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Review

An overview of Ecosystem service studies in a tropical biodiversity hotspot, Sri Lanka: key perspectives for future research

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Abstract: Tropical island countries are often highly populated and deliver immense ecosystem service benefits. As human wellbeing depends on these ecosystems proper management is crucial in the resource-rich tropical lands where related research is less. Though the ecosystem service and biodiversity studies are a promising path to inform the ecosystem management for these mostly developing countries published evidence of using ecosystem service studies in decision-making is lacking. The purpose of this study is to provide an overview of ecosystem services and related research in Sri Lanka examining trends and gaps and how these studies are conceptualized. Out of considered 139 peer-reviewed articles majority of articles 42.4% were terrestrial and forest related while coastal ecosystems were considered in 34.5% of studies. In most studies, the ecosystem service category was provisioning (33.8%) followed by regulatory service (30.9%). Studies investigating and quantifying ecosystem services, pressures on ecosystems, and their management were fewer compared to studies related to biodiversity or species introduction. Moreover, studies investigating the value of ecosystem services and biodiversity to the communities or involvement of stakeholders in the development of management actions regarding the ecosystem services were rare in Sri Lanka and intense focus of future studies in these aspects are timely and necessary.

Keywords: Ecosystem services; Biodiversity hotspot; Sri Lanka; Forest; coastal ecosystems; management; policy

1. Introduction

Ecosystem services are identified as the benefits people receive from nature as climate regulation, food & clean water provisioning, spiritual, recreational, and cultural benefits, supporting services such as nutrient cycling, which are intermingled to provide and maintain the conditions for life on earth [1]– [4]. Resource-rich tropical islands as Sri Lanka provides immense ecosystem service benefits to its dwellers. As human wellbeing depends on ecosystems and ecosystem services, requiring an understanding of the provision and management of ecosystem services is crucial to the developing countries in the tropics where very fewer ecosystem service studies have been conducted compared to other countries. The tropics record an increasing population and anthropogenic activities thus imposing immense pressure on ecosystems. The ecosystem service and biodiversity

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studies are a promising path to inform the ecosystem management of these tropical countries. Still, there is a lack of understanding or discouragement towards better management of ecosystems among stakeholders including the public and the decision-makers, on the values of nature which is sustained from healthy ecosystems and how it affects life on earth leading to disastrous decisions in terms of ecosystems. Biodiversity loss and habitat degradation pose serious threats to natural habitats and ecosystem services [5] [6]. Therefore, studying and measuring ecosystem services and assigning accurate values for provided services are crucial to understand the links between each component of the system and to inform the consequent impacts if the balance between them is disturbed. Mapping and documenting ecosystem services is essential to understand how ecosystems contribute to human wellbeing and to support policies that have an impact on natural resources [7] as biodiversity loss and ecosystem damage is occurring at an unprecedented rate and is having a negative impact on human livelihoods. Information on ecosystem services can help to communicate the value of nature to decision-makers with the hope of reversing this trend [8].

During the past few decades, the global land cover has changed faster than the past few centuries posing great impacts on ecosystem services [9]. Tropical forests host at least two-third of the terrestrial ecosystem's biodiversity and from local to the global level, provide significant benefits to humans through the provision of economic goods and ecosystem services [10] [11]. Yet tropical forests worldwide are subject to high rates of deforestation and degradation with an estimate of 17 million ha or 1% of total forest area per year [12] with the growth of population and increase of demand for ecosystem products placing much pressure on the fragmented and secondary as well as primary forests. Agricultural expansion itself has cleared 27% of the tropical forest biomes already [13].

Here we selected tropical island nation, Sri Lanka, for the current study to understand key perspectives for future ecosystem service research. Despite the size of the island is 65,625 km^2, Sri Lanka has a high level of ecosystem and biological diversity. A wide range of natural ecosystems such as lowland rainforests, tropical montane forests, dry mixed-evergreen forests, grasslands, mangroves, and estuaries house an enormous amount of biodiversity [14].

As a part of a global biodiversity hotspot, Sri Lanka plays a major role in harbouring and preserving unique biodiversity. Despite the collective importance of the Western Ghats-Sri Lanka hotspot, the island Sri Lanka house some exceptional biodiversity that differs from the Ghats and southern India. For example, clad level diversity of several invertebrates and vertebrates is unique in the island [1], while much of the invertebrates in Sri Lanka are yet to study. Sri Lanka so far has described about 3350 species of flowering plants of which about 23% are endemic, and more than 50% of most invertebrates and vertebrates such as fish and frogs are endemic [1]. However, 94% of endemic angiosperm and majority of endemic vertebrates and invertebrates are confined to the wet zone, wet evergreen and wet montane forests of the Southwest and South-central part, of the island which is only about 7500 km^2 [2].

Habitable environments all over the island with favourable climatic conditions, relatively high rainfall, and yearlong sunshine along with fertile soils, historical and modern irrigation system have provided an abundant supply of food to the population which was later extended into various plantation agriculture. Sri Lanka is also abundant in numerous natural resources such as graphite, gems, high purity silica Quartz, and marine resources.

Rising population and parallel increment of agricultural production and industrialization in recent decades have been indiscriminately exploited many of these ecosystems for commercial, agricultural, residential, and industrial development and waste dumping [15] [25]. The colonial era of Sri Lanka (1800-1950) was started with the clearing of many natural ecosystems for economic plantations such as tea and rubber [16] thus eventually depleting the ecosystems, biodiversity, and ecosystem services they used to provide. The early 19th century triggered this by the drastic changes in the new land-use policies. Since

then, deforestation caused by unplanned developmental activities has become an inherent phenomenon in Sri Lanka [18]. Sri Lanka had a forest cover of 80% in the 1800's, which was reduced to 25% by 2010 [17].

Though Sri Lanka is a relatively large island country full of natural resources, studies assessing them as the ecosystem services they provide are rare. Sri Lanka recorded a 28.7% forest cover by the start of last decade [19] and terrestrial protected area coverage is 29.86% [20] by 2015 and the coastal area consists of 25% of the total land [21]. At the present, though some reports state Sri Lanka has 16.5% forest cover [22] no published data support this claim. But the recent years have recorded the worsen forest cover clearing due to infrastructure development activities in Sri Lanka [23], in addition to illegal logging activities recorded throughout the country through the country has suspended any form of commercial timber extraction [24]. Considering the intensity of resource and environmental degradation and exploitation occur in the country, it is essential to assess the ecosystem services for better planning of resource utilization and sustainable development.

Therefore, in this period where a majority of terrestrial and coastal ecosystems are being cleared, it is timely to study and gather information on the status of natural ecosystems in order to safeguard the valuable services they provide as most of the rural population depends directly on it for food, water, and numerous livelihoods. Although specific ecosystems as mangroves are extensively assessed in Sri Lanka [26] there is a huge gap of studies on many ecosystems, ecosystem services and biodiversity in Sri Lanka. The main aim of this study is to emphasize the gaps in the island-wide ecosystem service studies. Therefore, the major objective of this review was to assess the current condition and trends of ecosystem services in Sri Lanka and to explore the future management scenarios of ecosystem services in Sri Lanka with the empowerment of the local stakeholders.

2. Materials and Methods

Literature collection, eligibility and exclusion criteria

We identified publications related to ecosystem services and related studies in Sri Lanka. Our literature search was conducted between March 2020 and December 2020 using Web of Science (Clarivate Analytics, US) using the search terms: "Sri Lanka*" AND "ecosystem service*", "Sri Lanka*" AND "biodiversity*." We are aware that there might be publications covering similar issues that do not use the term "ecosystem services or biodiversity". Thus, the keywords used in the search strings were designed to capture related articles as much as possible and to keep the study objectives straightforward.

We determined few inclusion and exclusion criteria regarding literature type, only journal articles were selected. We excluded book series, book, chapter in book and conference proceedings. We retained publications that have quantified one or more ecosystem service and biodiversity studies related to any ecosystem type of Sri Lanka. As many Sri Lankan Ecosystem and biodiversity related research were unpublished and confined to thesis studies, we did not include them in this review as we couldn't get access to them during the review period. Moreover, to avoid confusion and difficulty in translating we excluded the non-English publication and focused only on articles published in English. With regard to timeline, no specific time range was selected as we wanted to see the evolution of research related to ecosystem services and biodiversity in Sri Lanka.

Systematic review process

We screened a total of 686 articles and excluded 547 of them from further analysis based on their irrelevance to Sri Lankan context and also, we removed papers that are not dealing with ecosystem services or biodiversity aspects and those only mentioned these two terms in their abstract or keywords and didn't identify or discuss any type of ecosystem service or biodiversity studies in the full article.

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Studies that only mentioned ecosystem benefits but that did not quantify, value them nor measured threats and pressures on ecosystems or biodiversity and didn't discuss any issues related to ecosystem and biodiversity management were not included as we were interested in the body of literature that actively deems themselves as ecosystem service and biodiversity research in Sri Lanka.

Data extraction, establishment of the database and analysis

We extracted data first by reading through the abstracts and then in-depth exploration of the full article to identify the methods and other details of ecosystem service study. For each selected study, we extracted information on the location of the study, the type and numbers of ecosystem services evaluated, and the methods used to quantify services. Selected articles were reported with the title, authors, journal, and date of publication. Each article was attributed an identification code as first author and date of publication for the feasibility of identification. Also, the geographical and climatic zones of the studies were recorded including the aim of the study and also type of the ecosystem study, nature of the used data (i.e. primary, secondary, remote sensing, combined). Two categories were considered as primary data (field and participatory). Finally, we recorded the technical methods used for the assessment (GIS, Modelling, statistics, Valuation, or combined) of each study.

Patterns across ecosystem service studies, quantification methods, and biodiversity research were evaluated using ggplot2 in R [27] and maps were created using Arc GIS (Version). We used descriptive statistics to calculate the number of publications for each category for the variable identified in the data collection section. Our results are reported as both the total and the relative proportion within the reviewed papers and are represented either as the count/portion of articles that met our objectives. A detailed description of the data that was collected on ecosystem service quantification and information about how it was collected is listed in the Supporting Information.

3. Results

One hundred and thirty-nine articles met the review criteria stated above and were authored between 1975 and 2020. The majority of the articles were about biodiversity (51.1 %) and primarily related to species introduction, species abundance-richness, or changes in biodiversity, and approximately half of studies were related to ecosystem services (48.9%). Studies that measured both biodiversity and ES were 15%. The number of papers discussing ecosystem services and biodiversity in Sri Lanka showed a peak in 2019 (Figure 1).

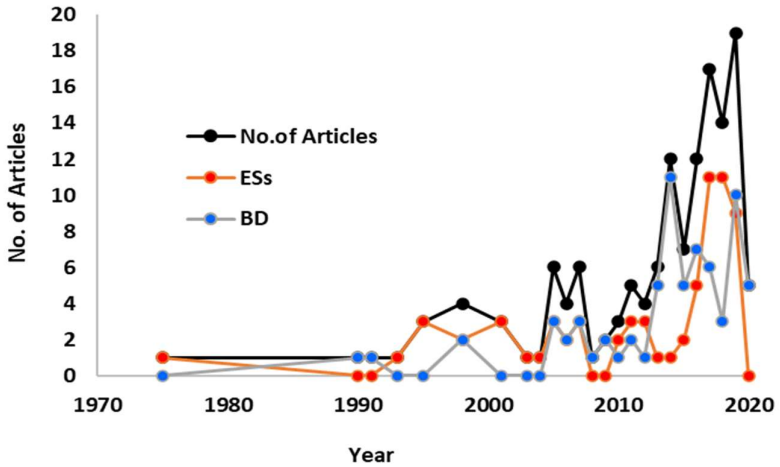

Figure 1. Number of published Ecosystem and biodiversity related research.

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As Sri Lanka can be classified into three distinctive climatic zones namely wet, intermediate and dry covering 23%, 12% and 65% respectively of the total land area [18] we further checked the study proportion distribution in these three zones. Though dry zone comprised highest proportion of the total land area, studies conducted in this climatic zone is proportionately low. Within the assessed ecosystem services and biodiversity studies in Sri Lanka we observed a geographical bias. The selected studies were widely distributed across wet zone 54.4% followed by dry zone 28.9% and intermediate zone 16.8% (Figure 2).

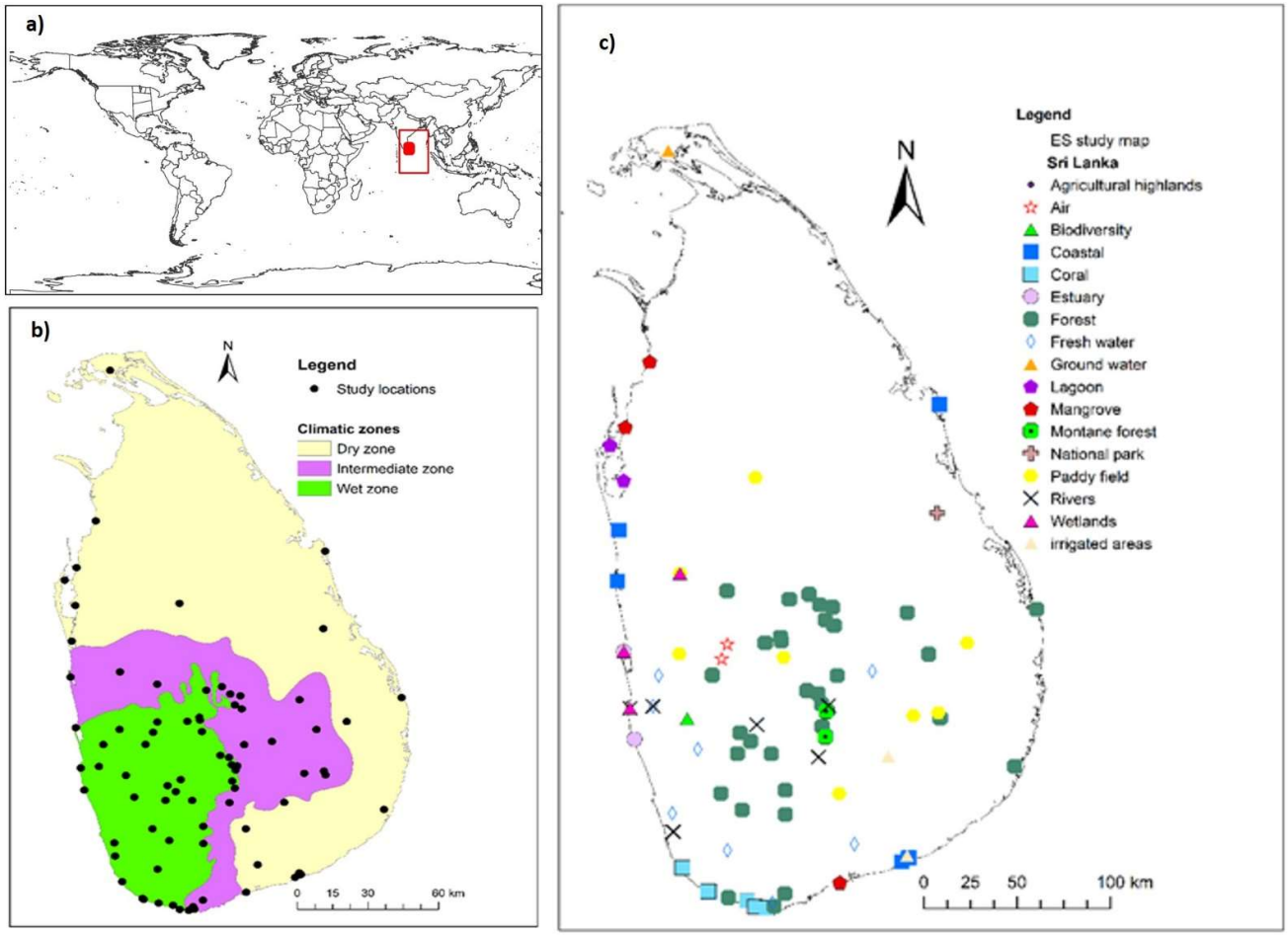

Figure 2. Types and distribution of reviewed ecosystem service and biodiversity studies in Sri Lanka a) location of Sri Lanka in the world map b) study distribution according to the climatic zone c) Study locations in relation to the ecosystem they were conducted.

The majority of studies were conducted in specific ecosystems while the studies investigated more than one type of ecosystem or their interrelatedness treating the whole country as one ecosystem were very few [28]. The highest studied ecosystem for any climatic zone was forest ecosystems (42.5%) followed by coastal ecosystems (21.8%) while the lowest studied ecosystem according to the peer-reviewed literature was soil (0.7%) for any climatic zone. Though Sri Lanka has 19,897 km2 (29.86%) terrestrial protected areas coverage [20] the number of published studies that were conducted in protected areas was very limited.

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Across the 139 studies 68 were solely on ecosystem services while 71 were related to biodiversity. We identified 21 unique ecosystem services (Figure 3) investigated in these studies. The most frequently quantified ecosystem services were food supply, carbon storage, climate regulation, water supply, and water quality. While provisioning (33.8%) and regulating services (30.9%) were quantified most often cultural (19.1%) and supporting ecosystem services (16.2%) were less frequently considered. Most studies (59) were considering one or two types of ecosystems service and we found that ecosystem services from all possible combinations of these four categories were evaluated together in a lesser number (9) of individual studies.

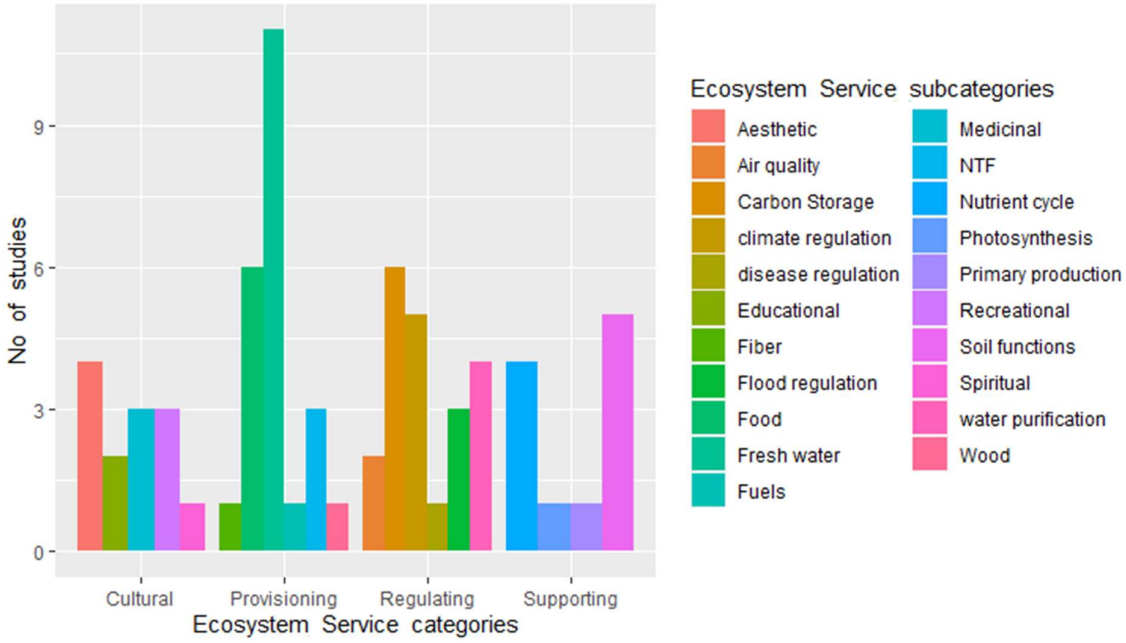

Figure 3. Ecosystem services evaluated among the reviewed studies conducted in Sri Lanka. The 21 types of ecosystem services identified in the studies are listed in the legend according to the definition of the Millennium Ecosystem Assessment and in this graph, we omitted the studies related to biodiversity.

Analysis of different study types for the identified ecosystem services and biodiversity studies for each considered ecosystem in Sri Lanka showed that for any given ecosystem the majority of the papers were biodiversity related (forest 38%, coastal 20%, national parks 40%) while the lowest study type were pressure related studies 9.4% in total. Papers related to pressures on ecosystems were 12.9% while local knowledge and stakeholder involvement was recorded in 10.8% studies, biophysical quantification in 24.5%, ecosystem trade-off in 2.2%, and ecosystem valuation studies were 11.5% in total.

Coastal and forest ecosystems have the highest number of studies related to stakeholders' ecological knowledge or stakeholder participation with 10.5% and 12.0% respectively of all studies in those habitats. In the reviewed literature, agricultural related ecosystem service researches and studies using social science techniques are underrepresented and hardly found. This is a tragic situation for a country that is one of the ancient agricultural civilisations with tremendous indigenous knowledge on different agricultural systems.

The more commonly studied pressures on Sri Lankan ecosystem studies were identified as water pollution, habitat loss, and degradation whilst studies on invasive species were also recorded and considered as pressures on studied ecosystems.

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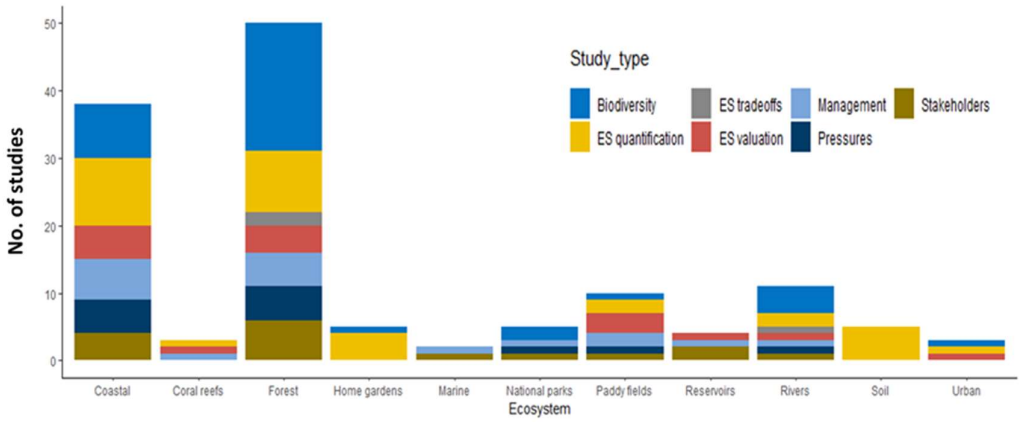

Figure 4. Frequency of different study types for the identified ecosystem services and biodiversity studies in Sri Lanka.

The peer reviewed articles have used five types of data sources in their studies namely primary, secondary, remote sensing and combined. We categorised primary data as field and participatory data. Any study that used two or more data sources were categorised as combined. We found that remote sensing data were frequently used in studies starting from 2010. The majority of services were quantified using primary data, and from that the highest was field data 48.9% followed by participatory data 10.8%, while studies that used some form of secondary data was comprised of 17.3% and studies that used remote sensing data were 15.1%.

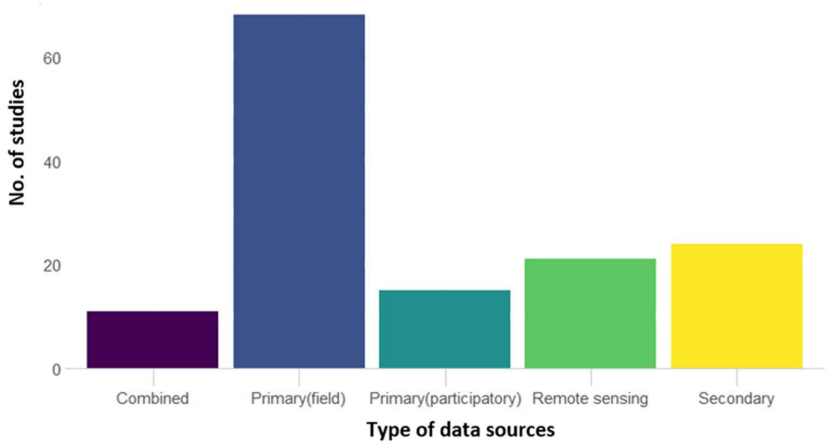

Figure 5. Different types of data sources used in the reviewed studies.

In the studies we assessed, three different groups of technical methods were used to quantify ecosystem services. The most frequently used were GIS and statistical analysis (descriptive or other) also followed by various modelling tools and valuation methods (Figure 6).

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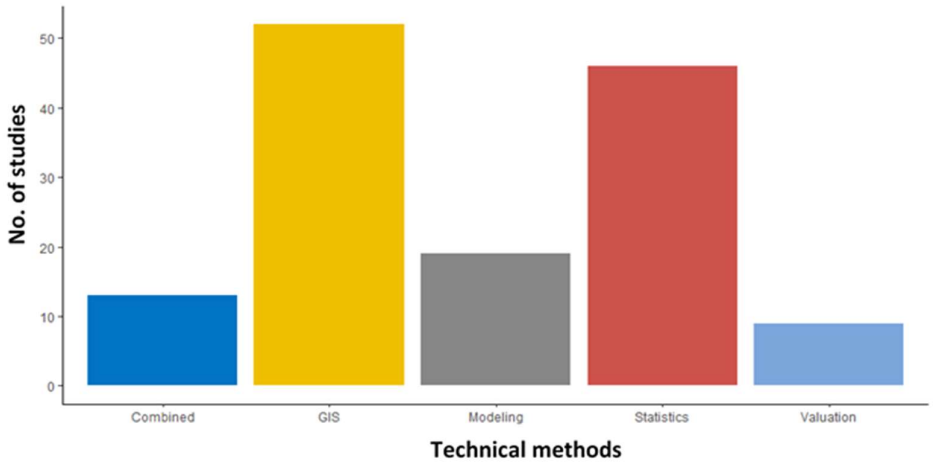

Figure 6. Different groups of technical methods used to quantify ecosystem services.

However, in the papers where a specific focus was identified, coastal ecosystems were the most frequently considered with mangroves being the most frequent focus (38 studies) with biophysical assessments or valuation (Figure 4). The studies investigating recreational and eco-tourism were rare (8) and the lowest was studies investigating gene pools (3).

4. Discussion

Most of the ecosystem services and biodiversity studies in Sri Lanka are related to coastal, freshwater, or wetland ecosystems and are interdisciplinary in nature and discussed resources, their utilization, environmental issues, and management options [29]–[43] compared to the number of forest related interdisciplinary ecosystem services studies [24], [44], [45]. Sri Lanka has assigned its forests primarily for conservation since 1989 due to their unique biodiversity and significance in the country's economy [24]. Though these forest ecosystems play a vital role in local economies and livelihoods, by provisioning traditional food and medicines, a rare number of studies are related to those aspects. Most of the forest ecosystem studies are related to biodiversity [46]– [55].

Limited research associated with terrestrial ecosystem biodiversity and ecosystem services attempted to estimate the composition of income in the peripheral communities from forest products [44], [56]–[58] but a proper assessment of ecosystem services and biodiversity in Sri Lanka's diverse terrestrial ecosystems are lacking. On the other hand, we found some studies related to biodiversity assessments in remote locations of Sri Lanka [48], [50], [59] but studies covering and discussing the interrelatedness of ecosystem services in all the climatic zones of Sri Lanka are rare or none.

Habitat loss and degradation were strongly associated with forest ecosystems, coastal habitats, and to a fewer extent with cultivated and freshwater ecosystems. Invasive species and water pollution from agricultural and industrial output were recorded as the drivers mainly in inland water, and studies dealing with erosion were mainly from the forest, rivers, and coastal habitats.

Even though Sri Lanka has lost an immense number of forested lands since the start of the colonial era, only a few restoration projects have been implemented and very few were scientifically recorded. Among these studies, only one recent study has discussed the potential of restoration projects to be sold as voluntary carbon credits in the international market by focusing on designing and certifying community-based payments for ecosystem services (PES) programs [60]. This kind of research rare among Sri Lankan ecosystem service and biodiversity studies, valuation of ecosystems through monetary terms is crucial as it helps to compare ecosystem services to other types of resources and

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promote the consideration of services that are not accounted for in the current global trade markets in management decisions [61]. Nevertheless, promoting these restoration projects and carbon trading concepts in the society itself will provide a good platform for conserving valuable ecosystems and endemic fauna and flora by providing income to the locals involved in these projects.

Nevertheless, some interesting and isolated studies conducted in different climatic zones targeting unique ecosystems were screened. One of those studies focused on using species diversity to measure the ecosystem services conditions showed how lichen diversity can be used as bioindicators to measure the air quality of rural-urban ecosystems which is very significant as it demonstrates how unique species can contribute to ecosystem service management [62]. Moreover, as a country with a traditional indigenous medicinal system Sri Lankan traditional medical practitioners have been using the vast floral biodiversity in the healing processes but we found only one published study that has focused on the significance of plant biodiversity in the healing of snake bites in which they found that 341 different plant species are utilized for traditional snakebite medication [63].

Within the assessed ecosystem services in Sri Lanka, we observed a bias towards the evaluation of regulatory and provisioning services which has a clear material value compared to cultural services. This may be due to the difficulty of assessing and quantifying those cultural services [64], [65]. Since these unexplored ecosystem services remain a significant component of the socio-ecological systems of Sri Lanka and failing to include them in studies will have negative impacts on the proper management of these ecosystems and ecosystem service benefits they provide to society.

Present focus of studies on man-made, agriculturally important ecosystems and ecosystem services

One of the most rapidly emerging threats to food and livelihoods is the loss of biodiversity from traditionally species-rich agroecosystems [66] due to development projects, increased monoculture, and urbanisation but these significant changes often go unnoticed because conventional conservation efforts repeatedly focus on endemic or charismatic species and intact ecosystems [67].

In order to assess the present focus of the published studies related to these ecosystems and services they provide and to identify drivers, pressures, and gaps that have an impact on them, we focused on two selected ecosystems in detail that are significant to Sri Lanka economically and rurally.

Paddy ecosystems

Though Sri Lanka is an agriculture-based country only a few published articles have focused on it. Soil ecosystem services is an important ecosystem service that agricultural civilizations heavily depend on [68]. However, research on how soil ecosystems are related to agriculture and food production in Sri Lanka is rare. The few studies we encountered are mostly focused on paddy cultivation [69], [70].

While rice is the staple food in Sri Lanka, we found only a few studies related to rice fields, and these studies were about water quality, nutrient loss, rice production, and soil quality [16], [71]–[76]. Very few research with interdisciplinary nature was conducted regarding paddy in Sri Lanka [69], [77] yet the main income for most of the rural farmers is rice production.

Home gardens

Another important ecosystem when mentioning food provisioning services in Sri Lanka is home gardens as they provide food security throughout the year at a low-cost while providing numerous other ecosystem services [78]. Though Eskil Mattsson, Ostwald, & Nissanka (2013) mentioned that current estimation of home garden distribution

in Sri Lanka as 15 % of the land area almost every home in Sri Lanka has some form of the home garden either small or large to self-provide some of the daily utilised food items. Many of the published studies on Sri Lankan home gardens are confined to upcountry or Kandyan home gardens and are focused on few specific ecosystem services they provide [78], [80]–[82]. Most have extensively focused on the carbon storage [79], [80], [83]. We only encountered 3 studies related to the biodiversity investigation of home gardens in Sri Lanka [82], [84], [85]. Among the few studies that addressed the ecosystem services provided by home garden systems except the studies from [81] on carbon storage in the dry zone home gardens, none of the other studies have focused on dry zone nor investigated the extent of home gardens on biodiversity conservation in different locations and in different climatic zones of the country which we suggest and encourage to expand to every climatic zone so that a valuable addition of flora fauna associated with Sri Lankan home gardens could be added to the scientific community thus enhancing their conservation opportunities.

Significance of ecosystem service and biodiversity studies for decision-making

For a developing country like Sri Lanka development projects are crucial and inevitable as set out in the National Physical Plan 2011-2030 [24]. But many projects are started without a proper environmental impact assessment due to various reasons including political interferences and the harm posed on less disturbed ecosystems is massive. To show this appealingly for the decision-makers it should be backed up with strong scientific evidence. Moreover, to support environmental management policies, ecosystem studies should also focus on biophysical and economic indicators integrating data and information with socio-economic system components and the societal and policy contexts in which they are rooted. Quantification of ecosystem services using these methods is significant not only in the proper management of ecosystems but also in the right decisions and policy formulation. But in many circumstances transferring the outcomes of the biophysical assessments to decision making are not upfront and requires further work and a strong voice to communicate to the right audience.

Moreover, ecosystem management methods should maximize the production of one ecosystem service without declining provision of other ecosystem services, therefore future research should aim to understand the relationships among multiple ecosystem services and the mechanisms behind these relationships to improve our ability to sustainably manage ecosystems. According to [3] though it is challenging to redefine the vision for the management of Sri Lanka's ecosystems to achieve sustainable development goals, and to build the necessary in-country capacity to demonstrate its benefits to policymakers. To reach a responsible greener economy, well-planned integrated ecosystem service studies covering all the climatic zones of the country should be an economic and research priority.

Moreover, corrective actions for rapidly diminishing ecosystems and related services should be a priority in any environmental upgrading plans and should assign full protection to any ecosystem and area wherever it is needed. Additionally, society should also be strengthened in the conservation of ecosystems by communicating, updating and providing understanding at all policy-making and decision-making levels in the government, business enterprises, educational institutions and general public. This can be done by prioritising and incorporating ecosystem and biodiversity conservation into the national planning process. Considering the diverse cultural, and religious aspects of Sri Lankan society, the best approach to protect its ecosystems is by implementing a more participatory approach considering local needs and national priorities [14].

Future perspectives for Sri Lankan ecosystem service and biodiversity studies

Our results show that there is an urgent necessity to evaluate diverse ecosystems across the country and the ecosystem services they provide and the biodiversity they

harbour as Sri Lanka is situated in a politically and economically important strategic location attracting new investors from around the world and implementing new development projects without proper environmental impact assessments. Therefore, this existing gap of knowledge on highly diverse ecosystems across the country should be bridged with the help of experts and committed personnel by building multi-disciplinary teams, referring to existing frameworks for guidance, and drawing the right resources.

The results obtained from this literature review strongly suggest that ecosystem service assessments and the management of those ecosystems are mostly hindered by the relative availability of published articles and conducted researches with unpublished studies containing information on ecosystems and biodiversity. Our review strongly points that studies investigating how cultural, provisioning, and regulating services are intertwined, and the role of ecosystems in the delivery of these services are lacking in Sri Lankan ecosystem service studies. These aspects are significant to identify management practices maximising the potential of each ecosystem to deliver ecosystem services and to protect biodiversity.

This study demonstrates a higher frequency of studies concerning the forest and other ecosystem's biodiversity or species identification. But studies investigating and quantifying ecosystem services, pressures on ecosystems, and the management of these were few, further studies investigating the value of ecosystems services and biodiversity to the communities or involvement of stakeholders in the development of management actions regarding the ecosystems and services are rare and need intense focus in any future study as they are significant in selecting and evaluating the possible management actions regarding each unique ecosystem of the country.

Considering these identified gaps and the extensive data requirements to assess multiple ecosystem services and to create a solid information database it is time to consult experts, locals, and stakeholders as an important starting point for providing a wider picture, developing integrative assessments of ecosystems in Sri Lanka. This can be done by focusing and monitoring the collected data and adding new data to the collection and by improving the understanding of the synergies and trade-offs between ecosystems. Moreover, it is vital to provide suggestions of ecosystem management measures that would be primarily favoured by the original dwellers of the ecosystems or adjacent communities and secondarily by other stakeholders considering the common challenges they face and the connectivity of ecosystems and services these ecosystems provide and the significant benefits communities derive from them.

As the number of studies that quantify the link between biodiversity and ecosystem services is rare in the surveyed literature in this review, we suggest more focus on this aspect in future studies. Additionally, as studies on the social dimension of ecosystem services in Sri Lanka investigating indigenous knowledge, human perception, and participation in decision-making are fewer so should be promoted, prioritised, and conducted. Similarly, very few valuation studies were found and the detected valuation methodologies, the analysis of beneficiaries, and the contribution of ecosystem services to human well-being were understudied in all the ecosystems and ecosystem services related studies in Sri Lanka. The small number of papers that quantify the contribution of biodiversity to ecosystem services suggests an important knowledge gap that should be addressed.5.

5. Conclusions

Our study demonstrates the current state of the Sri Lankan ecosystem service studies and identifies research challenges that must be addressed for the concept of ecosystem services to better inform ecosystem management. For individual studies, ensuring that the indicators, data, and techniques used to quantify ecosystem services are well defined, justifiable, validated, and reproducible are excellent starting points to move the field forward. There is a need to better understand the diversity of ecosystem service interactions and to consider the implications of using different spatial extents to quantify services and

to build multidisciplinary working teams across all the climatic zones. Though these are difficult challenges it's important to ensure that ecosystem service research is conducted in its full potential to improve management and decision making in a country like Sri Lanka with many diverse and unique ecosystems and a biodiversity hotspot.

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