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RESEARCH PAPER

Economic Valuation of Ecosystem Services in Indian Agricultural Landscape: A Meta-analysis

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ABSTRACT

India's economy highly relies on its agricultural sector to ensure food and livelihood security for its ever-going population. However, demographic, economic, social, and climatic changes exert pressure on natural resources. Ecosystem services play a pivotal role in adaptation and mitigating the climate change impacts. In this study, we examined the potential drivers and economic value of agro-ecosystem services in India by using a meta-analysis framework. A total of 817 data estimates were considered for the study. The results indicated that provisioning services contributed highest to the agro-ecosystem services with an estimated average value of ₹ 22306 ha^{-1} $year^{-1}$, followed by regulating services (₹ 9021 ha^{-1} $year^{-1}$) and supporting services (₹ 4613 $ha^{-1}year^{-1}$). Also, we found that land productivity and crop diversification have a positive effect on the value of agro-ecosystem services while population density had a negative effect. Further, the study revealed that cultural services have been least explored in agro-ecosystems nevertheless their actual value is much higher than the estimated one. We conclude that efforts should be diverted towards the promotion of crop diversification practices and providing incentives in the form of payment for ecosystem services to enhance agro-ecosystem services and mitigate climate change's impact on agriculture.

HIGHLIGHTS

- The valuation of agro-ecosystem services in India started only in 2017.
- Provisioning services contributed the highest to the values of agro-ecosystem services while benefit transfer methods were the most widely used for the valuation studies.
- Factors such as ecosystem service type, valuation methods, land productivity, crop diversification, and population density affected the value of agro-ecosystem services.
- Robust methodologies need to be developed for such valuation studies and the focus should be on the non-marketed services from agriculture, especially the cultural services which are the most ignored ones.

Keywords: Ecosystem Services, Ecosystem Valuation, Agriculture, India, Meta-Analysis

Ecosystems encompass a myriad of interconnected processes and functions vital for the well-being, sustenance, and livelihood of human beings (Sannigrahi *et al.* 2021). These services, known as ecosystem services (Costanza *et al.* 1997), are essential for our survival. Despite a few efforts since 1997, the concept of ecosystem services gained momentum with the Millennium Ecosystem Assessment (MEA) Report in 2005.

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The services are broadly categorized into four types viz. provisioning, regulating, cultural, and supporting services. Moreover, it is important to understand that "ecosystems" are multifunctional and multidimensional systems. It is very difficult to comprehend the exact and complex distinction between the direct and indirect contributions to human well-being (Costanza *et al.* 2017).

Agricultural ecosystems, commonly known as agroecosystems, foster multiple functions for human well-being, viz., production of different food and non-food products, providing rural employment, and most importantly supporting biodiversity and ecosystem services (Plieninger *et al.* 2019). In the realm of agriculture, however, humans play a profound role in shaping these systems. Agricultural ecosystems are intricate entities spanning various climate zones, influenced by factors such as temperature, rainfall, and other variables that directly or indirectly impact crop growth. The interactions within these ecosystems extend to the diverse flora and fauna inhabiting the soil, including growth-promoting microbiota (Yadav *et al.* 2021). However, agriculture serves a dual purpose by both providing and relying on ecosystem services (Garbach *et al.* 2014). Yet, the pervasive spectre of climate change looms large and is significantly affecting the agricultural ecosystem's capacity to deliver these essential services. India's economy highly relies on its agricultural sector to ensure food and livelihood security for its ever-going population (Kumara *et al.* 2023). However, demographic, economic, social, and climatic changes, are all exerting increasing pressure on natural resources, through a seemingly ever-growing global demand for energy, food, and water that threatens the well-being of the ecosystems we rely upon.

More than 40% of the Earth's terrestrial surface is occupied by croplands and pasturelands (Foley *et al.* 2011), with a cropland area of 1,100-1,900 Mha around the year 2020 (Tubiello *et al.* 2023). Even though agricultural expansion and intensification result in a loss of biodiversity (Tscharntke *et al.* 2012), there is an estimated cropland expansion rate of 2-10% (Tubiello *et al.* 2023). Intensification of agriculture may improve the supply of some provisioning services like food and fiber (Rey Benayas and Bullock, 2012), nevertheless, it affects the supply of other ecosystem services viz supporting, regulating, and cultural services (Bullock *et al.* 2011; Pilgrim *et al.* 2010). It has been found that over the last five decades, there has been a significant reduction in the supply of 15-24 ecosystem services that include pollination and biological pest control (MEA, 2005). Sustainable solutions are needed to enhance multiple ecosystem services and minimize the trade-offs between food security and environmental well-being (Lee *et al.* 2019).

The key to shifting towards sustainable development lies in the strategic decisions that we shall take for natural resources, which need to be better valued and more responsibly managed. Ecosystem services play an important role in strategies for tackling climate change: mitigation and adaptation (Turner *et al.* 2009). Given that ecosystems can provide mitigation and adaptation services at the same time, policies and local initiatives related to ecosystem management can integrate both climate change strategies and avoid trade-offs between them (Locatelli B., 2016).

As most of the regulating, supporting, and cultural ecosystem services from agriculture are invisible, there is a policy risk of assuming their value as zero due to complete unawareness of their real value. Furthermore, as a large portion of the agricultural landscapes are degraded, some studies have tried to identify if ecological restoration can enhance the supply of ecosystem services from agriculture (Aviron *et al.* 2011; 2008, Wang *et al.* 2011). Nevertheless, most of the studies are limited to specific ecosystems or a particular type of ecosystem service, putting forth a major question if the restoration of agroecosystems is feasible on a larger scale (Barral *et al.* 2015). Placing an economic value on the indirect and non-marketed services from agroecosystems may prove to be a powerful policy tool that makes the invisible benefits visible to society (Lara-Pulido *et al.* 2018). There has been significant progress in the economic valuation of ecosystem services in recent years (TEEB, 2010b). Moreover, as per Costanza & Kubiszewski, 2012, more than 2400 papers were generated on ecosystem services between 1990 and 2011.

India, with its agrarian economy, is abundantly blessed with natural ecosystems that largely remain unexplored and unassessed (Rath *et al.* 2023). Paradoxically, the stewards of nature, our farmers, often labor unrecognized and unrewarded for their contributions in securing these agricultural services. Agricultural ecosystems are a source of enormous invaluable goods and services in India, that are essential both for human well-being as well as livelihood security (Power, 2010; Swinton *et al.* 2007). Nevertheless, not many studies have been attempted to assess agro-ecosystem services in monetary terms. It was only in 2017 that the first study on assigning values to agro-ecosystem services was taken up in India. Given the huge uncertainties involved, it may never be possible to evaluate the agroecosystem services accurately. However, understanding the gaps and knowing the initial estimates of the limited studies done in this field will enable us to prioritize the need for additional research, especially in the specific areas that have not yet been explored (Costanza *et al.* 2017).

Therefore, this study has attempted to fill this knowledge gap by conducting a meta-analysis on the valuation of ecosystem services from the agricultural landscape in India based on published literature. We aim to identify the potential factors affecting the supply of different ecosystem services from agriculture and thereby suggest suitable recommendations for sustainable agricultural management and payment schemes for agroecosystem services.

MATERIALS AND METHODS

The current study followed a meta-analysis that quantitatively analyses a large amount of existing information for rightful decision-making and policy formulation (Taye *et al.* 2021). Furthermore, meta-analysis is a powerful tool for integrating a range of data on different valuation methods including those based on market data and those derived by other (non-market and shadow market) valuation techniques (Nelson and Kennedy, 2009), thereby playing an important role in building a more comprehensive body of knowledge (Chiabai *et al.* 2011).

Systematic literature review

We conducted a quantitative review of results from published studies and sought available literature related to the economic valuation of agroecosystem services in India. A list of 58 articles was generated before the year 2023 using the keywords "ecosystem service valuation", "India", "agriculture", "agricultural landscape", "agro-ecosystem services", and "assessment" in the database of Google Scholar, Krishi Kosh and Web of Science.

From these papers, each title and abstract were examined to determine whether the literature met the following criteria for our meta-analysis: (i) reported quantifiable results (ii) listed a study location in India (iii) belonged to a purely agricultural landscape or not. Even though we prioritized the studies from academic journals for our analysis, we also included some academic theses, reports, and policy documents. After the preliminary screening, 20 papers were identified and fully reviewed to determine whether they contained relevant and usable data on the agricultural ecosystem. The papers that did not have relevant data on ecosystem services values, review papers, and other ecosystems were excluded. The detailed selection process has been described in the Prisma framework in Fig. 1.

The final database included 13 papers from 2017-2023, of which 10 were from academic journals and 1 from reports, seminar proceedings, and academic thesis each. Furthermore, all the studies were split into multiple entries since they reported different years of studies and multiple locations across India.

We then recorded the geographic locations (coordinates) of the study area (if not mentioned in the study, then Google Earth was used to identify the same), study year (publication year if year of study was not mentioned), ecosystem service values (ESV), methods of valuation, units of the ESV, type of ecosystem service, type of valuation method, population and population density of the state where the study was conducted, GDP of the state, net sown area, extent of crop diversification and journal type.

The studies recorded values both in US dollars and in rupees. We converted all the values to ₹/ha/year using the exchange rate of the particular year of study. Furthermore, we converted all the estimated values to a constant price for the year 2022 by multiplying with the adjusted GDP deflator for each year.

Based on the identified studies, we gathered 817 economic values for different agroecosystem goods

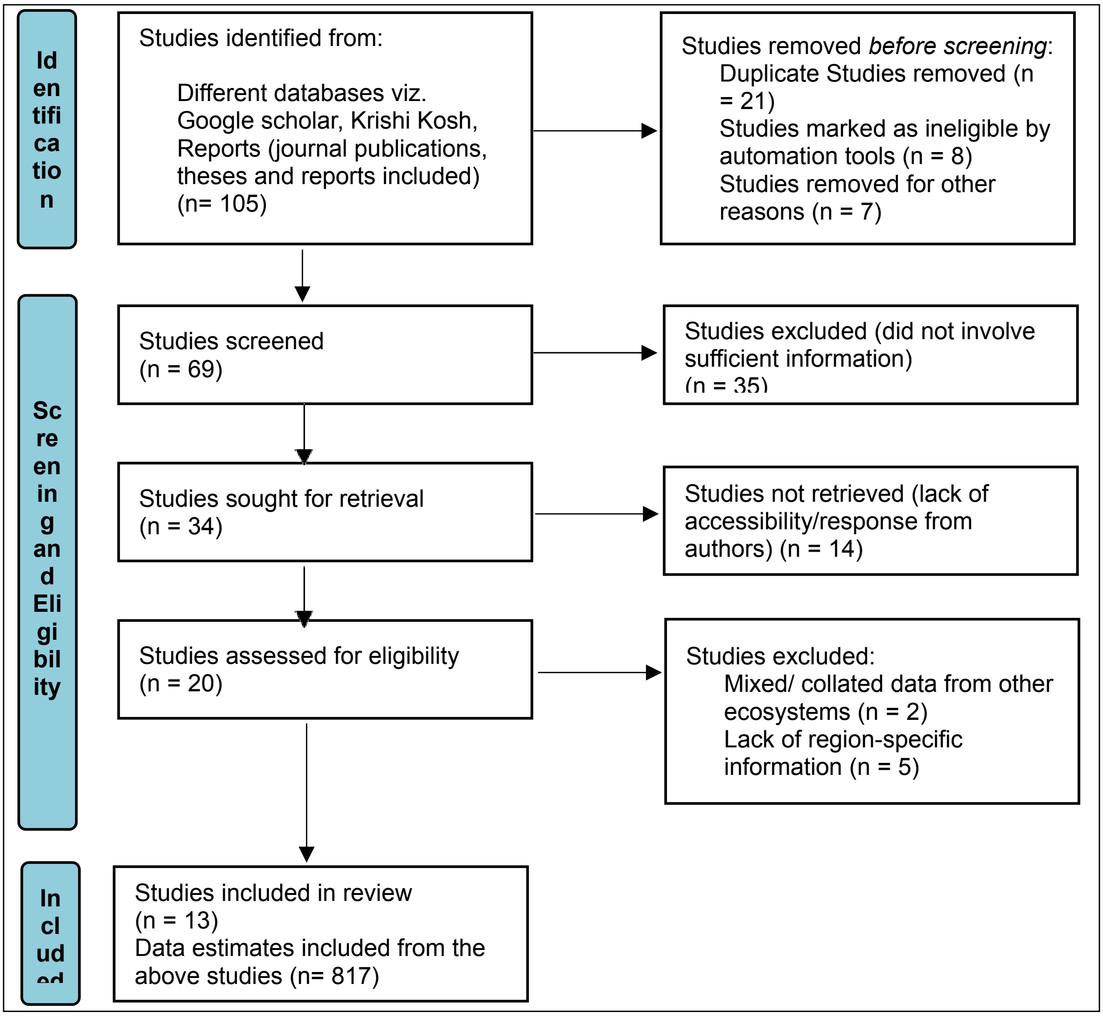

Fig. 1: PRISMA Framework adopted in the Systematic Review

and services in India. On average we recorded 62.85 values per study. The two most common methods of valuation were found to be the benefit transfer method (60.09%) and the direct market valuation method (26.93%).

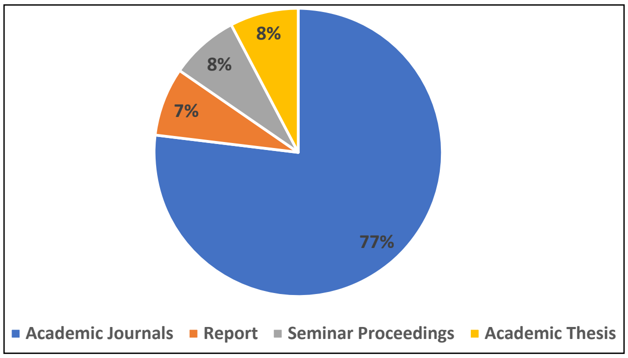

Fig. 2: Types of Studies included in the review

Further, each value was classified according to the ecosystem service function and the type of ecosystem service as per the MEA, 2005 classification system and the framework established by Costanza *et al.* in 2017. First, we included the publication characteristics (data type, source, scale of study, location, year), ecosystem types, and categories. In the second stage, we prepared a coded database and included other parameters that could probably explain the economic estimates of the ecosystem services. Based on other similar studies (Quintas-Soriano *et al.* 2016; Eric *et al.* 2022), we specified some explanatory variables [GDP, population density, land diversity, valuation technique (direct market-based methods, revealed preference methods, stated preference methods, benefit transfer methods, others), ecosystem service categories (provisioning, regulating, supporting and cultural)] that could determine that variation in the monetary values of the agroecosystem services.

Empirical model

Meta-analysis involves applying regression analysis to a pool of comparable empirical estimates (Nelson and Kennedy 2009; Richardson *et al.* 2015). In this study, we have conducted a meta-regression analysis of evidence from previously published studies on our selected topic and the reasons behind the variations in their estimates. First, we identified the different parameters (explanatory variables) to frame the model: (i) type of ecosystem services (ii) methods of valuation (iii) population density of the study area (iv) diversification in agriculture (v) land productivity (vi) journal type. Here we have considered the individual effects (Ghermandi *et al.* 2008; Brander *et al.* 2013) of the attributes of the ecosystem service values across the Indian agricultural landscape. We used Akaike's Information Criteria (AIC) and Bayesian Information Criteria (BIC) to select the best model (Burnham and Anderson, 2002).

All the estimates were converted into log to frame a linear model (log-log model):

$$ln\,(y) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \mu$$

where, y = agroecosystem service value, a = constant, b_i = co-efficient, X_1 = Regulating ecosystem service, X_2 = Supporting ecosystem service, X_3 = Cultural ecosystem service, X_4 = Revealed preference method, X_5 = Other methods, X_6 = Stated preference method, X_7 = Population density, X_8 = Land productivity, X_9 = Crop diversification, X_{10} = Journal type and μ = vector of residuals.

The type of ecosystem services, methods of valuation, and journal type were categorical variables while population density, land productivity, and crop diversification were taken as continuous variables. Provisioning service and direct market valuation were the reference categories for the ecosystem service type and valuation methods respectively. The final set of data for our econometric model included 817 observations that had complete information for all the variables. The summary statistics are presented in Table 1. We also tested and checked for the normality of the dependent variable and found that the skewness and kurtosis were consistent with a normal distribution. Fig. 3 presents the histogram and kernel density to show the graphical distribution of the dependent variable.

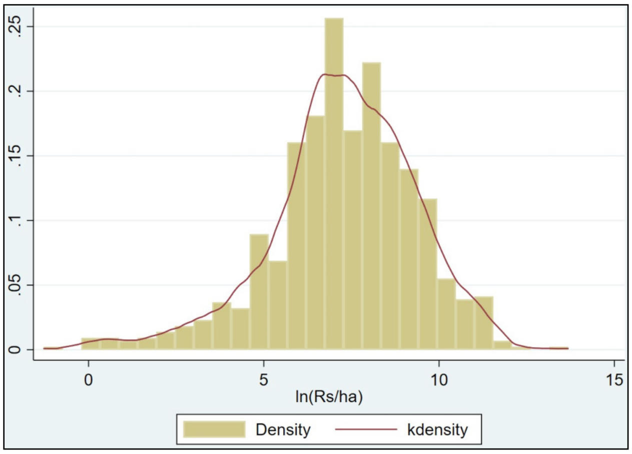

Fig. 3: Histogram and kernel density of *ln*(*y*)

Table 1: Summary Statistics of observations included in regression

Parameters	Variable Description	Mean	Standard Deviation	Minimum	Maximum	Count
Provisioning	Categorical/ dummy variable (1=yes; 0=no)	0.27	0.44	0.00	1.00	817.00
Regulating	Categorical/ dummy variable (1=yes; 0=no)	0.45	0.50	0.00	1.00	817.00
Supporting	Categorical/ dummy variable (1=yes; 0=no)	0.17	0.37	0.00	1.00	817.00
Cultural	Categorical/ dummy variable (1=yes; 0=no)	0.11	0.31	0.00	1.00	817.00
Direct market	Categorical/ dummy variable (1=yes; 0=no)	0.27	0.44	0.00	1.00	817.00
Revealed preference	Categorical/ dummy variable (1=yes; 0=no)	0.04	0.20	0.00	1.00	817.00
Benefit transfer	Categorical/ dummy variable (1=yes; 0=no)	0.60	0.49	0.00	1.00	817.00
Other	Categorical/ dummy variable (1=yes; 0=no)	0.08	0.28	0.00	1.00	817.00
Stated preference	Categorical/ dummy variable (1=yes; 0=no)	0.00	0.07	0.00	1.00	817.00
Population density	Continuous variable	327.93	95.62	56.00	860.00	817.00
Land productivity	Continuous variable	1.06	0.18	0.94	1.71	817.00
Diversification	Continuous variable	0.78	0.17	0.20	0.88	817.00
Journal type	Categorical/ dummy variable (1=SCI; 0=non-SCI)	0.35	0.48	0.00	1.00	817.00

Furthermore, we also categorized the ecosystem service values as per the ecosystem service type and estimated the average value along with the upper and lower bounds of the values.

RESULTS

Overview of economic valuation studies

The general descriptive analysis revealed that more than half of the economic value estimates (54.67%) were derived from both primary and secondary data. Estimates from purely primary data (7.94 %) were much less than those derived from secondary data (37.99 %). The location of the studies conducted in the Indian agroecosystem was not evenly distributed. Most of the studies were from 3 states viz. Karnataka, Kerela, and Odisha. The location of the agricultural ecosystem studies is shown in Fig. 4.

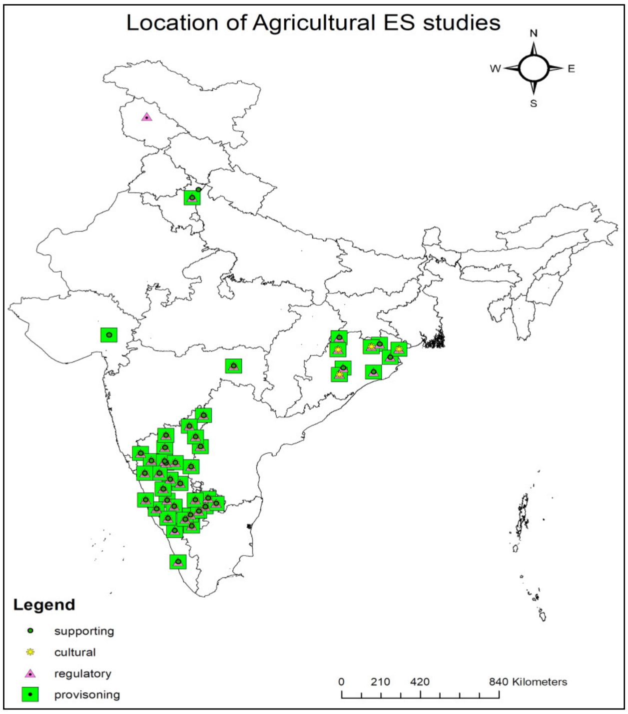

Fig. 4: Location of Agroecosystem Valuation Studies across India

The scale of study involved local, district, state, and national level studies. It was clear from the observations that local (4.73 %), state (7.57 %), and national (3.67 %) included very few estimates while district-level studies (84.02 %) contributed the maximum to the economic estimates of agroecosystem services in India. It was interesting to see that valuation studies in the Indian agroecosystem are a very recent intervention in the field of research. It was not until 2017 that the first quantification study was taken up by Pathak *et al.* (2017) on ecosystem services from wheat. However, we cannot rule out the fact that many reviews had been attempted earlier. Despite much effort, agroecosystem services have not been quantified evenly across the Indian landscape. It was only in 2022 that the United Nations conducted a state-level estimation of the agroecosystem services in Karnataka state over two different periods viz. 2005 and 2019. Furthermore, most of the studies concentrated on the estimation of provisioning ecosystem services that had a direct market value. While regulating services did gradually gain momentum in the valuation studies, supporting and cultural agroecosystem services have not been explored much. The different studies under each ecosystem service type are shown in Fig. 5.

We also observed a significant bias in the valuation methods used in the study. Most of the studies followed the benefit transfer method (51.12 %) for quantifying the agroecosystem services. The direct market valuation method (32.07 %) was the second most widely used method that was mainly followed for valuing the provisioning services. While revealed preference and stated preference methods were the least used methods in the identified studies, some economic models were however followed widely in the report by the United Nations for the state of Karnataka (Ramachandra *et al.* 2023). Fig. 6 narrates the trend in the use of different valuation methods from 2017-2023.

Despite the uneven distribution of the studies across the country, it was observed that regulating services were the most widely studied services in agricultural landscapes apart from provisioning services. Carbon sequestration, as a supporting service, was found to be widely valued both at local and national scales. Not many attempts were made to value the cultural services of agriculture. Some of the very few ecosystem functions from cultural services included recreation, tourism, aesthetic value, and inspiration for art and culture. Interestingly many studies had clearly stated their limitations and lack of sufficient information for taking up cultural service valuation in agroecosystems (Nayak *et al.* 2019; Rath *et al.* 2023). The detailed list of services identified in the study is given in Table 2.

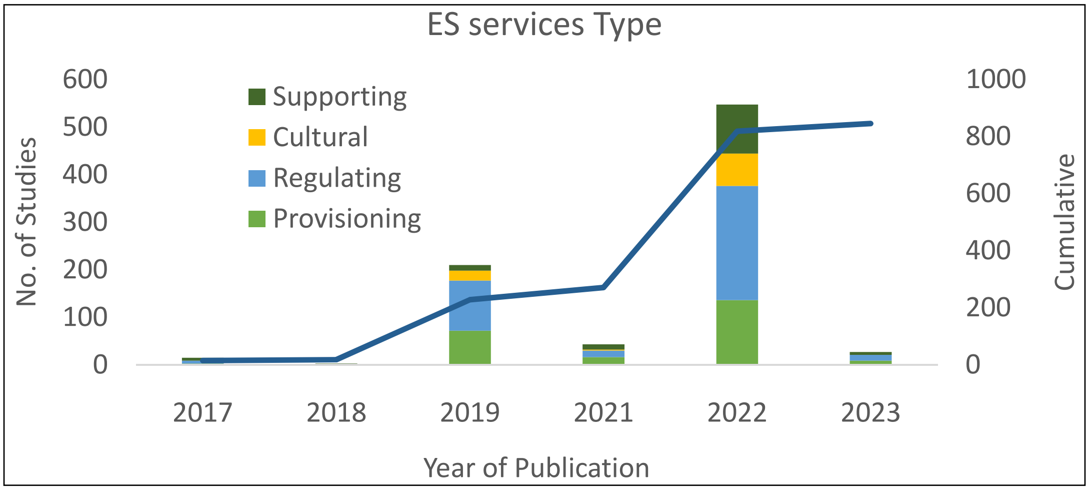

Fig. 5: Number of Studies across Different Ecosystem Service Types

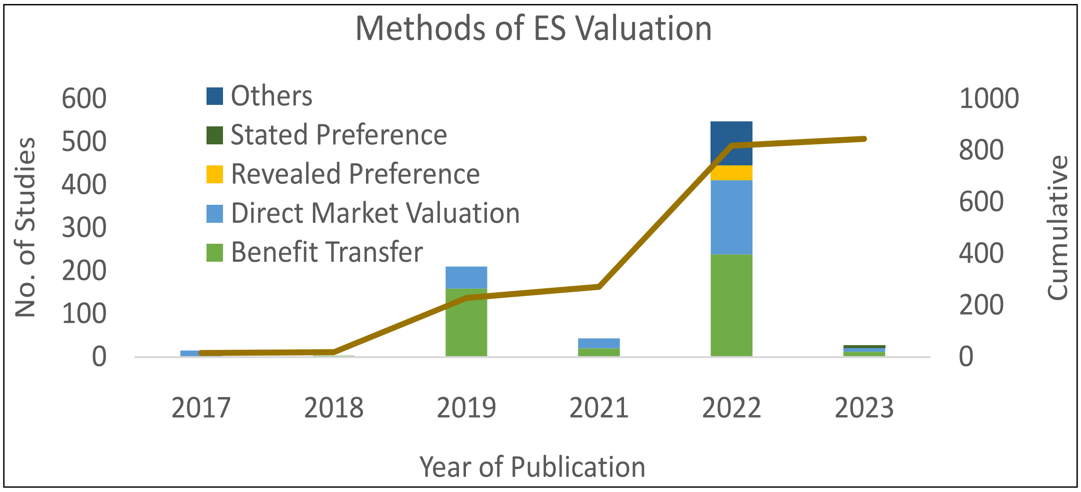

Fig. 6: The trend in the use of different valuation methods

Table 2: Different Ecosystem Services identified in the study

Provisioning Services	**Regulating Services**	**Cultural Service**	**Supporting Services**
Food	Soil retention	Recreation and tourism	Soil carbon
Raw materials	Water augmentation	Inspiration for culture, art, and design	Soil nutrients
Timber/ wood/ fuel wood	Soil formation	Aesthetic value	Carbon sequestration
Straw	Water holding capacity/ Water infiltration		Micronutrients (Iron, Zinc)
Non-timber forest products (bamboo)	Flood mitigation		Nitrogen fixation
By products	Groundwater recharge		Mineralization of soil nutrients
Playground	Soil erosion prevention		Biodiversity maintenance
Fodder/ fibre	GHGs emission		Hydrological flow
Genetic diversity	Biocontrol of pest		
Water supply	Soil fertility		

Table 3: Economic values of Agroecosystem services in India (₹/ha/year)

	N	Mean Value	Standard Deviation	Upper bound	Lower bound
Provisioning service	220	22306.14	29310.04	26200.71	18411.57
Regulating services	371	9020.66	62870.29	15439.10	2602.22
Supporting Services	135	4612.87	7782.62	5937.66	3288.08
Cultural services	91	3640.84	9331.36	5584.19	1697.49

We identified the number of economic estimates under each ecosystem service type and found out the average value of the agroecosystem services. All the values were adjusted to the year 2022 and were converted into ₹/ha/year. Agriculture being a commercial landscape is contributed highest by the provisioning of services like food and raw materials. Most of these services have a direct market value that makes their quantification convenient. Regulating services were the second most quantified agroecosystem service with an average value of ₹ 9020.66 per hectare per year. Although agriculture is highly dependent on supporting services and has many cultural services associated with it, the quantification of these services does not show promising outputs. Supporting and cultural services have an average value of ₹ 4612.87 and ₹ 3640.84 per hectare per year. The summary statistics of different types of ecosystem services derived from the study are given in Table 3.

We should not rule out the fact that these estimations are based on the average values and do not necessarily represent all the agroecosystems and services across the Indian agricultural landscape. Moreover, site-specific and region-specific studies are necessary to determine an accurate value for all the non-marketed services viz, regulating, supporting, and cultural services. Nevertheless, our estimates may help in decision-making or further estimation of specific agroecosystem services in the future.

Factors affecting the economic values of agroecosystem services

We followed a mixed effect model to find out the factors affecting the values of agroecosystem services in India. Since agricultural ecosystems deliver a major amount of marketable products, provisioning services and direct market valuation were taken as the reference categories and the effects of other variables were observed on the value of agroecosystem services. Table 4 shows the factors that affect the values of agroecosystem services from the different studies that were identified before.

Table 4: Parameter estimates of mixed model for Agroecosystem services

ln (₹/ha)	Coefficient	Standard Error
Constant	-6.027	4.152
Ecosystem Services: Provisioning[1]		
Regulating	-1.663***	0.218
Supporting	-1.723***	0.225
Cultural	-1.054***	0.312
Valuation Method: Direct Market[2]		
Revealed	-0.143	0.455
Benefit transfer	**0.397***	0.212
Stated Preference	1.106	1.064
Other	**1.067*****	0.328
Population Density	-0.00343**	0.00163
Land Productivity	9.761***	2.864
Diversification	7.090***	2.137
Journal Type	-1.288**	0.530
n	817	
AIC	3405.381	
BIC	3471.26	
Log-likelihood	-1688.6906	

Note: ****, ** & * indicate 0.001, 0.01 & 0.05 level of significance, respectively.*

[1,2]: These are the reference categories

Provisioning services contributed the highest to the values of agroecosystem services as compared to the other ecosystem service types. Nevertheless, regulating, supporting, and cultural services have significantly impacted the value of agroecosystem services across the country. Revealed preference and stated preference methods did not affect the ecosystem services values significantly while benefit transfer methods and economic models (like the Invest model) had considerable effects on them when compared with the direct market valuation method. The population density had a significant but negative effect on the agroecosystem services. This indicates that the greater the population pressure, the lesser the delivery of ecosystem services from agriculture. This could be attributed to the over-exploitation of the agricultural landscape for better yield that however reduces the other non-marketable services. On the other hand, land productivity and crop diversification have highly positive and significant impacts on the ecosystem services from agriculture. Furthermore, the publication (journal) type was divided into Science Citation Index (SCI) and non-SCI. Reports, thesis, and seminar proceedings were categorized into non-SCI and the journal papers were kept under SCI. The estimates from the non-SCI publications showed a significant impact on the agroecosystem service values. This could be attributed to the fact that the majority of the estimates were from the UN report on the Karnataka state.

DISCUSSION

The present study has provided a comprehensive review of the estimation of economic values from agroecosystems of India. A similar temporal trend in the publications was found at the international level by Groot *et al.* 2012 and Quintas-Soriano *et al.* 2016. Most of the studies used both primary and secondary data as their source of information. Moreover, coming to the scale of the study, very few studies were found at the national scale, indicating that it is difficult to perform assessment studies at a large scale due to variability in the agricultural landscapes. Also, the majority of the studies used benefit transfer methods (Fre´ Nicholas *et al.* 2014) for their valuation owing to a lack of adequate information and data.

In terms of the number of studies in agroecosystems of India, our observations were consistent with the findings of Chopra *et al.* 2022. Both studies found that there are significantly fewer studies attempted in the estimation of agroecosystem services in India. This could be due to the highly interdependent nature of agroecosystems that makes their quantification less accurate and difficult. Our study even emphasizes the fact that the current studies are not representative of the diverse agroecology of India. Furthermore, the studies are very localized and are often restricted to similar kinds of agroecosystem services. Despite the identification of gaps in studies related to supporting and cultural services, none of the studies developed a concrete framework or attempted to value these services robustly. This necessitates the urgency to take up valuation studies in cultural and supporting types of services from agriculture that contribute the highest to the sustenance of agroecology.

Another important finding of our study is the value of regulating services. Regulating services plays a very important role in sustaining the agroecosystems. However, a lack of awareness of their inherent economic values, often makes the agroecosystems vulnerable to unsustainable practices that decrease the services derived from agricultural landscapes. If the conservators and providers of the regulatory services are not incentivized for the benefits they render, more agroecosystems will likely be degraded ultimately affecting the economic activities. Coming to the valuation methods, the most common method was direct market valuation which was predominantly used for provisioning services due to its direct market benefits (Scholte *et al.* 2015) followed by benefit transfer methods that were most used for regulating and supporting services.

The results of the mean economic values were congruent with those of De Groot *et al.* (2012). The provisioning services had the highest mean economic value with the highest contribution from food. While climate regulation, gas regulation, and soil supporting services contributed highly within the regulating and supporting services, recreation and tourism were the main functions that comprised the value of cultural agroecosystem services. This could be due to the rising importance of eco-tourism. However, we cannot rule out the fact that in a country like India, spirituality is very much associated with agriculture. The cultural service related to spirituality has not yet been explored and needs further attention. Furthermore, the values of cultural services were difficult to quantify due to their association with non-use values and the requirement to be measured by stated preference methods that are difficult to implement evenly.

To our knowledge, no national-level studies exist that have analyzed and identified the overall gaps and areas of study under agroecosystem service valuation. Some meta-analyses have however been attempted but they are very much region and ecosystem-service-specific (Kumara *et al.* 2023; Meena *et al.* 2022). We recognize that our findings are an imperfect approximation of the agroecosystem service values in India. This could be attributed to the very few and uneven distribution of studies across the country. Furthermore, one of the major challenges in quantifying the mean economic values was to homogenize all the studies with different scopes, methods, values, and areas of agroecosystems. Also, many studies had incomplete information that made the validation of data difficult. Some studies had aggregated data that included many ecosystems or ecosystem services together. Extracting data from such studies was also one of the major challenges in this study. Nevertheless, this study can prove to be a strong base for taking up valuation studies in the agroecosystems of India and framing effective policy for the sustainability of the agroecosystems.

CONCLUSIONS AND POLICY RECOMMENDATIONS

We conclude that even though the majority of the Indian population live in rural areas and depend on agriculture for their livelihood, agroecosystem services have not been explored and valued rightly as of now. More studies need to be conducted to understand and assess the real and inherent value of agroecosystem services to follow sustainable agricultural practices. The promotion of crop diversification represents a win-win strategy to enhance agroecosystem services and mitigate climate change's impact on agriculture. Also, the study highlights the urgent need to develop tools for estimating the ecosystem services from agriculture rather than relying on the benefit-transfer method from other studies. Supporting and cultural services should be valued efficiently for realizing the extensive benefits derived from the agroecosystems. In a country like India where most of the farmers are small and marginal, valuing agroecosystems may bring in a positive externality through the creation of payments for ecosystem services schemes. This will solve the dual purpose of food security and livelihood security by incentivizing farmers to adopt eco-friendly and conservation-centric agricultural practices. Since agroecosystems have a huge capacity to provide ecosystem services, any policy related to agriculture should consider these enormous values that are provided to society naturally by agroecosystems. Nevertheless, valuing agricultural landscapes for their services also puts forth the need to value the dis-services from agriculture to maintain a balance in the concerned agroecosystems. Quantification studies in agroecosystem services will also enable policymakers to integrate green technologies in the farmers' field without affecting food security adversely. Furthermore, these studies form a base for linking farmers to different recently developed government programmes for sustainable development viz. green credit programme. A decent knowledge of the economic values of agroecosystem services will aid the government in repurposing the existing subsidy programs and upscaling improved agricultural practices in the farmer's field. Finally, our study strongly suggests the urgent need for region-specific, robust, and dynamic quantification of ecosystem services and dis-services in the Indian agricultural landscape for a sustainable future.

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