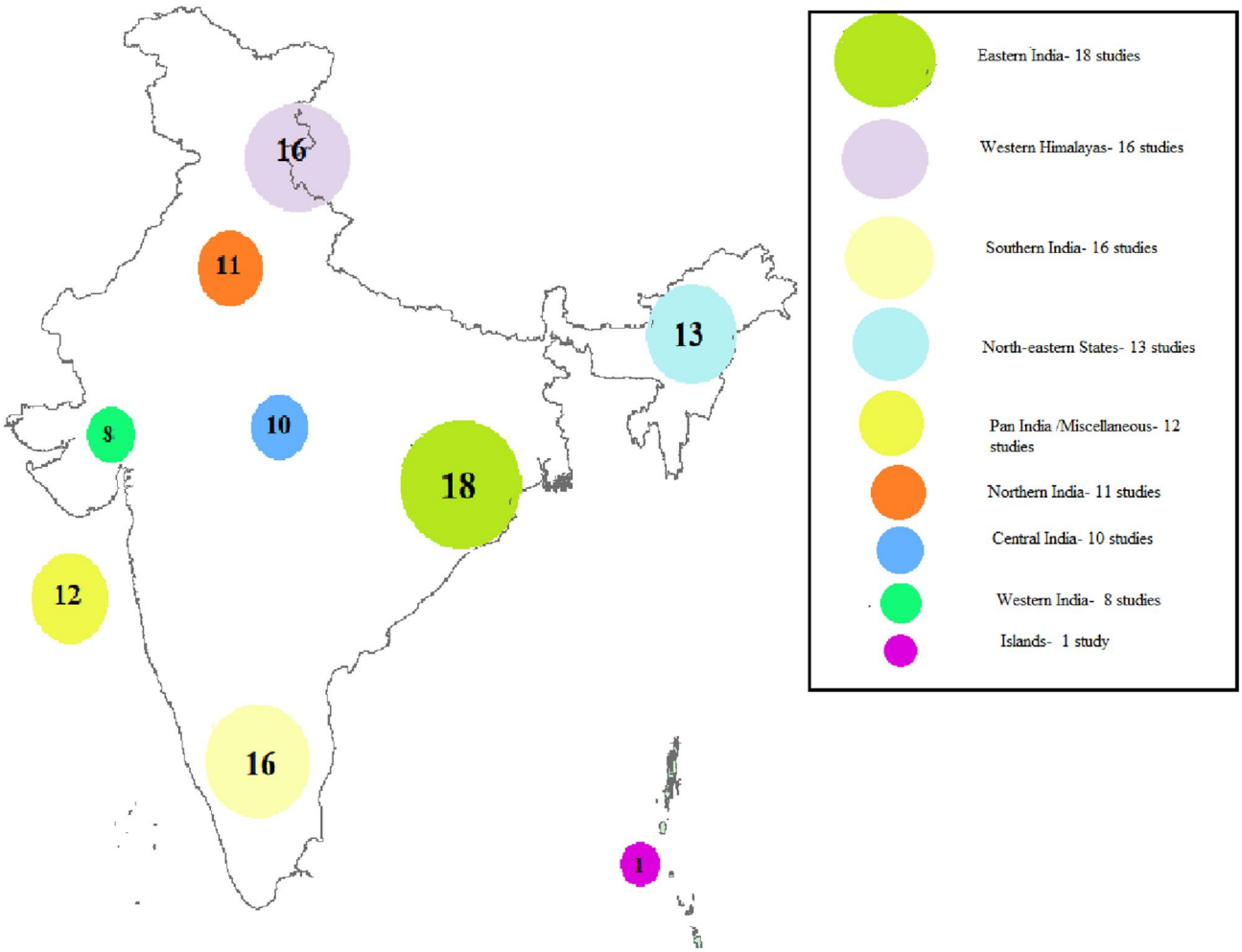


**Fig. 5** Map of India showing region-wise number and distribution of ES Studies used in the current review

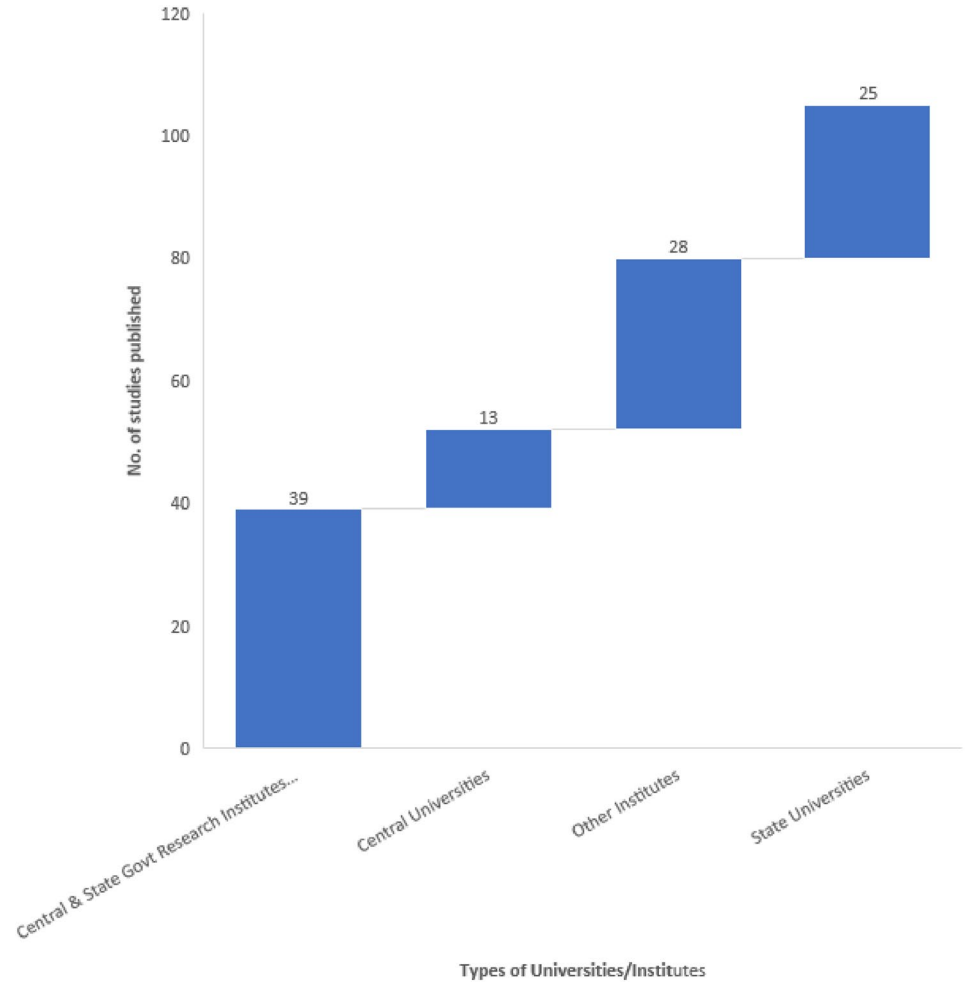


**Fig. 6** Institutional sources of various ES assessment studies conducted in India (2010–2021)

agencies (39 studies). Some of the prominent institutes among these are Indian Institute of Forest Management (IIFM), CSIR—National Environmental Engineering Research Institute (NEERI), Forest Research Institute (FRI), Wildlife Institute of India (WII), Indian Institute of Technology (IITs), Indian Institute of Science (IISc) among others. This was followed by 28 studies from other institutes that include private universities, foreign research institutes and NGOs. Some examples of these include Nature Conservation Foundation, TERI University, Cranfield University, Ashoka Trust for Research in Ecology and the Environment, United Nations University Institute for the Advanced Study of Sustainability, World Wildlife Fund, etc. This was followed by state universities with 25 studies while there were 13 studies that were contributed by central universities. University of Gour Banga, Malda, University of Burdwan, Guru Gobind Singh Indraprastha University are some of the state universities while Jawaharlal Nehru University and Hemvati Nandan Bahuguna Garhwal University are examples of Central Universities that contributed towards ES literature in the country.

The scenario of ES-related research work is quite promising in India but it still lags behind other countries. A recent bibliometric analysis by Wang et al. (2021) critically examined the productivity of countries from 1900 to 2018 in terms of ES literature. The USA had the maximum number of publications at 592 and was followed by the UK (313 publications), Australia (199 publications), Germany (187 publications) and China (164 publications).

Present review also underlines the dearth of risk assessment studies in Indian context. Although, there is evidence that Indian researchers are now focusing on the impact of climate change on the ecosystem services however, this needs to be further buttressed. Some recent works such as by Sannigrahi et al. (2020) predicted the impact of climate change and land-use dynamics on the Sundarbans Biosphere Reserve while Momblanch et al. (2020) studied the impact of climate change on freshwater ecosystem services of Sutlej Beas Basin. There is need to intensify the research related to the effect of climate change on the ecosystem services derived from other ecosystems as well especially urban ecosystems and agri-ecosystems.

Lack of interdisciplinary research is also evident. These lacunae must be addressed with multi-model integration in research work where economic and environmental information should be integrated. Similarly, ES tradeoffs must be incorporated in spatial planning studies. Studies with critical analysis of impact of loss of biodiversity on ecosystem services needs to be integrated and given priority. Moreover, there is growing need to focus on specific studies related to regulating and supporting ecosystem services in the country.

Besides this, there is crucial need to critically investigate the linkage between cultural ecosystem services and human well-being beyond the aspects of recreation. Islands-based indigenous tribes and their cultural associations with the biodiversity and forests and ecosystem services derived from the biodiversity-rich forests of these islands have to be empirically investigated. The cultural manifestations of ongoing development projects and the resultant decrease in forest cover of fragile ecosystems such as that in Himalayas, Western Ghats, Coastal zones, Island mangroves and northeast India needs to be empirically investigated. It is equally important to amalgamate them in policy formulations and the decision-making process.

Our review work provides a new perspective regarding evolution of ES literature in the country in terms of latest trends, knowledge base and methodological approaches. Similarly, linking of ES studies to their institutional sources has highlighted the ES research epicenters in India and recognized their role in investigating the multi-faceted dimensions of ES valuation. Moreover, this review will also help the researchers and academicians in quantifying the under-researched ecosystems in the country.

## 4 Conclusion

There are enhanced efforts to capture the economic value of various ecosystems services in India. In this paper we reviewed 105 ES assessment studies, traced their sources, type of ES, ecosystems and region they have covered along with gaps. There exists a geographical bias with some regions have got wide coverage in ES literature while others haven't. Similar trend can be seen in the case of ecosystems where ES derived from grasslands and marine ecosystems along with semi-arid and arid regions of the country are still under-researched. Hence, there also is need for efforts to scale up the integration of these values in decision-making process, however, focus is required on the trade-offs when ecosystems are degenerated by unfettered human activities. Empirical studies that highlight the impact of infrastructure building and urbanization on ecosystem services in the country may further facilitate eco-centric decision-making process. At the same time, we feel the growing need to integrate strong modelling tools within ES assessment framework so that future changes can be predicted that can help in scenario building and scenario based proactive planning with a priority on sensitive areas. India with its rich biological diversity; in this context, desires to uptake more studies that explore the relationship between biodiversity loss and its impact on ecosystem services according to regional basis. We propose evidence-based studies quantifying the effect of environmental pressures such as invasive species, pollution and climate change on the ecosystem services in the region. It is equally important to commingle indigenous and traditional knowledge base and related cultural aspects in assessment framework which overwhelmingly rely on recreational and tourism-associated values and benefits. Moreover, it is important that financial support and special incentive packages must be provided for ES research at regional and national level in the country to strengthen the empirical research evidences related to biodiversity and ecosystem characteristics and loss of ES. We strongly recommend the adoption of a multidisciplinary and transdisciplinary approach that can strengthen evidence-based strategies in the formulation of conservation and restoration policies for the management of various diverse ecosystems across the country. More investments must be placed on ecological infrastructure while strategizing the policies for smart-city projects to ensure both short as well as long term urban sustainability.

Present review does have some limitations especially as it is based on critical analysis of limited ES studies that were easily accessible. On the other hand, this paper should be considered as a step forward in understand the methodological approaches, regional dimensions and sources of ES valuation studies available in India. It also highlights the major gaps that needs to be addressed by efficient discussions and brainstormings to improve the ecosystem valuation research atmosphere in the country.

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## Declarations

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