

Annexures

Accelerating Investments towards Nature-based Solutions in the Global South

A Unified Framework for Mapping and Estimating Benefits

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Annexure I: Gaps and Challenges associated with NbS

The following are the two categories of gaps and challenges associated with NbS namely, the implementation and the investment barriers. The implementation barrier is more specific to the stakeholders in the Global South which do not possess the required knowledge and tools for implementing NbS at scale. The investment barrier is experienced by implementation agencies and investors and is primarily due to the absence of any market value of NbS interventions and due to the uncertainty revolving around the returns and benefits of such solutions. Figure 4 provides an overview of the gaps and challenges associated with NbS.

1. Implementation Barriers

Several countries have a recorded history of communities following traditional forms of NbS for the purpose of supporting livelihood and increasing resilience against natural disasters (Raman 2023). However, many of these solutions have either been replaced by alternative solutions or do not have the capacity to be scaled up to meet the present set of challenges faced by both the communities and nature. Such challenges include rampant urbanisation, extreme events due to rapidly changing climate, and unstable inflation rates, amongst others. Thus, establishing the roles of different agencies and ensuring effective communication and participation by local communities would require a defined approach for adopting NbS (Eggermont, et al. 2021). The implementation gaps can be further broken down as follows:

1.1 Absence of policies for the adoption of NbS: The countries in the Global South require the inclusion of NbS in policies given the large amount of natural reserves present in these regions. A majority of the biodiversity hotspots, critical ecosystems and nature-based livelihoods exist in these countries, which makes the inclusion of NbS necessary (Jordan 2019). However, several of these countries have yet not explored the potential of NbS to meet the targets set under the adaptation and mitigation goals.

The inability to assess the scope of NbS comes from a lack of policies which further fail to build resources such as technical expertise and tools necessary to understand the benefits of nature (McQuaid, et al. 2021). In the absence of any defined policy, these nations require longer periods of time and external support to develop the resources necessary for adopting NbS (Mulongoy and Gidda 2008). Even though there have been financial incentives and support mechanisms established for developing nations around NbS, such as the financial incentives provided to developing countries under REDD+¹ for reducing emissions in the forest sector (Morita and Matsumoto 2021), a majority

¹REDD+ stands for Reducing Emissions from Deforestation and Forest Degradation in developing countries. It is a framework which was adopted to protect forests as part of the Paris Agreement.

of the countries continue to face challenges to define and integrate NbS in policies and climate change action.

1.2 Lack of knowledge of natural capital: Natural capital refers to the stock of natural assets present in a region and includes elements of nature such as geology, soil, air, water and biodiversity (CBD 2021). It is necessary to take account of natural capital to understand the pattern of growth or decline with respect to the elements of nature. Such an account will guide policymakers and governments to identify the area of action. However, several countries do not conduct a stocktake or have dedicated databases which identify the different elements of the ecosystem and their benefits, ecosystem thresholds, best practices, etc. (Seddon, et al. 2020).

The lack of accounting of natural capital often leads to poor understanding of the issues associated with the elements of nature that further disrupt environmental cycles and adversely impact livelihoods. A failure in recognising the relation between elements of nature may also lead to cases of maladaptation. There have been cases where excessive intervention by humans in the form of NbS has led to undesired impacts (Aggestam, et al. 2020). For example, plantation of non-native species such as eucalyptus trees in areas which face water scarcity has contributed to more problems (Chandraprakash 2020).

2. Investment Barriers

Investments play a key role in strengthening action in adopting suitable NbS. The MEA identified the lack of understanding of the value of nature as the primary reason behind the decline of various ecosystems (Millennium Ecosystem Assessment 2005). The value of nature here refers to the economic cost of the services or the benefits provided by nature. It is important to understand the value of nature to make data-driven decisions based on factors like the benefits produced by different NbS, alternatives available in the market and opportunity costs associated with the interventions (Knight, Stephenson and Chellew 2022, Gómez, Purata and Rodríguez 2023). Certain solutions are more attractive in terms of benefits produced which may be non-economic in nature (Moraes, et al. 2022). The various gaps and challenges triggering such investment barriers are as follows:

2.1 Uncertainty associated with NbS: It is essential for investors to understand the potential of NbS. The current available knowledge lacks an integration of climate change projections and their impact on the NbS (Raymond, et al. 2017). The investors will demonstrate more confidence in NbS if evidence pertaining to the flexibility of such solutions to future climate stressors is estimated. Further, monitoring plays a critical role in any project as not only does it provide information on the different factors influencing a solution but also makes it easier for a stakeholder to check if the desired path is on track or not (Directorate-General for Research and Innovation 2021, Somarakis, Stagakis and Chrysoulakis 2019). However, there is no defined way to assess the performance of an NbS at different stages of its lifecycle. Moreover, a few cases have also shown the large costs involved in maintaining a monitoring system for longer periods of time (Hamel and Tan 2021). Even solutions involving the community as a monitoring system have demonstrated irregularities in tracking the progress of NbS. All these factors lead to an increase in uncertainty associated with the project.

This uncertainty associated with NbS could be reduced through two ways. First, a proper set of guidelines and indicators could be developed to monitor the implementation of a NbS and measure the effectiveness of the same vis-a-vis the objectives (Brugnach and Hoek 2023). Such guidelines must be adaptable in nature and should have the ability to be used in multiple contexts. Second,

climate risk assessments must be integrated in feasibility studies to understand the effectiveness of NbS with respect to future climate projections (World Bank 2023).

2.2 Lack of market analysis: As more and more NbS are being recognised around the globe, investors might be interested in specific solutions based on factors such as investment rates, rate of return, non-economic benefits, etc. Some regions recognise traditional solutions more due to cultural value and support across generations whereas other regions tend to skew more towards modern solutions having technological significance (Rocha, Almassy and Pinter 2017). Such varying receptions of NbS in different parts of the world makes it necessary to recognise the local context and market dynamics, to better understand the direction of investments (Throp, Yang and Sherman 2021). Several solutions might produce countless benefits but fail to establish due to a lack of interest of the community and investments from relevant stakeholders (Knight, Stephenson and Chellew 2022). The lack of market analysis is further supplemented by a poor understanding of the opportunity costs and failure to assign an economic value to nature.

- **No opportunity cost analysis**: This holds relevance in those projects of NbS which are either new solutions or aim to get integrated into the existing grey infrastructure (World Bank 2023). Investors require information about the costs and benefits of all the possible solutions to compare and make the best possible decision.
- **Failure in identifying the value of nature**: Several schools of thought do not recognise nature or its related elements as an economic good (Government of UK 2021). Since parts of the ecosystem such as biodiversity and bio-physical elements cannot be traded, thus a value cannot be associated with them (Fish and McKelvey 2021). Nevertheless, ecosystem valuation methods have been developed to assign a price to the ecosystem by evaluating the services provided by it. Even though such methods have been available for more than three decades, the ecosystem valuations have not been concise and are often riddled with limitations (Ludwig 2000). Moreover, implementation agencies and stakeholders such as private investors lack the technical expertise required to conduct the valuation studies properly which leads to errors. Hence, ecosystem valuation methods must be reconfigured and simplified to represent the value of nature more accurately.²
- **No framework for estimating benefits**: There are no unified frameworks which map the wide range of benefits being generated from an ecosystem for the countries present in the Global South (Nelson, et al. 2020). The developed countries have witnessed the largest push for NbS in terms of both finances and literature which has enabled them to develop tools and frameworks to scale NbS (UNEP 2022). However, developing and low income countries which are more dependent on natural resources are compelled to follow such frameworks due to lack of the required tools and expertise available in the local regions (Seddon, et al. 2020). The Adaptation Gap report released by UNEP identified the lack of data collection on NbS as the potential reason behind the absence of any defined framework for calculating the effectiveness of NbS (UNEP 2020).

² The authors would also like to point out that currently the the narrative around identifying the value of nature is limited to the traditional idea of economic value, which does not depict the entire value of nature since there are few benefits provided by nature such as habitat for endangered species, stabilising flow of water, etc. which cannot be quantified. It is necessary that a new way of understanding the value of nature must be developed which takes into account elements beyond the economic value of nature.

Annexure II: Existing efforts to map and estimate benefits of NbS

The most significant contribution to the field of ecosystem valuation was the MEA conducted in 2005. The assessment provided the first comprehensible list of ecosystem services along with the guidelines of selecting the relevant valuation methods (Millennium Ecosystem Assessment 2005).

The ecosystem valuation method is considered as a validation tool for NbS (World Bank 2023). It provides the evidence required by investors and other stakeholders to examine the effectiveness of an intervention. Over the years, several tools have been created which have utilised the ecosystem valuation method as a part of decision-making analyses such as cost-benefit analysis (CBA), multi-criteria analysis, etc. (Raymond, et al. 2017). The ecosystem valuation method provides the basis for highlighting the economic potential of an ecosystem. However, the recent discourse around NbS has highlighted the need to identify more criteria for making decisions.

The importance of integrating socio-economic indicators has been well highlighted in the tools concerning the valuation of ecosystem services, however, only a few tools contain proper guidelines or list of indicators which must be considered to make an informed and targeted decision (IUCN 2018). An analysis by UNDP of NbS related toolkits reveals that while many tools offer best practices and outline costs and benefits for interventions, however, none incorporate a climate lens for valuation (Northeastern University: School of Public Policy and Urban Affairs 2021). Moreover, a lot of the tools fail to incorporate the socio-economic indicators which may influence the implementation of the interventions.

Over the years, the advancements in geo-spatial technology have led to the development of several tools which map the different benefits arising from an ecosystem.. A list of these tools is available in Table A1.

Table A1: Existing tools and frameworks to map and estimate NbS

S.No.	Agency	Tool	Description
1	TEEB	The Economics of Ecosystems and Biodiversity (TEEB) Framework and Valuation Database	It provides a brief categorisation of services and necessary ecosystem valuation tools for determining the economic value
2	ESTIMAP	Ecosystem Services Mapping Tool	It supports the mapping and modelling of ecosystem services by providing spatial information on different modules of ecosystem services including pollination services, recreation, air quality regulation and coastal protection
3	Stanford University	Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST)	This suite of models is employed to map and assess the natural resources supporting human life. It encompasses a wide range of benefits, including water, agriculture, and climate change.
4	IUCN	Global Standard for Nature-based Solutions	The global standard for NbS provides a systematic learning framework which guides

			relevant stakeholders to implement NbS on the ground, accelerate policy development, and create conservation science on NbS.
5	EU	LIFE Programme	The document provides concepts and methods to implement ecosystem services assessments according to the framework developed under EU Mapping and Assessment of Ecosystems and their Services (MAES).
		NATURVATION	A comprehensive collection of methods used to calculate value and benefits of NbS in urban areas, specifically for the European Union.
		EKLIPSE Framework	A comprehensive framework which elaborates the different categories of benefits of NbS into indicators for evaluation in urban areas.
		NbS Impact Evaluation Framework	This handbook is an upgrade to the EKLIPSE framework in terms of scope as well as in providing case studies and tools to evaluate NbS.
		Integrated system of Natural Capital and Ecosystem Services Accounting (KIP-INCA)	Building upon the UN System of Environmental Economic Accounting - Experimental Ecosystems Account (SEEA-EEA) framework ³ , the objective of KIP-INCA is to determine the value of all the ecosystems of the EU using past studies which have already been conducted.
6	Toolkit for Ecosystem Service Site-based Assessment (TESSA)		This toolkit was developed with the primary purpose of catering to the need of non-specialists in the field of NbS. It maps and estimates services across 3 broad categories of benefits.

Source: Authors' analysis

These tools are often defined to a limited geographic area and have several limitations based on the applicant of the tool. The majority of the tools have been developed in the EU and lack replicability and flexibility which would allow the framework to be used in other countries, especially the developing and low-income countries which do not possess the required resources and expertise to utilise such tools to its full potential. Moreover, these tools do not often map the socio-economic benefits and their interactions with various biophysical elements. Even though there are a few frameworks which map the wide variety of benefits, the progress on the unification of a common framework across countries has been negligible.

³ The SEEA Experimental Ecosystem Accounting (SEEA EEA) framework was endorsed by the United Nations Statistical Commission in March 2013 as an important first step in the developing a statistical framework for ecosystem accounting ([Link](#)).

Annexure III: Umbrella Concept for NbS

The Table A2 highlights the definition of all the different types of NbS.

Table A2: Umbrella Categories and different type of NbS

S.No	Umbrella Category	Type of NbS	Definition	Examples
1	Ecosystem restoration approaches	Ecological Restoration	The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed	Restoration of flood plains; Restoration of mined areas
		Ecological Engineering	The management of systems involving human and environmental co-design or gentle management that harmonises human design with environmental self-design, fostering mutual symbiosis	Constructed wetlands; Oyster breakwater reefs
		Forest Landscape Restoration	The long-term process of regaining ecological functionality and enhancing human well-being across deforested and degraded landscapes	Tropical forest restoration; Ecological restoration of degraded forests
2	Issue-specific ecosystem-related approaches	Ecosystem-based Adaptation	The use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change	Rooftop farming practices; Climate resilient agricultural interventions
		Ecosystem-based Mitigation	The enhancement of benefits and avoidance of negative impacts on biodiversity from reducing emissions, while ensuring the active participation of indigenous and local communities in relevant policy-making and implementation processes	Restoration of mangrove ecosystems; Creation of urban jungles
		Ecosystem-based Disaster Risk Reduction	The sustainable management, conservation, and restoration of ecosystems to provide services that reduce disaster risk by mitigating hazards and enhancing livelihood resilience	Identification of climate change hotspots in a region; Capacity building programme to build climate resilience
		Climate Adaptation Services	Benefits to people resulting from increased societal capacity to respond to change, facilitated by ecosystems' ability to moderate and adapt to climate change and variability	Restoration of wetlands to manage floods; Nature-based landslide risk management

3	Infrastructure-related Strategies	Blue Infrastructure	It encompasses strategies that utilise natural water bodies like rivers, lakes, and coastal areas to mitigate the impacts of climate change and enhance societal well-being.	Urban tree canopy and green roofs; Permeable paving
		Green Infrastructure	Strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue, when aquatic ecosystems are involved) and other physical features in terrestrial (including coastal) and marine areas	Rainwater harvesting; Management of riverfront
4	Ecosystem-based Management Approaches	Integrated Coastal Zone Management (ICZM)	It focuses on the sustainable utilisation of coastal resources while safeguarding the ecological health and resilience of coastal ecosystems. It encompasses a range of activities such as land use planning, disaster risk reduction, and biodiversity conservation within coastal areas	Natural coastal embankment; Bio-dykes
		Integrated Water Resource Management (IWRM)	It involves the coordinated development and management of water, land, and related resources to ensure equitable access to water for various users while protecting ecosystems and maintaining water quality	Spring revival; Restoration of lake
5	Ecosystem Protection Approaches	Area-Based Conservation Approaches	These are pivotal in ecosystem protection measures, emphasising the preservation of specific regions or habitats to safeguard biodiversity and ecosystem health	Wildlife sanctuaries; Biodiversity parks
		Protected Area Management	Effective management of protected areas is fundamental to ensuring the sustained protection of ecosystems and their inhabitants	Community conservation reserve; National parks and protected areas

Source: Authors' compilation based on IUCN. 2020. *Global Standard for Nature-based Solutions: A user-friendly framework for the verification, design and scaling up of NbS*. Gland, Switzerland. IUCN

Annexure IV: Key to Figure 8

Targets strongly impacted by nature-based solutions

India's Updated National Determined Contributions (NDC)

- Target 1: To put forward and further propagate a healthy and sustainable way of living based on traditions and values of conservation and moderation, including through a mass movement for 'LIFE' – 'Lifestyle for Environment' as a key to combating climate change
- Target 2: To adopt a climate friendly and a cleaner path than the one followed hitherto by others at corresponding level of economic development
- Target 3: To reduce Emissions Intensity of its GDP by 45 percent by 2030, from 2005 level
- Target 5: To create an additional carbon sink of 2.5 to 3 billion tonnes of CO₂ equivalent through additional forest and tree cover by 2030
- Target 6: To better adapt to climate change by enhancing investments in development programmes in sectors vulnerable to climate change, particularly agriculture, water resources, Himalayan region, coastal regions, health and disaster management.

National Biodiversity Action Plan (NBAP)

- Target 3: Strategies for reducing rate of degradation, fragmentation and loss of all natural habitats are finalised and actions put in place
- Target 4: Invasive alien species and pathways are identified and strategies to manage them developed so that populations of prioritised invasive alien species are managed.
- Target 5: Measures are adopted for sustainable management of agriculture, forestry and fisheries
- Target 6: Ecologically representative areas under terrestrial and inland water, and also coastal and marine zones are conserved effectively and equitably
- Target 7: Genetic diversity of species is maintained, and strategies have been developed and implemented for minimising genetic erosion and safeguarding their genetic diversity.
- Target 8: Ecosystem services are enumerated and measures to safeguard them are identified

National Report to UNCD

- Strategic Objective 1: To improve the condition of affected ecosystems, combat desertification/land degradation, promote sustainable land management and contribute to land degradation neutrality
- Strategic Objective 2: To improve the living conditions of affected populations.
- Strategic Objective 3: To mitigate, adapt to, and manage the effects of drought in order to enhance resilience of vulnerable populations and ecosystems
- Strategic Objective 4: To generate global environmental benefits through effective implementation of the United Nations Convention to Combat Desertification

National Action Plan on Climate Change (NAPCC)

- **National Mission on Sustainable Habitat**
 - Objective 1: Promote low-carbon urban growth towards reducing GHG emissions intensity for achieving India's NDC

- Objective 2: Build resilience of cities to climate change impacts and strengthen their capacities to 'bounce back better' from climate-related extreme events and disaster risks.
- **National Water Mission**
 - Objective 1: Comprehensive water data base in public domain and assessment of impact of climate change on water resource
 - Objective 2: Promotion of citizen and state action for water conservation, augmentation and preservation
 - Objective 3: Focused attention to vulnerable areas including over-exploited areas
 - Objective 4: Promotion of basin level integrated water resources management
- **National Mission for a Green India**
 - Objective 1: Increased forest/tree cover on 5 m ha of forest/non-forest lands and improved quality of forest cover on another 5 m ha of non-forest/ forest lands (a total of 10 m ha)
 - Objective 2: Improved ecosystem services including biodiversity, hydrological services, carbon sequestration from the 10 m ha of forest/non-forest lands
 - Objective 3: Increased forest-based livelihood income of about 3 million households, living in and around the forests
 - Objective 4: Enhanced annual CO₂ sequestration by 50 to 60 million tonnes in the year 2022
- **National Mission for Sustainable Agriculture**
 - Objective 1: To make agriculture more productive, sustainable, remunerative and climate resilient by promoting location specific Integrated/Composite Farming Systems
 - Objective 2: To conserve natural resources through appropriate soil and moisture conservation measures.
 - Objective 3: To adopt comprehensive soil health management practices based on soil fertility maps, soil test-based application of macro & micro nutrients, judicious use of fertilisers etc.
 - Objective 4: To optimise utilisation of water resources through efficient water management to expand coverage for achieving 'more crop per drop'.
 - Objective 6: To pilot models in select blocks for improving the productivity of rainfed farming by mainstreaming rainfed technologies

Annexure V: Decision-making Tools and Ecosystem Valuation Methods

Decision-making tools

There are often multiple solutions which can be implemented for achieving a singular target. Such choices differ in several aspects including the list of benefits provided by each, the costs associated with the intervention and other resources which may be utilised or produced. In the case where a limited amount of resources are available, it becomes crucial to have a framework for identifying the intervention which provides optimum results for the given time and resources available.

The decision-making tools differ from each other in the kind of inputs which are used to determine the intervention which would provide the maximum amount of benefits. Some tools are economic in nature while others consider a variety of factors including economic and biophysical indicators. The

following are a few of the tools which can be used for choosing a specific nature-based solution (NbS):

1. Cost-Benefit Analysis

This is a simple economic decision-making tool which considers both the benefits and costs associated with a specific intervention. The availability of different ecosystem valuation techniques for calculating the benefits of NbS ensure that both the perception of the market as well as the multiple stakeholders such as the community, implementation agency, government, etc. are recognised. The primary advantage of using this method is the measurement of benefits in a common unit which allows comparison between both monetary and non-monetary values (Atkinson and Mourato 2008). This method also accounts for temporal changes through the use of discounting.

However, the methods for the valuation of benefits itself has several limitations. Moreover, since ecosystem services are customised according to the local needs and requirements, it is essential to differentiate between the benefits based on their relevance to the community or the geography where the intervention has been implemented. In other words, CBA does not provide a weightage to all the benefits which might provide a false basis for making decisions.

2. Participatory Cost-Benefit Analysis (PCBA)

This is an evolved form of CBA in its scope as it accounts for the relevance of each benefit to the different stakeholders using participatory research appraisal methods. This method improves upon the existing CBA but expands the process of decision-making since a large dataset is required for this method, which makes this process unsuitable for short time-bound projects. Moreover, the availability of data with respect to the relevance of the benefit does not guarantee the true price of the ecosystem service or benefit.

3. Cost Effectiveness Analysis (CEA)

This method is an alternative to the CBA as even though it identifies the cost in economic terms but highlights the benefits in physical units. This method is utilised in those cases where an economic valuation of an ecosystem service or good cannot be conducted with the given resources or datasets. This method has been widely used after the release of the Water Directive Framework (European Parliament and The Council of the European Union 2000).

4. Multi-Criteria Analysis (MCA)

This method measures both monetary and non-monetary benefits based on the several criteria decided by the stakeholders. These criteria decide the weightage and relevance of each benefit. This kind of analysis solely depends on the priorities and objectives of the stakeholders and hence is prone to biases.

As mentioned above, cost-benefit analysis continues to be one of the most prevalent methods in the research community as well as government efforts. This study also pursues cost-benefit analysis primarily with the purpose of providing recommendations to the methods already in use by multiple stakeholders. Moreover, the other methods such as PCBA and CEA could not be pursued because of the limited amount of resources and time available.

Ecosystem-Valuation Methods

The process of ecosystem valuation maps the different benefits associated with the different services and goods produced by the ecosystem to provide economic value to the entire ecosystem. This valuation is necessary for governments, policy-makers and businesses to make informed decisions with respect to resource allocation, invest in specific nature-based solutions to build

adaptive capacity and generate livelihoods. The process has evolved over the years with one example being the development of the System of Environmental-Economic Accounting (SEEA) which is a standard for environmental-economic accounting and provides a framework around the relationship between environment and economy. It analyses the behaviour of individual environmental assets and how they interact with the natural environmental processes in a given spatial area (Ministry of Statistics and Programme Implementation 2021).

The total economic value provided by an ecosystem service or good provides a basis for the application of the valuation methods. The economic value of a product is determined on the usefulness of a product. The total economic value is divided into use and non-use values which further have their respective categories. The category of the economic value determines the type of valuation method which will be employed. Such uses have been identified as benefits in the framework for the purpose of excluding the view of the ecosystem services and goods as merely forms of utility.

Several ecosystem valuation methods have evolved over the years and have been employed to calculate the economic value of different types of ecosystem services and goods. The most commonly used methods are:

1. Deduction Methods (DM)

Such methods calculate the costs of ecosystem services through the costs which would have been incurred in the case of the absence of the ecosystem itself. The different methods included within this category are the Avoided Cost Method (ACM), Replacement Cost Method and Substitute Cost Method.

1.1 Avoided Cost Method (ACM)

The ACM identifies the economic value of an ecosystem by assessing the value of the assets and livelihoods which would have been damaged in case the ecosystem was not available. Some variations of this method include the replacement cost and the substitute cost methods. The first step in ACM involves determining the impact of a disaster or environmental change, which will be followed by assessing the damage for the level of impact. The economic value of the asset and livelihood could be determined using various methods with the most common and straightforward means being the proxy unit method. This method assumes that a similar asset or livelihood will not be built if the damage to the original unit can be avoided. Thus, determining the value of this new asset or livelihood serves as the avoided cost.

ACM has been used most notably in identifying costs related to flood control and carbon emissions through avoided deforestation (Kindermann, et al. 2008) but recently this method has also witnessed some other applications.

This method is limited in its scope as it only considers the cost of the damage which could be avoided based on the assets and livelihoods. This prevents the method from considering sociological implications and costs related to the damage. Moreover, this method also assumes that the replacement of the existing asset or livelihood will remain the same which might not be the case where people may choose alternative options or innovations to completely replace the existing system. ACM also faces the risk of double counting since the ecosystem service might be providing multiple benefits.

2. Revealed Preference Method (RPM)

Such methods infer the cost of the ecosystem by analysing the existing market situations for the preferences made by the individuals. In the case where the ecosystem service or goods are not marketable, then the economic value is determined by analysing the market price of products with similar attributes as the original product. RPM includes methods such as Market Price Method (MPM), Hedonic Pricing Method (HPM), Production Function Method (PFM) and Travel Cost Method (TCM).

2.1 Market Price Method (MPM)

This method involves a market analysis to determine the economic value of the ecosystem services or goods. MPM is used most commonly for ecosystem produced goods which can be traded in the market. A unique advantage of using this method is that it allows to map changes occurring in the market with respect to the price of the good, thus making it easier to understand the preferences of the market.

This method has seen applications in identifying the value of various ecosystem services in China (Kang, et al. 2022) and mangroves in South-East Asia (Malik, Fensholt and Mertz 2015). There has also been evidence of the use of this method in optimising decisions related to land management.

This method has significant barriers for ecosystem goods for which a market does not exist and ecosystem services which are not marketable in nature. Moreover, this method assumes the existence of a perfect market which is often not available due to the presence of irrational buyers and sellers, seasonal variations and local factors of influence. Such reasons do not allow the true price of the goods or services to be reflected, thus leading to incorrect results.

2.2 Hedonic Pricing Method (HPM)

HPM determines the value of an ecosystem good or service by individually calculating the value of the benefits derived from the goods or services. In the case of a forest for example, this method derives the economic value of the forest by identifying the values of benefits derived from the forest which may include forest products such as timber and leaves, recreational value derived from visits by tourists, value saved by reducing pollution, etc. In the case where there is an absence of a market for a specific benefit derived from the ecosystem, the HPM utilises a good or service with similar attributes which acts as a 'surrogate' for valuing the ecosystem services.

HPM is a common method which has been utilised globally by several scholars. The method has been used in identifying different kinds of benefits including recreational and property values derived from estuaries in the US (Opaluch, et al. 1999) and lakes in India (Aswathy and Elsamra 2020). HPM has also been used in agriculture to determine the use value of irrigation water and has also seen functions in identifying the benefits of reducing air pollution in urban India.

One of the most common difficulties faced during the application of HPM is the requirement for large sets of data. This method requires an extensive assessment of the market and requires the existence of either a market for the benefits or the presence of an alternate good or service which can be utilised as a surrogate. Moreover, similar to MPM, this method is also vulnerable to the existence of an imperfect market and variations.

2.3 Production Function Method (PFM)

The PFM, also called the net factor income or the derived value method, is used to determine the value of an ecosystem service or good where these products are used as inputs to manufacture another product. Their value is determined by identifying changes in either the quality or quantity of the final product by changing the proportion of the inputs. For example, in the case of rooftop forests, it reduces pollution in an area. The economic value of the reduction in air pollution from its normal state upon increasing the quantity of rooftop forests will determine the value of the forests.

PFM has found its use in valuing ecosystems on several occasions in India.

In the case of ecosystems, several inputs such as soil, water, biodiversity, temperature, etc. influence the quality of the good produced by the ecosystem. Hence, this method is dependent on large sets of data which are often unavailable. Moreover, this method is not applicable to benefits which do not contribute to the production of some other good, thus overlooking several benefits related to the ecosystem.

2.4 Travel Cost Method (TCM)

The TFM is used primarily for determining the economic value of recreational benefits provided by an ecosystem. This system has been employed most often in developed countries but recently it has also seen applications in developing countries. TCM involves identifying the cost of time and travel based on the number of visits conducted by tourists over a period of time. In other words, the total cost of time and travel reflects the willingness of the tourists to pay to experience the benefit provided by the ecosystem.

TCM has been used in evaluating recreational services of ecosystems situated in both rural and urban areas. Some examples include public parks, lakes and forests.

The method contains several fallacies with respect to travel cost. Most notably, the method becomes illogical in the case where tourists visit multiple places near the ecosystem since the purpose of the visit becomes unclear. Moreover, the price of travel differs greatly in the case where both public and private methods of transportation are available. TCM also ignores the benefits experienced by the tourists during the travel, thus leading to incorrect evaluations.

3. Stated Preference Method (SPM)

Such methods involve the use of a survey to understand the preferences or willingness to pay for a specific ecosystem service or product. For such methods, the participants are directly asked to either state the value of a product or select the value of the product from a set of options after understanding the costs and benefits associated with each. These methods include the Contingent Valuation Method (CVM) and Contingent Choice Method (CCM).

3.1 SPM - Contingent Valuation Method (CVM)

The CVM is one of the most common methods for ecosystem valuation because of its ability to determine both use and non-use values. CVM involves the use of a survey to ask questions from a range of stakeholders based on the goods and services related to the

ecosystem. The stakeholders respond with their willingness to pay for using or experiencing the good or service or their willingness to accept compensation for the loss of the same.

CVM is a method which has been utilised all around the globe to determine the economic values of forests, river basins, watersheds and even entire ecosystems.

This method is based on the preference of the stakeholder and not on the actual behaviour which is observed, thus the process is riddled with biases and errors. There have been some guidelines given to address the biases and errors, but the most significant disadvantage of using this method lies in the core argument which assumes that stakeholders would reveal the prices which they originally used in the markets, however, research suggests that people often do not have the capability to attach values to several services, thus rendering the method inadequate.

3.2 Contingent Choice Method (CCM)

This method is similar to CVM in its scope as it can also be used to determine both use and non-use values. Moreover, CCM also involves a survey and depends upon the responses from the stakeholders. However, unlike CVM, this method provides the participants of the survey with several options, each with different characteristics and costs. Thus, where the participants were responding to their willingness to pay for services and goods from their own expertise, this method provides them with a set of options, thus removing the chances of non-responsiveness. This method is based on the value of the trade-off selected by the participant after receiving complete information about each option.

CCM has been utilised in assessing the economic value of wetlands and coastal ecosystems (McGonagle and Swallow 2005).

This method shares its disadvantages with the CVM. The structure of the survey along with the manner of conduct holds several implications for these methods since they rely on the behaviour of the participant. Moreover, in CCM, all the choices must be familiar to the participant to get better results.

4. Benefit Transfer Method (BTM)

All of the above-mentioned methods require primary data collection which might not be possible for studies with a large sample size. Moreover, these methods also require the availability of both market and statistical professionals. In such a case when such methods could not be pursued, BTM could be employed which considers the findings of existing studies conducted across similar environmental regions to estimate the monetary value of the natural ecosystem.

This is a method where data for the economic value of a service is taken from a 'reference' location and used to make inferences to determine the economic value of the service at the study location. It is important to note that both the locations must be similar based on the objectives of the study. For example, in the case of using BTM to determine the economic value of a service in a wetland (Brander and Schuyt 2010), the reference location must have similar environmental and socio-economic characteristics. One of the earliest use of this method dates back to 2001 wherein BTM was used to calculate the use values of outdoor recreation services (Rosenberger and Loomis 2001).

This method has also been used by Costanza to determine the value of the ecosystem services delivered by 16 biomes. The method has also seen applications in India, China and South-East Asia especially with respect to the valuation of wetlands.

However, there are a few disadvantages linked to this method. Most notably, the method depends on a significant assumption that the quality of the ecosystem is at its most optimum level which might not be applicable to the ecosystems present at the study location. Moreover, several ecosystems provide services which might have not been considered in other studies, thus rendering the BTM ineffective in determining the value of the ecosystem service.

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