Cost-Benefit Analysis of Landscape Restoration: A Stocktake

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Abstract: With the increase in demand for landscape restoration and the limited resources available, there is need for economic analysis of landscape restoration to help prioritize investment of the resources. Cost-benefit analysis (CBA) is a commonly applied tool in the economic analysis of landscape restoration, yet its application seems limited and varied. We undertake a review of CBA applications to understand the breadth, depth, and gaps. Of the 2056 studies identified in literature search, only 31 met our predefined criteria. Three studies offered a global perspective, while more than half were conducted in Africa. Only six countries benefit from at least 2 CBA studies, including Brazil, Ethiopia, Kenya, Vietnam, South Africa, and Tanzania. About 60% focus on agroforestry, afforestation, reforestation, and assisted natural regeneration practices. Only 16% covered all cost categories, with opportunity costs being the least covered. Eighty-four percent apply direct use values, while only 16% captured the non-use values. Similarly, lack of reliable data due to predictions and assumptions involved in data generation influenced CBA results. The limited number of eligible studies and the weaknesses identified hereinabove suggest strong need for improvements in both the quantity and quality of CBA to better inform planning, policies, and investments in landscape restoration.

Keywords: cost-benefit analysis; landscape restoration; global; stocktake

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1. Introduction

There is a growing demand for restoration globally aimed at stopping further degradation and reversing degradation. Forest degradation, soil erosion, peatland, wetland drainage, and salinization have been the leading causes of land degradation globally over the past 50 years. According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [1], 75% of the global land surface is significantly degraded, 66% of the ocean area is experiencing increasing cumulative impacts, and over 85% of wetlands have been lost. This has affected almost a quarter of the world's total land area, and the damage is felt through the loss of ecosystem goods and services. The damage costs the world an estimated USD 6.3 trillion a year in lost ecosystem service value, which includes climate regulation, clean air, recreational opportunities, freshwater, and fertile soils [2]. Besides, due to land degradation, the livelihoods of about half a billion people, especially poor people who depend on agricultural and forestlands, are jeopardized. Decreasing land productivity threatens water and food security, destabilizes sustainable development, and results in civil conflicts and human migration.

Global efforts have been put in place to stop further degradation and reverse degradation through restoration of forest and landscapes ecosystems. Over the last decade, there have been global restoration initiatives, including 'The Bonn Challenge' and 'The New York Declaration on Forests (NYDF)'. The Bonn Challenge is a global effort to bring 150 million hectares of the world's deforested

and degraded land into restoration by 2020, and 350 million hectares by 2030[2], while the NYDF is a political declaration among governments, companies, indigenous peoples, and civil society to take action to halve the loss of natural forests by 2020 and halt it by 2030[1]. Within Africa, the African Forest Landscape Restoration Initiative, AFR100 aims to restore 100 million hectares of land in Africa by 2030[3]. Specific countries have also set definite restoration goals; for example, Kenya has committed to restoring 5.1 million hectares of degraded land[4], and Malawi committed to about 4.5 million hectares of land by 2030 [3].

Restoration is generally a costly undertaking, partly because it often begins after the environmental degradation is well-advanced and expensive to reverse, and is often labor and resource-intensive [4]. Funding sources for investment in landscape restoration include (1) Private finance, where capital is managed mainly to earn a financial return for the investor. (2) Public finance where funding comes from the government bodies. Public finance can further be divided into international donor support and domestic public expenditure. In public finance, public investments are largely made to generate economic, environmental and social benefits for the public. However, there may be a return to the government. (3) Philanthropic finance, which is charitable giving by individuals or organizations, typically with no intention of earning a financial return [5].

Numerous environmental, economic and social benefits are generated when degraded lands are restored. These benefits may range from conservation of biodiversity, creation of jobs, improvement in agricultural productivity, and so on. Despite the numerous benefits accruing from restoration, funding for landscape restoration falls short by about USD 300 billion a year [2]. Investment is inadequate for several key reasons, among them: (1) many of the benefits are public goods, which are difficult to monetize; (2) the long-term nature of investments does not match investors' desire for liquidity, i.e., restoration usually requires large investments upfront and has long lags before generating benefits, and (3) landscape projects are perceived to be risky. Overall, landscape restoration activities are often misunderstood as involving high up-front costs and low rates of return, and these ideas persist because few evaluations of restoration activities include a comprehensive and objective accounting of restoration's ecological and economic impacts. Economic analysis can encourage investment in restoration by clearly laying out the benefits and costs of restoration projects and their distribution among stakeholders. It is also instrumental in prioritizing scarce resources accordingly.

Cost-benefit analysis (CBA) is the commonly applied approach in the economic analysis of landscape restoration. However, compared to the significant number of landscape restoration projects and studies globally, relatively few CBA studies have been conducted on restoration projects. Reference [6] conducted a review of the rehabilitation of degraded dryland ecosystems. They found that, while numerous studies have been undertaken on restoration and rehabilitation of degraded ecosystems, there remains a gap in cost-benefit analysis of these interventions. They largely attributed this to missing data on the benefits and costs accruing from the restoration projects. Similarly, in a review of more than 2000 restoration case studies, the "The Economics of Ecosystems and Biodiversity (TEEB)[5] "2009 study found that less than 5% of the case studies provided meaningful cost data, and none provided an analysis of both costs and benefits [7].

While CBA continues to be a primary approach of economic assessment, adequate use of the tool requires a clear understanding of its limitations and pitfalls. Thus, the paper seeks to understand the breadth and depth of existing CBA studies. It also highlights gaps in the existing CBA studies on landscape restoration and how further studies can address these gaps.

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2. Background

2.1. Brief Background on Landscape Restoration

　　Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed [8]. The goal is to repair the ecosystem to its integrity and its health and to reverse land degradation, increase the resilience of biodiversity, and deliver important ecosystem services [9,10]. Ecological restoration also includes forest and landscapes restoration, which is a process that aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscapes. A key feature of forest and landscapes restoration is that a combination of forest and non-forest ecosystems, land uses, and restoration approaches can be accommodated within a landscape to achieve sustainable food production, ecosystem services provisioning, and biodiversity conservation [11].

　　Landscape restoration is not just a matter of planting trees but also involves assisting the recovery of a damaged or destroyed ecosystem. The restoration activities range from small local activities carried out by individuals or community groups through to regional, country, and even global-scale activities involving multiple agencies and large numbers of people [12]. Restoration can either be achieved through natural regeneration or active restoration. For example, natural forest regeneration is the spontaneous recovery of native tree species that colonize and establish in abandoned fields or natural disturbances. This process can also be assisted natural regeneration, whereby it is assisted through human interventions, such as fencing to control livestock grazing, weed control, and fire protection [13]. Active restoration, on the other hand, involves human involvement in a range of ways and involves a considerable cost in terms of labor and time [14]. It may require planting of nursery-grown seedlings, direct seeding, and/or the manipulation of disturbance regimes (for example, thinning and burning) to speed up the recovery process. This is often at a high cost to establish the vegetation structure, reassemble local species composition, and/or catalyze ecological succession.

　　Effective restoration should aim at the reestablishment of fully functioning ecosystems. To ensure effective restoration and achieve sustainability and resilience into the future, Reference [15] advocates for four principles of restoration; (1) restoration should increase ecological integrity (2) restoration should be sustainable in the long term (3) restoration ought to be informed by the past and future, and (4) the restoration benefits and engages society through direct participation. Ecological integrity has been defined as the "ability of an ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat [16].

　　Several factors ought to be considered while deciding on the restoration strategy to be employed; the specific ecosystem resilience, the land-use history, the landscape context, the goal for the restoration, and available resources [14]. In addition, depending on the level of land degradation, and the intended impact of restoration on land use and land-use changes [17] distinguishes four intensities/levels of restoration; ecological intensification, recovery/regeneration, reparation/recuperation, and remediation. Table 1 presents a summary of some of the commonly practiced landscape restoration options/strategies in different land use or ecosystem types adapted from Reference [18,19]. A detailed explanation of most of these landscape restoration practices and their restoration goals is provided by Reference [19].

Table 1. Landscape restoration options for different land-use types.

Land Use/Ecosystem Type	Landscape Restoration Options/Strategies
Forest land	- Afforestation and reforestation - Planted forests and woodlots - Natural regeneration - Silviculture - Assisted natural regeneration/Reclamation/Rehabilitation

Table 1. *Cont.*

Land Use/Ecosystem Type	Landscape Restoration Options/Strategies
Agricultural land	- Agroforestry - Integrated soil fertility management - Climate-smart agriculture - Improved fallow - Extended rotations in plantations - Farmer managed natural regeneration (FMNR)
Protective land and buffers	- Mangrove restoration - Watershed protection - Erosion control - Bamboo planting along water bodies and wetlands
Urban areas	- Green and blue infrastructure in urban areas
Wetlands	- Wetlands restoration and conservation
Freshwater (Rivers/lakes)	- River and lake restoration - Sediment management - Pound restoration - Integrated watershed management
Grasslands and Shrublands	- Assisted natural regeneration

Adapted from Reference [18,19].

2.2. Economic Cost-Benefit Analysis of Landscape Restoration

Generally, cost-benefit analysis can be either financial or economic; there are similarities and differences in both. In both analyses, the net benefits of a project investment are estimated, and the estimation is based on the difference between with-project and without-project situations. While conducting both analyses, the assumption of constant prices is made and, the techniques of evaluating costs and benefits through the discounting method remain the same. However, in financial CBA of projects, benefits and costs are compared to the enterprise, while, in economic CBA, benefits and costs are compared to the whole economy.

The true value that a project holds for society is highly considered in economic analysis. It considers all members of society and measures the project's positive and negative impacts in terms of willingness to pay (WTP) for units of increased consumption and to accept compensation for foregone units of consumption. Importantly, the economic analysis covers even the costs and benefits of goods and services which have no market price. In financial analysis, the project's sustainability and balance of investment is checked using market prices. In economic analysis, the legitimacy of using national resources to a certain project is measured using economic price, which has been converted from the market price by excluding tax, profit, subsidy, etc. In financial analysis, the taxes and subsidies included in the price of goods and services are integral parts of financial prices, but they are treated differently in economic analysis.

There is also a significant difference between financial and economic analysis in the way they treat their external effects (costs and benefits). Such externalities, health effects and non-technical losses tend to be valued in economic analysis. Both financial and economic analyses are supposed to include such externalities (side effects). In addition, economic and financial returns in both analyses do not converge. This is because what counts as a benefit or a cost to the project operator does not necessarily count as a benefit or cost to the economy. When restoration is viewed through a financial accounting lens that ignores public values and the inter-generational nature of restoration, the conclusions that are drawn tend to favor investing in less restoration than society would prefer [20]. For this review, we consider those studies that conducted an economic CBA.

There are nine steps for conducting an economic cost-benefit analysis for landscape restoration as outlined by Reference [21]: (1) Specify the set of restoration transitions: Define which degraded land

uses will be restored and the activities that will be used to restore them, (2) Define the stakeholders who will be impacted by restoration, (3) Catalogue the impacts and define how they will be measured: Which impacts matter most to the stakeholders, who will be impacted by restoration and what units of measurement are most useful for measuring them? (4) Predict the impacts quantitatively over the time horizon of the project: Use ecosystem service models, household surveys, stakeholder engagement, and other estimation methods to quantify the expected impacts of restoration activities, (5) Monetize all of the impacts: Use appropriate direct and indirect methods to value the estimated impacts, (6) Discount benefits and costs to obtain present values: Select appropriate discount rates to make streams of future benefits and costs comparable at the present moment, (7) Calculate the Net Present Value (NPV) of each alternative: Subtract the discounted stream of implementation, transaction, and opportunity costs from the discounted stream of benefits as shown in the equation.

$$Net\ Present\ Value = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+r)^t},$$

where B_t is the benefits from restoration at time t; r is the discount rate, and C_t is the total restoration costs at time t.

(8) Perform sensitivity analysis: The results of the CBA depend on assumptions, and the sensitivity of the results to changes in the underlying assumptions should be evaluated, (9) Make policy recommendations: From a Pareto-efficiency perspective, the restoration activities with the largest NPV should be recommended.

Overall, several categories of costs and benefits ought to be accounted for in a comprehensive CBA. The total cost of landscape restoration depends on how degraded a site is and how difficult it is to restore. Additionally, costs vary according to geography, degradation category, the objectives and contexts of specific restoration activities, and the types of restoration methods that are used. There are three investment phases involved in forest and landscape restoration: (1) Phase 1 is the initial readiness investment or up-front investment. During this phase, investments flow towards designing projects, planning, stakeholder engagement and participation, developing safeguards and capacity building. (2) Phase 2 is the investment for actual implementation. During this phase, it may involve policy reforms, implementation of the restoration of degraded lands, educational activities, land-use zoning and strengthening of capacities. (3) Phase 3 focuses on sustained financing for landscape ecosystem services and product services, for self-sustaining funding of the project's long-term running costs [5,18].

Similarly, these costs can be broadly categorized into three: (1) Implementation costs (usually very high); these costs include costs of raw materials, such as tree seedling, fencing, labor costs, transport costs, and other costs. In addition, this includes costs incurred in capacity building and training the local stakeholders. They are mostly the direct costs incurred in the project. Land users usually incur these costs, or they can be covered by the project. (2) Opportunity cost: this represents the cost of foregone opportunities and, represents the tangible goods and services that were foregone to make restoration possible. To capture the opportunity cost, it is necessary to conduct a baseline before implementing the project. (3) Transaction costs; transaction costs represent the cost for landowners and implementing agencies to identify viable land to restore and negotiate over terms that ensure restoration meets both local and national priorities [21]. These may include monitoring costs, as well.

Additionally, for a comprehensive economic CBA on restoration, the benefits to be considered ought to include both use and non-use values, as well as private and public benefits arising from the restoration, i.e., the total economic value of the restoration. The total economic value (TEV) of an investment attempts to estimate and monetize all economic impacts of the investment [22]. TEV recognizes that benefits and costs radiate far beyond the landowner or investor to the global effects. The TEV approach accounts for both the use and non-use benefits values [22].

The use-values are categorized into:

(a) Direct use values: These relate to the benefits obtained from the direct use of an ecosystem. Most of the direct products have market values, such as timber, poles, charcoal, gum arabica, and medicine, as well as other non-timber forest products (NTFPs), such as wild fruits, honey, fodder, crop harvests, recreation value, and others. They are the most straightforward benefit category to capture and account for since the data on quantities and value is available for most of the restoration projects.

(b) Indirect use values: These are usually associated with regulating services. These may include services, such as carbon sequestration, water treatment and regulation, soil erosion control, pollination, and so on.

(c) Option values: These include valuing ecosystem services for the option of future use, such as medicinal purposes.

Non-use values, on the hand, are categorized into:

(a) Bequest value: This captures the value arising from the satisfaction of knowing that future generations will access nature's benefits. This value is concerned with intergenerational equity.

(b) Altruist value: This value concerns intragenerational equity, i.e., the satisfaction of knowing that other people can also access nature's benefits.

(c) Existence value: This value is derived from the satisfaction of knowing a certain species exists. For example, indigenous trees, endangered species, and medical trees.

Direct use values are relatively easy to identify and value since they are tangible and usually have market values. On the other hand, indirect use and non-use value pose a challenge in valuation, and the valuation methods employed are often time and resource intensive. Several studies, such as Reference [23–25], detail how to adequately value these benefits through a wide range of valuation methods, including: production methods, choice experiments, contingent valuation methods (CVM), hedonic pricing, travel cost methods, cost-based approaches, benefit transfer, and mean-variance analysis.
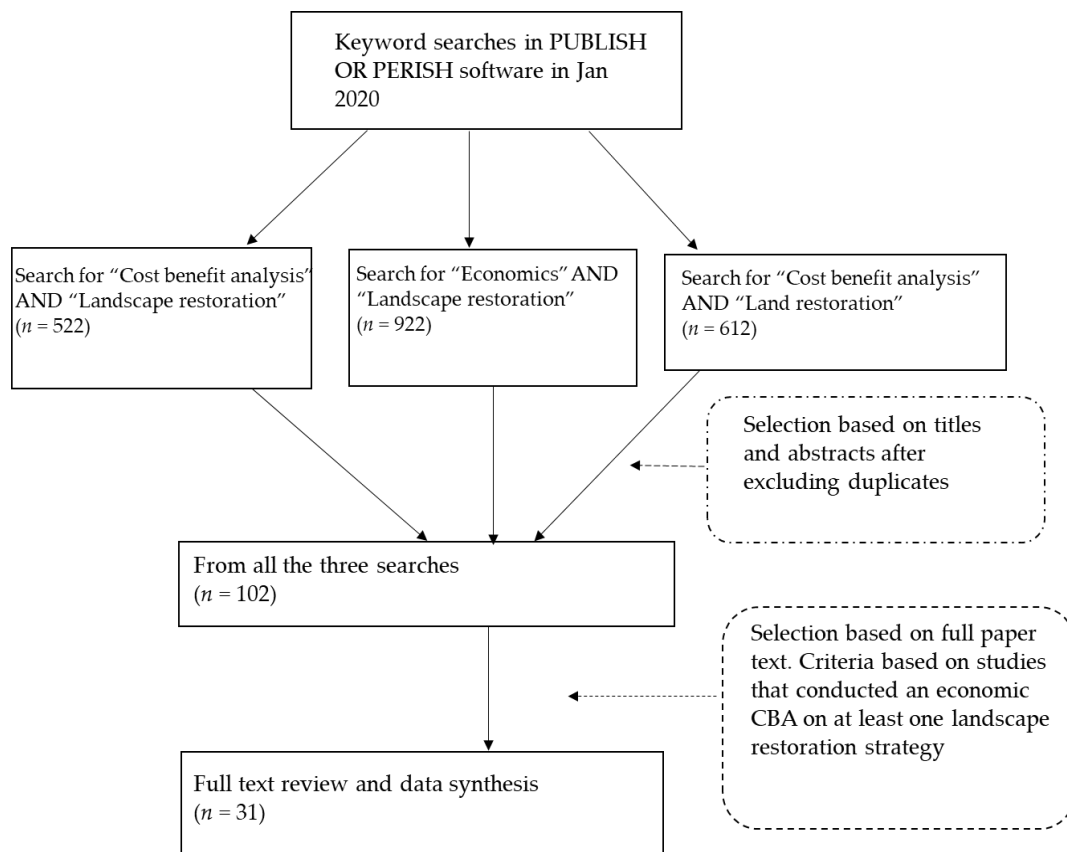
3. Materials and Methods

Reviews aim to identify the most reliable research on a given question in a manner that minimizes selection biases in the literature search and screening process [26]. A comprehensive review of studies was conducted on cost-benefit analysis for landscape restoration by following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[6] guidelines. Figure 1 shows the process of the review followed. The first step was a keyword search using the "publish or perish"[7] software. We searched for a combination of three phrases (1) "Cost-benefit analysis" and "Landscape restoration" (2) "Economics" and "Landscape restoration" (3) "Cost-benefit analysis" and "Land restoration". The search for "Cost-benefit analysis" and "Landscape restoration" generated 522 studies, while the search for "Economics" and "Landscape restoration" generated 922 studies and that of "Cost-benefit analysis" and "Land restoration" generated 612 studies.

For step two, the total 2056 publications were filtered down by titles and abstracts, resulting in 102 relevant publications. For the 102 publications, after reading through the full text, 31 publications were found that either entirely focused on CBA of landscape restoration or had a component of CBA of landscape restoration. The 31 publications are the ones that have been considered in the review, and a summary of these studies is presented in the Appendix A (Table A1). The summary is based on restoration options/strategies, country of focus, the year the study was conducted, data sources, the time considered in the CBA analysis, benefits and costs components, sensitivity analysis conducted, and the reported NPV. These variables are discussed in detail in Section 4 under results.

Figure 1. Review process of the studies on cost-benefit analysis (CBA) of landscape restoration.

4. Results

From the review process explained in the materials and method section, we found 31 publications of CBA on land restoration. In this chapter, we discuss these publications based on several attributes.

4.1. Country of Focus and Study Year

The 31 studies under review were conducted in about 20 countries distributed across five regions: Africa (10), Europe (2), N. America (2), S. America (3), and Asia & Middle East (3). Almost all the 31 studies reviewed, were conducted in a single country and only five focused on multiple countries. Of the five, three studies focused on a global perspective [18,27,28], while one focused on multiple African countries[8] [29], and one focused on several countries in Latin America[9] [7]. As shown in Figure 2, countries that have had the most CBA studies conducted there over the years had, on average, three studies and include South Africa, Brazil, Tanzania. Ethiopia, Kenya, and Vietnam, where each have had two CBA studies conducted.

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[8]　Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo, Côte D'Ivoire, Djibouti, DR Congo, Egypt, Eritrea, Ethiopia, Gabon, Ghana, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Swaziland, Togo, Tunisia, Uganda, UR of Tanzania, Zambia, Zimbabwe.

[9]　The focus Latin America countries include: Mexico, Argentina, and Chile.
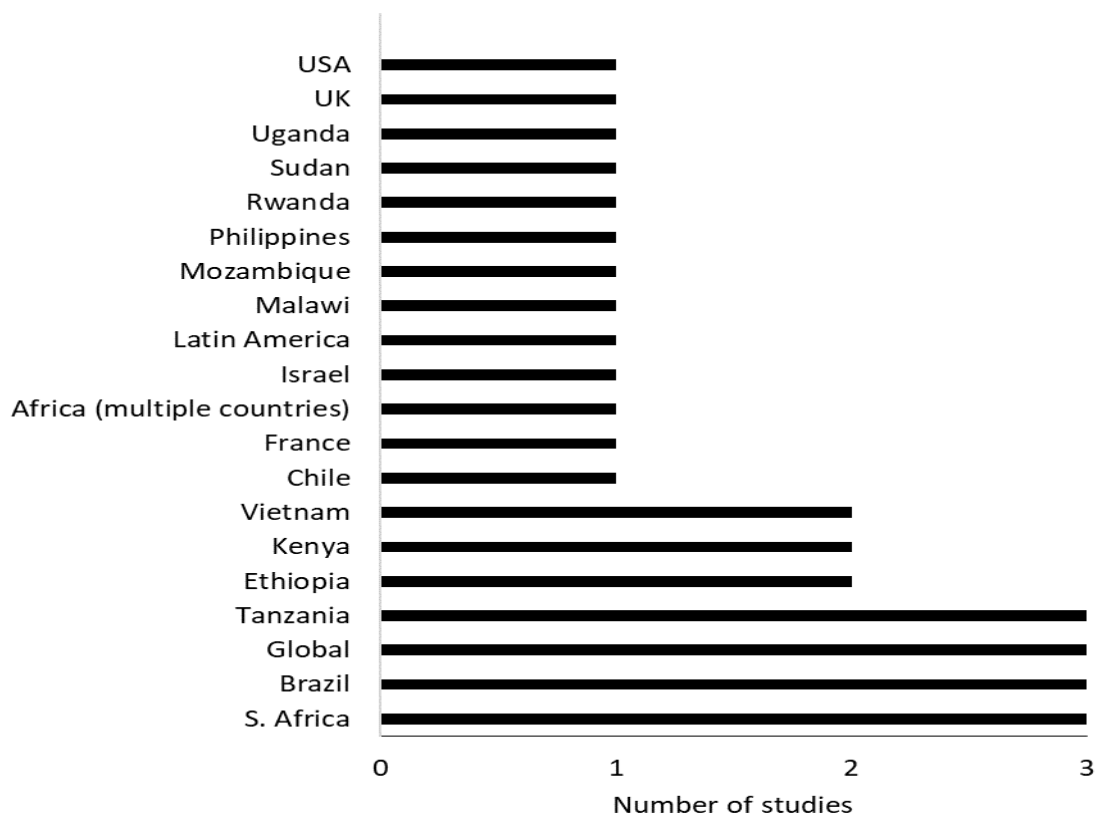
Figure 2. Distribution of CBA studies across various countries.

Figure 3 presents a trend of the year studies on restoration under review were conducted. The oldest study we reviewed was conducted in 1997 in France and focused on landscape restoration using hedgerows [30]. The was no study under review conducted between 1997 and 2005. The most recent studies were conducted in Kenya by Reference [31] and in Brazil by Reference [32].
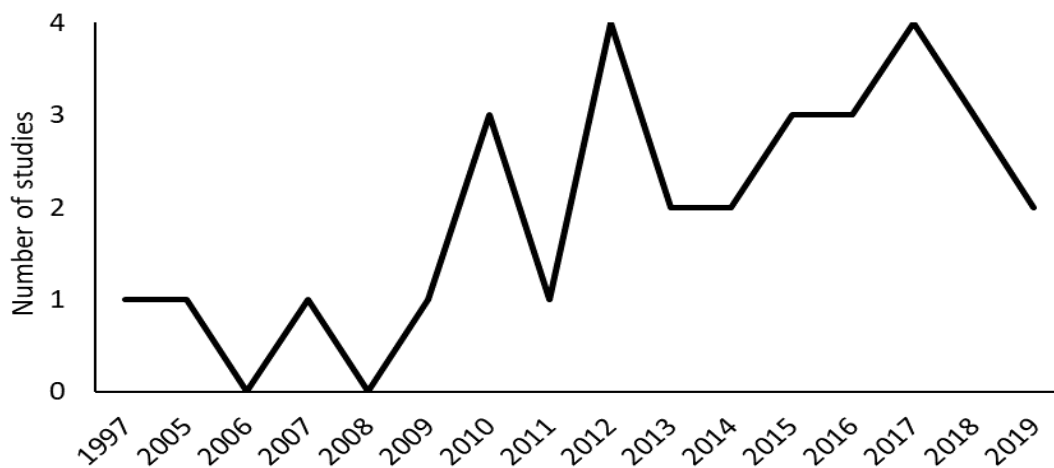

Figure 3. Year the CBA studies were conducted.

4.2. Landscape Restoration Options

As shown in Table 2, the CBA studies we reviewed were conducted for different types of restoration options/strategies, including: reforestation & afforestation, agroforestry, biofuel agroforestry, participatory forest management, woodlots establishment, sustainable land management practices, natural regeneration, assisted natural regeneration, mangrove restoration, clearing of invasive alien

species, urban area restoration, and buffer areas restoration. The specific studies are presented in the Appendix A in Table A1. Some studies focused on only one type of restoration, while others conducted a comparison of different restoration options depending on the land use type. One of the most comprehensive CBA study we reviewed was conducted in Kenya by Reference [31] and compared returns for several landscape restoration strategies, including: afforestation or reforestation of degraded natural forests, rehabilitation of degraded natural forests, agroforestry in cropland, commercial tree and bamboo growing on potentially marginal cropland and un-stocked forest plantation forests, tree-based buffer zones along water bodies and wetlands, tree-based buffer zones along roads, and restoration of degraded rangelands. Overall, the most popular landscape restoration options for which CBA studies were conducted include: reforestation and afforestation (8), agroforestry (7), farmer-managed natural regeneration/Assisted natural regeneration (5), soil and water conservation practices (5), and establishment of woodlots (4). Further still, Reference [20] assessed the net present value of the Bonn Challenge, which is a global effort to restore 350 million hectares of degraded forest landscape.

Table 2. Landscape restoration options considered in the CBA studies reviewed.

| Landscape Restoration Options	Number of Studies	Countries of Focus
Reforestation and Afforestation	8	Brazil, Chile, Ethiopia, Kenya, Uganda, USA, Chile, Tanzania
Agroforestry	7	Brazil, Ethiopia, Kenya, Sudan, Tanzania, Uganda, Malawi
Participatory forest management/FMNR/ANR	5	Brazil, Ethiopia, Malawi, Vietnam, Tanzania
Soil and water conservation measures and SLM practices, e.g., bunds, terracing, zero tillage,	5	Ethiopia, Kenya, Malawi, Vietnam, multiple countries in Africa
Establishment of woodlots	4	Ethiopia, Malawi, Uganda, Tanzania, Rwanda
Mangrove restoration (protective and planting)	3	Mozambique, Philippines, Vietnam
Natural regeneration	2	Uganda, Rwanda
River restoration/habitat restoration for river catchment	2	Israel, UK
Dryland forest restoration	2	Latin America, Chile
Alien vegetation clearing for water yield and tourism	2	South Africa (2)
Biofuels agroforestry or biofuel for energy, thus reducing deforestation	1	Tanzania,
Landscape restoration using hedgerows	1	France
Urban area restoration (green and blue infrastructure in urban areas)	1	Multiple countries
Tree-based buffer zones along water bodies and wetlands	1	Kenya
Tree-based buffer zones along roads and riparian land	1	Kenya
Restoration of degraded rangelands	1	Kenya
Subtropical thicket restoration	1	South Africa

Figure 4 below shows reported NPV (positive or negative) by the various CBA studies for the different landscape restoration options. For some of the restoration options, all the studies conducted reported positive NPV; agroforestry (8 studies), soil and water conservation (5), mangrove restoration (3), and alien vegetation clearing (3). However, for some of the restoration strategies, some of the studies reported negative NPV; for reforestation and afforestation, the number of studies that reported positive NPV (4) was equal to those that reported negative NPV (4). For other restoration options—FMNR/ANR and woodlot establishment, the number of studies that reported positive NPV was higher than those which reported negative NPV. None of the restoration strategies had more studies that reported negative NPV compared to those that reported positive NPV.
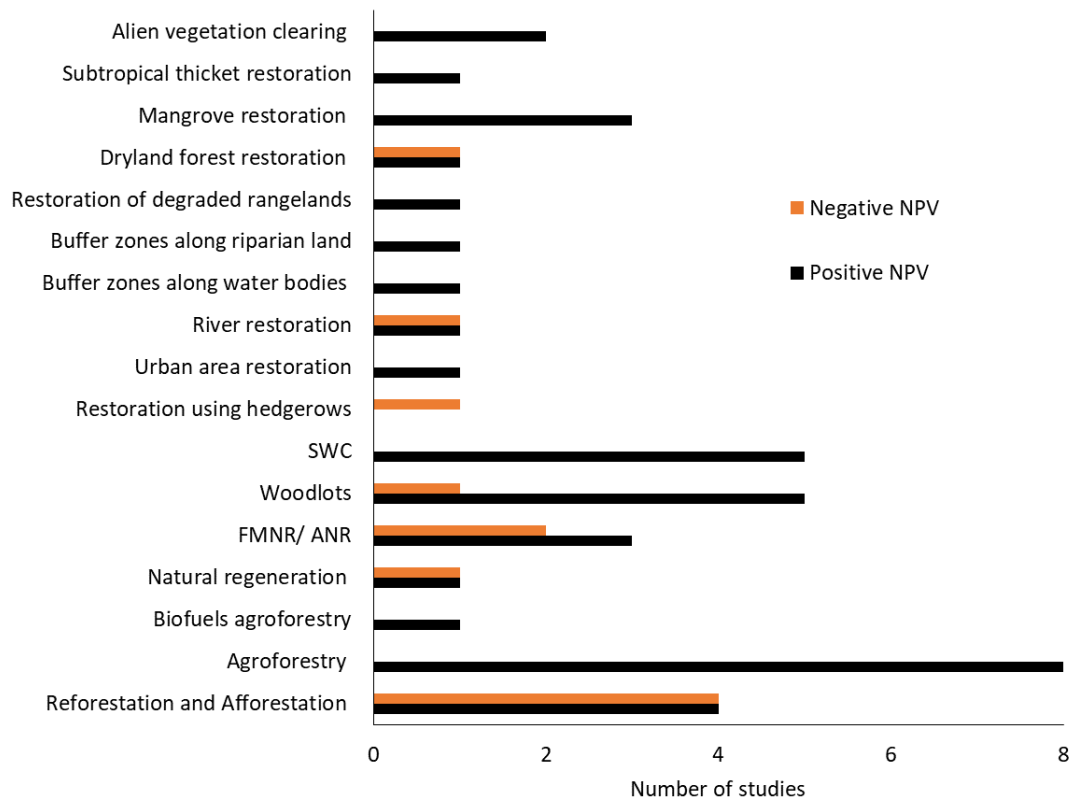
Figure 4. Reported Net Present Value (NPV) for the various landscape restoration type by the reviewed studies.

4.3. Age of Restoration in the CBA Studies

Figure 5 shows the time in years for which different studies under review considered. A higher number of CBA studies, (8) covered restoration benefits and costs for 16–20 years. Another six studies covered between 21–25 years. The maximum duration that was considered was 100 years by two studies, Reference [33] in Mozambique and [30] in France. A further three CBA studies, Reference [34–36], covered restoration benefits and costs for 50 years.
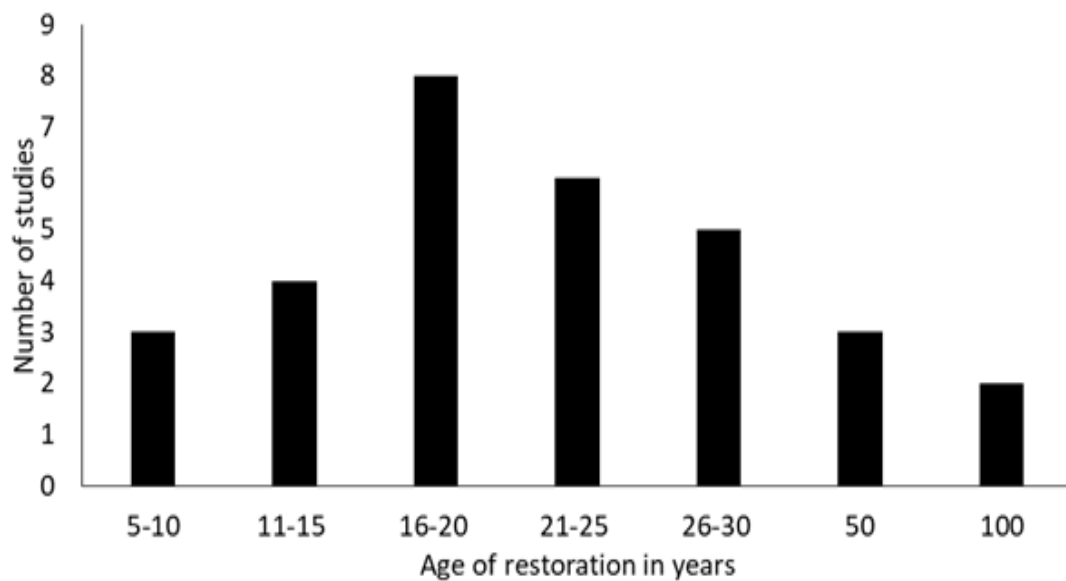
Figure 5. Restoration project timeline considered in the CBA studies.

4.4. Data Source

The CBA studies we reviewed sourced data from different sources; 12 studies used primary data, 11 applied secondary data, and the remaining 8 used both primary and secondary data. For primary data, various studies applied different data collection methods and techniques, as shown in Figure 6. Approximately seven studies used expert discussions, key informants' interviews (KIIs) or focus group discussions (FGDs). Others employed other data collection techniques, including: surveys, reviewing budgets, spatial analysis, and field observations.
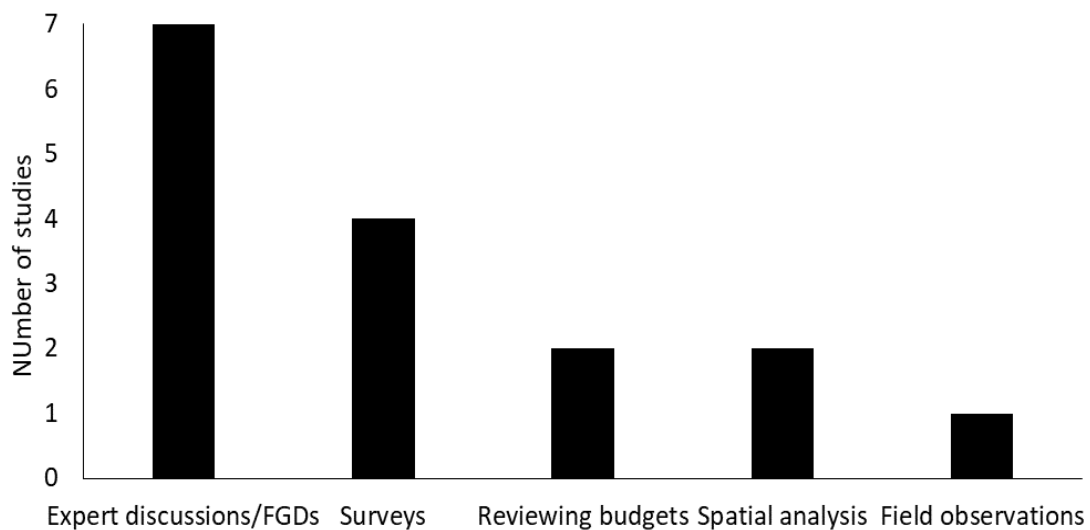
Figure 6. Primary data collection methods employed in the restoration CBA studies.

For those studies that considered indirect use and/or non-use benefits in their analysis, different approaches were applied in valuing these benefits since they mostly do not have a market value. Three studies applied the contingent valuation method, and at least one used either hedonic analysis, travel cost method, or benefit transfer method.

4.5. Benefits and Cost Components in the CBA Studies

Figure 7 shows the proportion of studies that considered different benefits and cost categories. Most of the studies accounted for the use-values only (either direct use, indirect use, or both) and only around 16% accounted for the total economic value of the project (both use and non-use values). About half the studies accounted for both direct and indirect use-values. Of these, the indirect use benefit that was mostly considered in these restoration studies was carbon sequestration. Other indirect use benefits that were accounted for include: erosion control, stormwater control, air regulation, temperature regulation, recreational value, avoided nutrient loss, nitrogen fixation, soil fertility improvement, and aquifer recharge. Non-use values that the reviewed studies accounted for include: aesthetic value, bequest (inheritance) values, and existence value.

The studies applied different valuation methods to value the respective benefits, as shown in Table 3. A more detailed explanation of these benefits by the specific study is provided in Appendix A, Table A1. The provisioning services were considered in almost all the studies. They were commonly assessed by collecting primary/secondary data on the quantities of these goods and valuing them at the current market price. Carbon sequestration was valued by either spatial analysis (e.g., Reference [7,37]) or sourcing the quantities from secondary data and valuing them at the market price of carbon. Contingent valuation method was applied by several studies in valuing benefits, including: air pollution & regulation [38], public benefits [30], cultural, aesthetic & recreation values [35], and inheritance and bequest values [39].
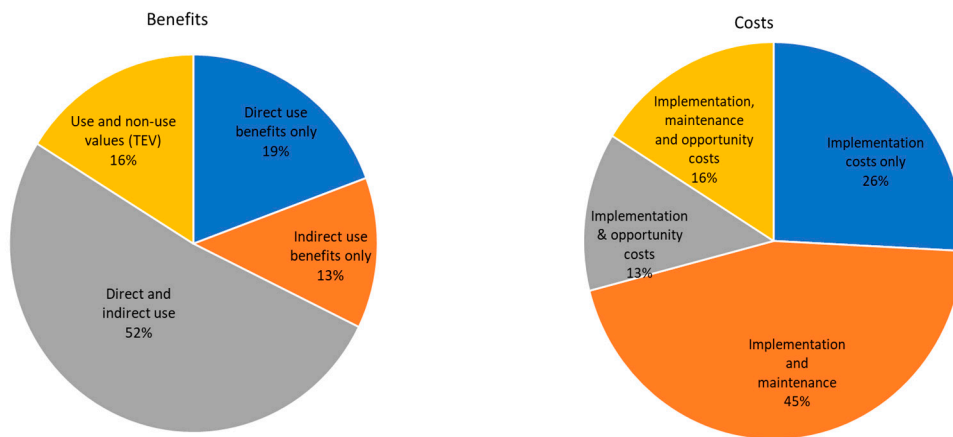
Figure 7. Benefits and cost categories considered in the CBA studies reviewed (*n* = 31).

Table 3. Valuation methods applied across various benefits.

Benefits	Valuation Methods	
Timber, wood fuel, non-timber forest products (NTFPs), livestock, yield benefits	-	Primary data valued at existing market price
	-	Expert opinion
Tourism	-	Value of tickets paid at the entrance
	-	Travel cost method
	-	Spatial analysis
Carbon sequestration	-	Secondary data valued at the market price of carbon
Public benefits	-	Contingent valuation methods, i.e., assessing willingness to pay for these benefits
	-	Hedonic method
Air pollution and air regulation	-	Contingent valuation method
	-	Benefit transfer
	-	Hedonic methods
Stormwater control/reduction	-	Benefit transfer
	-	Replacement cost method
Increased soil fertility	-	Benefit transfer
	-	Avoided cost
Soil erosion control	-	Benefit transfer
Temperature regulation	-	Benefit transfer
Cultural, aesthetic and recreation	-	Contingent valuation method; assessing willingness to pay
Positive health effects	-	Benefit transfer
	-	Secondary data with simulations
Biodiversity recovery	-	Benefit transfer
Inheritance and bequest values	-	Contingent valuation methods
Total economic value for global studies	-	Secondary data and benefit transfer particularly from the TEEB valuation database

Benefit transfer method was frequently applied in valuing many indirect use benefits, such as air pollution & regulation, biodiversity improvement, soil fertility, soil erosion control, temperature control, positive health effects, recreation, and stormwater control. A comprehensive example of the use of benefit transfer is in Reference [27], where they used data collected from 94 studies, from which they created a database of benefits and costs for conducting CBA in seven biomes. In addition, Reference [18] used secondary data and the comprehensive TEEB database due to Reference [40] in valuing benefits while assessing the CBA of forest landscape restoration within the Bonn Challenge for six different biomes. In the absence of site-specific valuation information, benefit transfer is an alternative to estimating non-existing values. It adapts existing valuation information to a new context (location or time), and it is principally useful when there are budget and time constraints with the

collection of primary data [24]. However, there is a need to ensure that the ecological conditions are the same; otherwise, the value may be overstated or understated.

Hedonic pricing method was the least frequently applied valuation method; only one study used the approach in valuing stormwater control and air pollution control [34]. The study employed the hedonic models through controlling for the price of housing in different locations. The reason the hedonic method is rarely applied is that the data required can be quite intensive. Similarly, this method works well if markets can pick up quality differentials, which may not be the case for agricultural and forest land, due to the non-observability of some attributes [23]. Further still, Reference [31] applied the replacement cost approach to value the soil fertility and the avoided loss approach to value soil erosion control.

Three cost categories were considered in the studies we reviewed, as shown in Figure 8: implementation costs, maintenance costs (mostly annual costs of maintaining the restoration infrastructure), and opportunity costs (cost of foregone opportunities). All the CBA studies we reviewed considered implementation cost since this is the most direct cost in restoration and is easily captured. Approximately 25% considered only the implementation costs, and a further 45% covered both implementation and maintenance costs—only 16% of the reviewed studies included all the three cost categories. Implementation and maintenance costs were mostly sourced from the costs incurred in the projects. Implementation costs included the investment costs, such as seedlings, materials, and other inputs labor, and training costs, among others. Maintenance cost includes monitoring and transaction costs. For opportunity cost, on the other hand, the studies had to conduct baseline assessments to ascertain the value of foregone opportunities. For example, Reference [41] assessed the baseline situation of agriculture and grazing, which was translated into the opportunity cost of the land.
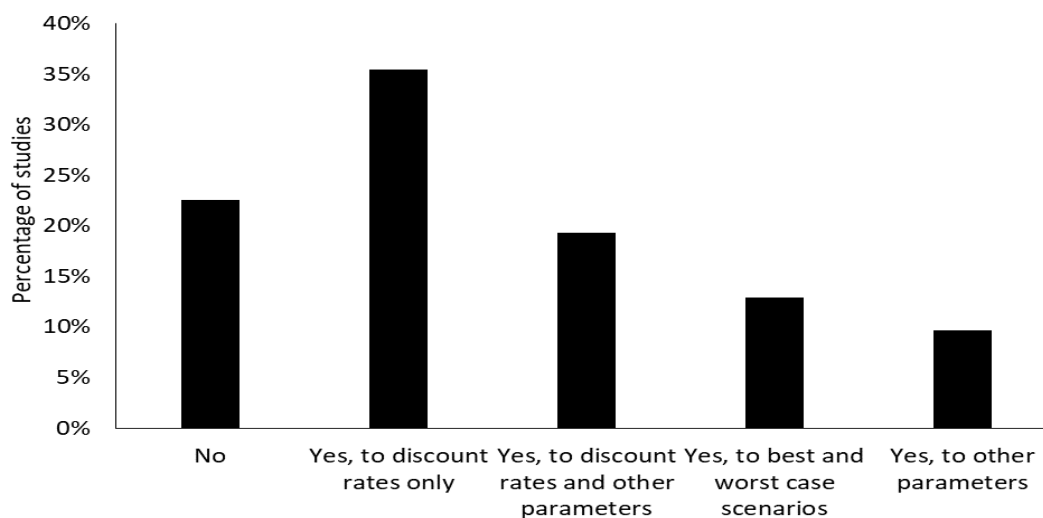

Figure 8. Sensitivity analysis across the CBA studies under review ($n = 31$).

4.6. Sensitivity Analysis

The uncertainties in the entire CBA process, such as fluctuating prices, discount rates, and unseen events within the restoration lifetime, can affect the estimated results especially when the CBA is conducted ex-ante. Hence, after conducting a CBA, it is necessary to conduct a sensitivity analysis by altering various parameters of the estimation, such as the discount rate or prices. Alternatively, one may conduct a Monte Carlo simulation. A Monte Carlo simulation is similar to sensitivity analysis in that it demonstrates how a project's profitability varies. However, instead of altering one input variable and analyzing how that changes in that variable affects the project viability, a Monte Carlo simulation attempts to model uncertainty across multiple inputs assumptions. The model is run thousands of times to understand different possible outcomes and the likelihood of them occurring [19]. Hence, it is more rigorous and robust compared to regular sensitivity analysis.

Figure 8 shows the proportion of studies under review that conducted a sensitivity analysis to test the validity of their results. Of the 31 studies we reviewed, none of the studies applied the rigorous Monte Carlo simulation. Approximately 23% of the studies did not conduct any form of sensitivity analysis. The majority of the studies (about 35%) conducted a sensitivity analysis by varying the discount rates only. Additionally, a further 19% varied the discount rates and other parameters, such as carbon prices, products prices, maintenance costs, and so on. Approximately 13% tested the validity of the CBA results by varying the best- and worst-case scenarios by assuming a very optimistic scenario where most of the assumptions hold and a very pessimistic scenario where most of the assumptions do not hold. Still, 10% of the reviewed studies only varied other parameters without varying the discount rate.

5. Discussion

We present a discussion of the results with respect to the quantity and quality of CBA for landscape restoration and the implications for moving forward with restoration in terms of planning, policies, and investments. There is a need to grow the quantity of evidence in specific areas, as well as economic evidence to make restoration attractive to investors. A number of areas for improvement emerge from our analysis. These include capturing all costs categories; going beyond direct use values; capturing public benefits; sensitivity analysis; and the need for standardization and or guidance. We briefly discuss each below.

5.1. Capturing All Costs Categories

Most of the studies do not account for all the costs associated with restoration, thus overstating the profitability of restoration. All the reviewed studies accounted for implementation costs, but relatively few covered all the cost categories (16%). The least accounted for cost category is the opportunity cost; probably because it is often difficult to estimate this cost since it is not a direct cost. Estimating the opportunity cost requires a baseline assessment to identify the foregone uses of the land. For example, Reference [41] assessed the baseline situation of agriculture and grazing, which was translated into the opportunity cost of the land. Most of the studies do not conduct baseline assessments since this involves committing more resources and time, making it challenging to provide an estimate of the opportunity cost. In addition, for some land uses, the opportunity cost may be negligible, especially if the land is highly degraded. However, degraded lands with high surface runoff can be used for water harvesting, providing a positive externality that may get lost if infiltration and vegetation water use increase as a result of landscape restoration [42].

In addition, there is a need to include maintenance and monitoring costs in accounting for the total economic costs. Most restoration projects fail to account for maintenance and monitoring costs since they view restoration as a one-time cost activity as opposed to a continuous activity—for example, tree planting as opposed to tree growing [43]. Tree planting is a one-time cost activity where only the implementation cost will be significant. On the other hand, tree-growing is a continuous activity, implying that maintenance and monitoring costs are significant and accountable, as well. Hence, all the three cost categories ought to be accounted for, in order for a cost-benefit analysis to reflect the actual economic viability of a restoration project.

5.2. Going Beyond Direct Use Values

A major challenge in conducting an economic CBA is that it is difficult and controversial to monetize social and environmental benefits. Environmental benefits are valued differently by different stakeholders, which disputes the findings of the analysis. For instance, greenhouse gases (GHG) mitigation, which is a global ecosystem service, maybe prioritized over reducing soil erosion which is a local benefit. Additionally, the value of some environmental benefits, such as supporting biodiversity, are often excluded because monetizing them is challenging [19]. However, it is still possible to include non-monetized values, such as biodiversity, in the decision-making.

Based on the stocktake, a significant proportion of existing CBA studies do not account for indirect use benefits, and an even more substantial proportion do not account for non-use benefits (84%). This is mostly because most of these benefits are "invisible" and do not have a market value, thus making valuing them quite challenging. Some of the studies that included the indirect and non-use values applied various methods for evaluating them, including: benefit transfer, contingent valuation method, travel cost method, hedonic pricing models, replacement cost, avoided loss, and spatial analysis. Benefit transfer and contingent valuation methods were frequently applied compared to the other methods. This is probably because, these methods can be applied in the valuation of almost all the benefits, such as air pollution control, biodiversity, inheritance and bequest value, cultural and aesthetic values, and so on [23,24]. Similarly, benefit transfer is generally cost-effective and is commonly applied when there is limited budgetary allocation.

On the other hand, some of the other methods (e.g., hedonic models, avoided loss, replacement costs) are data-intensive and, cannot be universally applied for most of the benefits. For example, only one study, Reference [34], employed the hedonic models in valuing stormwater control and air pollution control through controlling for the price of housing in different locations. This method works well if markets can pick up quality differentials, which may not be the case for agricultural and forest land, due to the non-observability of some attributes [23]. Hence, there is a need for understanding the methods that can be used to reasonably value the specific benefits arising from the project depending on the nature of the benefit/ecosystem services data availability, time and cost constraint, and so on. Conducting a comprehensive economic CBA for restoration is costly and time-consuming; thus, there is a need for restoration projects to budget for this.

5.3. Capturing Public Benefits and Implications for Government Investments in Restoration

In addition,, some of these benefits are public benefits attributable to other stakeholders beyond those directly targeted by the restoration projects. A comprehensive economic CBA ought to account for all these benefits. Otherwise, the estimated NPVs for these restoration projects are undervalued. Hence, to present a true picture of the profitability of restoration projects, future CBA studies should aim to capture all the benefits arising from the restoration projects—use and non-use benefits, as well as private and public benefits. This particularly useful for large-scale restoration projects where the benefits accrue to the broader public beyond the targeted stakeholders. Reference [20] also found that when the value of public goods and services are accounted for in the cost-benefit analysis, the benefits of large-scale restoration outweigh the costs and targets like the Bonn Challenge can be met efficiently.

There is also a need for information on public benefits to drive government investments in restoration. Investors require good information on costs and benefits for investment proofing and decision-making. To this end, there is a need for a cost-benefit analysis (CBA) database compiling existing data on landscape restoration costs and benefits more so information on indirect and public benefits [18].

5.4. Improving Sensitivity Analysis

CBA of restoration attempts to model or estimate the future; therefore, a certain degree of uncertainty is involved. For example, unforeseen events and climate change may affect productivity in ways that are difficult to predict, and they should be considered. Similarly, applying a discount rate is also an inherently subjective decision, but it is important for prioritizing near-term benefits versus long-term benefits [19]. Thus, CBA is based on certain assumptions that vary in their degree and level of confidence. The assumptions made during CBA include political and/or social assumptions that may not necessarily hold.

This calls for the need for sensitivity analysis in the CBA process to provide a robustness check for the results. While conducting sensitivity analysis, almost all the existing studies we reviewed conducted a direct sensitivity analysis by varying only one or just a few variables, mostly the discount rate, e.g., Reference [7,27,32] or carbon prices, e.g., Reference [35]. None of the studies applied a

more rigorous sensitivity test, such as the Monte Carlo simulation approach. For more robust and comparable results, future CBA on restoration should consider more rigorous approaches for sensitivity analysis, such as the Monte Carlo simulation.

5.5. The Need for Standardization and Guidelines

During CBA of land restoration, it is difficult to monetize social or political considerations. Restoration options selected during CBA should produce maximum benefits for all, but this is usually not the case. Due to political reasons, benefits to one group may be valued more than the benefits of another group and such is not usually included in the CBA [19]. Data collection to be used for CBA of restoration can be time-consuming and expensive since the impacts of restoration transitions are felt over long-time periods. One requirement for a comprehensive CBA is to quantify all the impacts for each land use (degraded and restored) for the relevant time horizon of the project [21]. Predictions about the levels of inputs (i.e., costs) and the production of ecosystem services must be made for each year and each land use in a restoration transition. This can be the most challenging aspect of CBA because there is not always a complete scientific understanding of how complex natural systems work, especially when significant changes to their structure are made.

Closely related, lack of reliable data owing to poor data-keeping during the restoration period also affects the CBA results. It takes time to realize the actual profitability of these restoration investments since returns to landscape restoration projects are not immediate. For example, in the studies we reviewed, the restoration age considered was even up to 100 years for some projects, with the minimum being seven years. This requires data over several years, and most projects do not keep a record of this data. Hence, even for ex-post CBA evaluations, a lot of predictions and assumptions are involved in data generation. Thus, there is need to adopt standardized methods of data prediction if the results are to be comparable across different restoration projects in deciding the allocation of funds. Similarly, the Food and Agriculture Organization (FAO)"The Economics of Ecosystem Restoration" (TEER), points to need for a comprehensive tool on costs and benefits of Ecosystem Restoration (and FLR) interventions[10]. In an on-going project, TEER aims to "offer a reference point for the estimation of costs and benefits of future ecosystem restoration projects in all major biomes, based on information from comparable projects on which data are collected through a standardized framework". Of course, the question of whether a standardized approach is feasible remains, considering the diversity in landscapes and land-use practices. But such an initiative is a good starting point for providing the missing database on all costs and benefits categories, particularly the indirect use and non-use benefits, as well as maintenance and opportunity costs categories, which are rarely captured in CBA. It can also provide guidelines to be used broadly by supporting donors, investors, and a wider range of stakeholders10.

5.6. Economic Attractiveness of Restoration and Implications for Private and Impact Investments

From the analysis, proportionately, more studies reported positive NPVs for most of the restoration strategies. In fact, for some restoration options, all the studies conducted reported positive NPV: agroforestry, soil and water conservation, mangrove restoration, and alien vegetation clearing. None of the restoration strategies had more studies that reported negative NPV compared to those that reported positive NPV. Positive NPV and economic viability, as confirmed in these studies, is a good starting point for promoting investments and financing. Investors will only be attracted to landscape restoration if their risks are covered, or at least mitigated to an acceptable level [18]. CBA is a first step in documenting the economic viability of landscape restoration and providing empirical evidence that in the long-term, benefits accruing from restoration outweigh the vast investment costs associated with landscape restoration.

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10   https://www.vi-med.forestweek.org/sites/default/files/presentations/docs/c5-teer-garavaglia.pdf

5.7. Insufficient CBA Evidence on Landscape Restoration

Compared to the relatively large number of restoration projects and studies, few have conducted comprehensive CBA. These studies were skewed towards some regions and some restoration options. For example, almost half of the existing studies were conducted in Africa. Similarly, substantially more studies focused on reforestation & afforestation and agroforestry; this is probably because these are among the common landscape restoration options. However, there remains a gap in CBA studies for other popular restoration options, including soil and water conservation practices and establishment of woodlots.

Nonetheless, some of the studies took a global focus, and some assessed and compared CBA results over many restoration strategies. For example, one of the most comprehensive CBA study we reviewed was conducted in Kenya by Reference [31] and compared returns for several landscape restoration strategies in different landscapes. In addition, Reference [20] took a global focus by assessing the net present value of the Bonn Challenge. Such studies form a good starting point for building a comprehensive CBA database upon which resource allocation in restoration can be based.

Overall, a major reason for the relatively few CBA studies is because most restoration projects do not budget for a CBA study. This may be due to an assumption that such projects always yield positive gains which may not necessarily hold. However, owing to scarce resources and the growing global demand for restoration, CBA studies can provide empirical evidence of restoration options with good returns on investment under different landscapes. Conducting a comprehensive economic CBA for landscape restoration is costly, data-intensive, and time-consuming; thus, there is a need for restoration projects to budget for this adequately.

6. Conclusions

This study set out to understand the breadth and depth of current CBA applications in landscape restoration, in a bid to find ways of improving its usefulness in planning, investments, and policies related to land restoration. Thirty-one out of 2056 studies were found to meet the CBA study selection criteria, i.e., they had conducted an economic CBA on at least one landscape restoration strategy. Three of these studies were of global character, while more than half covered African countries, with about two each covering Europe, Asia, Latin America, and the Middle East, respectively. Agroforestry, afforestation, reforestation, and assisted natural regeneration seem to be the most studied with at least five studies each. Other forms of land restoration are lagging. Most studies show a positive NPV for at least one restoration option, pointing to and confirming that restoration can be a viable private investment. Because most studies do not capture public benefits, evidence for public investments remains thin and could potentially hamper prioritization of government investments where resources are scarce. The study also identifies a number of areas for improvement in CBA from the stocktake. These include capturing all costs categories, including opportunity costs and maintenance and monitoring costs; going beyond direct use values; capturing public benefits; conducting thorough sensitivity analysis; the need for standardization and or guidance; and the insufficient CBA evidence on landscape restoration. Overall, the limited extent and depth in landscape restoration CBA studies suggest a great need to improve both quantity and quality in order to better inform planning, policies and investments in landscape restoration.

Appendix A

Table A1. A summary of studies conducted to assess CBA of Landscape restoration following a systematic review.

No.	Paper	Country	Type of Restoration	Data Source	Years	Benefits	Costs	Net Present Value	Sensitivity Analysis	Private or Communal
1	Baig et al. (2016) [44]	Philippines	Ecosystem-based adaptation using mangrove protection and planting	Secondary data	20	Total economic values (direct use, non-direct use values and non-use values	Implementation costs,	Positive	Yes, to discount rate	Communal
2	Becker et al. (2018) [39]	Israel	Full and partial river restoration	Primary data through CVM and travel cost methods	varies	Total economic values; Use values (direct and optional use values) and non-use values (inheritance (bequest) and existence values)	Restoration costs (fixed value and the yearly value of maintenance)	Positive	No	Communal
3	Birch et al. (2010) [7]	Latin America	Dryland forest restoration	Primary data through spatial analysis	20	Carbon sequestration, NTFPs, timber, tourism and livestock products (benefit between restoration and BAU scenario)	Implementation costs (fencing and fire suppression), opportunity costs (cost foregone from livestock production from forest expansion	Positive	Yes, to discount rates and market price of carbon	Private and communal
4	Bonnieux and Le Goffe (1997) [30]	France	Landscape restoration using hedgerows	WTP (to assess public benefits	100	Firewood, timber and public benefits	Planting and regenerating costs, maintenance costs	Negative	No	Communal
5	Chadourne et al. (2012) [34]	USA (Tennessee)	Forest landscape restoration	Primary data-hedonic models were used to	50	Indirect use values (air pollution mitigation and stormwater control)	Explicit costs (land acquisition, labor, seedlings, materials) and amenity value	Positive	No	Private and communal
6	De Groot et al. (2013) [27]	Global	Restoration of 9 different biomes	Secondary data Reviews of 94 studies	20	Total Economic value of all services	Implementation costs, Maintenance costs	Positive for the various restoration types considered	Yes, to discount rate and to worst-case and best-case scenarios	Communal
7	ELD Initiative and UNEP (2015) [29]	Africa (FDjibouti,	Sustainable land management against soil erosion	Secondary data mostly from FAO and world bank data	15	Avoided crop damages from erosion control	SLM establishment cost and SLM maintenance costs	Positive	Yes, by varying discount rates, prices of cereals, capital and maintenance costs.	Private and communal

<p style="text-align:center">**Table A1.** *Cont.*</p>

No.	Paper	Country	Type of Restoration	Data Source	Years	Benefits	Costs	Net Present Value	Sensitivity Analysis	Private or Communal
8	Elmqvist et al. (2015) [28]	Global	Urban areas restoration (Green and blue infrastructure in urban areas)	Secondary data (review)-Benefit transfer	20	Ecosystem services (pollution and air regulation, carbon sequestration, stormwater reduction, temperature regulation, recreation, positive health effects)	Costs for planning, preparation, modest soil restoration, plant propagation, and planting both for grasslands and woodlands	Positive	Yes, to discount rates and max/min benefits and costs	Communal
9	Verdone and Seidl (2017) [20]	Global	CBA of FLR within the Bonn Challenge within six different biomes	Primary and secondary data from TEEB	varies	Total Economic value both direct and indirect benefits	Bonn challenge cost of restoration	Positive	No	Private and communal
10	Gasparinetti et al. (2019) [32]	Brazil (South Amazon)	FLR through agroforestry with cocoa, coffee and Guarana	Primary data	30	Direct outputs and ecosystem services	Maintenance, fencing, labor costs, machine costs	Positive	Yes, to discount rates	Private
11	Hofer et al. (2010) [45]	Brazil (Amazon)	Reforestation (land use from pastures to forest for carbon sequestration (carbon for credits)	Secondary data	20	Carbon sequestration	Opportunity, implementation, and transaction costs	Negative	Yes, to different carbon prices	Communal
12	Narayan et al. (2017) [33]	Mozambique	Mangrove restoration to shelter against storms and flooding	Secondary data from an adaptation project conducted in 2013	100	Reduction in storm damages to houses, fish production, aquaculture, apiculture, carbon sequestered by growing mangroves	Costs of buying the seedlings; labor for planting, maintenance, and support staff; and hydrological restoration	Positive	Yes, to different carbon prices and discount rates	Private and communal
13	Newton et al. (2012) [35]	UK	Habitat restoration for river catchment	Primary data	10 and 50 years	Marginal value of benefits- carbon, timber, crops, livestock and recreational, aesthetic and cultural values	Initial capital investment and annual maintenance costs	Negative	Yes, to different carbon prices and discount rates	Communal
14	Pistorius et al. (2017) [37]	Ethiopia	FLR-(1) Afforestation/ reforestation (2) participatory forest management (3) sustainable woodland management (4) restoration of afro-alpine or sub-afro-alpine (5) establishment of woodlots	Primary data- spatial analysis and expert opinion	20	Provisioning services (timber & NTFPs), Carbon sequestration	Investment costs and labor costs	Positive except for the afro-alpine slope restoration	No	Communal

Table A1. *Cont.*

No.	Paper	Country	Type of Restoration	Data Source	Years	Benefits	Costs	Net Present Value	Sensitivity Analysis	Private or Communal
15	Mills et al. (2007) [36]	South Africa	Restoration of natural capital through Subtropical Thicket Restoration	Secondary data with simulations	50	livestock and game production, harvesting plant products (assuming natural recovery of biodiversity), and carbon sequestration	Transaction costs (including costs of verification of carbon stocks), labor costs, opportunity costs	Positive	Yes, to various parameters including biomass growth rate,	Communal
16	Holmes et al. (2007) [46]	South Africa	Restoring Natural Capital Following Alien Plant Invasions in Fynbos Ecosystems	Projections from secondary data	30	Direct and indirect use benefits	Clearing costs, installation costs	Positive	Yes, to discount rates	Communal
17	Rizzetti et al. (2018) [47]	Vietnam	FLR through ANR, extended acacia rotation, native species rotation, SWC	Projections from secondary data	23, 30, 2	Crop income, income from timber	Labor costs, seedling cost	Positive	No	Private and communal
18	Schiappacasse et al. (2012) [38]	Chile	Dryland forest restoration thru reforestation using native trees	Primary data using contingent valuation method	25	WTP for forest restoration for the entire pollution of the city	Implementation costs, operating costs,	Negative	Yes, to discount rate	Communal
19	Currie et al. (2009) [48]	South Africa	Alien vegetation clearing for water yield and tourism	Primary data and projections	15	water and tourism benefits (tourism benefits involved revenue from the sale of tickets)	Costs of alien invasive plant removal, gully-erosion repair and reseeding with indigenous plants	Positive	Yes, to discount rates and with realistic and pessimistic scenarios	Communal
20	Silva and Nunes (2017) [49]	Brazil Amazon	Forest restoration through sustainable forest management (legal logging) and agroforestry	Secondary	11	Timber from logging, financial benefits of AFS (timber and NTFPs)	Implementation costs, transaction costs, opportunity costs (loss from agriculture and livestock)	Negative	Yes, to discount rates and different scenarios	Communal
21	Tuan and Tinh (2013) [50]	Vietnam	Mangrove restoration	Secondary and primary using CVM to value non-use values and market methods to value use values	22	Direct use values, indirect use values and non-use values. WTP for non-use values,	Maintenance and protection costs, mangrove restoration	Positive	Yes, to discount rates	Private and communal
22	Monela (2005) [51]	Tanzania	FLR through agroforestry and silviculture (Ngitili)	Primary data through expert evaluation and literature review	20	Direct use values (timber and other NTFPs), time saved in collecting firewood and water,	Total project cost for restoration	Positive	Yes, to discount rates	Private and communal

Table A1. *Cont.*

No.	Paper	Country	Type of Restoration	Data Source	Years	Benefits	Costs	Net Present Value	Sensitivity Analysis	Private or Communal
23	Cheboiwo et al. (2019) [31]	Kenya	Afforestation or reforestation of degraded natural forests, Rehabilitation of degraded natural forests, Agroforestry in cropland, Commercial tree and bamboo growing on potentially marginal cropland and un-stocked forest plantation forests, Tree-based buffer zones along water bodies and wetlands, Tree-based buffer zones along roads and restoration of degraded rangelands)	Expert discussions, activity restoration budgets and extensive review of various land use literature. Benefits and opportunity costs were valued using market prices, avoided cost/replacement cost and benefit transfer approaches	30	Direct (crop harvests, timbers and NTFPs) and indirect use values (carbon sequestration, soil erosion control and increased soil fertility)	Implementation costs, opportunity costs, monitoring and maintenance costs	Positive for the various restoration types considered	Yes, to discount rates	Private and communal
24	Ministry of Natural resources, energy and mining-Malawi (2017) [3]	Malawi	Conservation agriculture, agroforestry, FMNR, Community plantations and private woodlots, Natural forest management	Primary data	20	Direct and indirect use benefits	Implementation costs and opportunity costs	Positive for the various restoration types considered	Yes, to discount rates	Private and communal
25	Ministry of Water & Env-Uganda (2016) [52]	Uganda	Reforestation and afforestation, woodlots, Agroforestry, Natural regeneration	Budgets, expert discussions and secondary sources	30	Direct and indirect use benefits	Implementation costs	Positive for the various restoration types	Yes, to discount rates	Private and communal
26	FAO and UNHCR (2018) [53]	Tanzania	Wood-energy rehabilitation (Afforestation and reforestation), Agroforestry, Rehabilitation of degraded native forests	Primary data (field observations, KIIs, FGDs) secondary data	10	Direct benefits (wood fuel) and indirect use benefits (carbon sequestration)	Implementation, operational and opportunity costs	Positive for wood energy plantations and agroforestry but negative for the rest	Yes, to discount rates and wood prices	Private and communal
27	Aymeric et al. (2014) [54]	Sudan	SLM through *A. senegal* Agroforestry	Secondary data	25	Direct use benefits (fuelwood and Gum arabica) and indirect use benefits (N fixation, avoided nutrient loss, aquifer recharge, carbon sequestration)	Implementation and maintenance costs	Positive	Yes, to discount rates	Private

Table A1. *Cont.*

No.	Paper	Country	Type of Restoration	Data Source	Years	Benefits	Costs	Net Present Value	Sensitivity Analysis	Private or Communal
28	Ministry of Natural resources-Rwanda (2014) [55]	Rwanda	Agroforestry, Well managed woodlots, Natural forest regeneration, protective forests	Primary and secondary data through simulations and predictions	20–30	Direct use benefits (crops, wood) and indirect use benefits (carbon sequestration and erosion control	Implementation, operational and monitoring costs		Yes, to discount rates	Private and communal
29	Tesfaye et al. (2016) [56]	Ethiopia	Soil conservation measures (soil bunds, stone bunds, Fanya juu bunds)	Primary data	27	Yield increment from implementation of bunds	Investment and maintenance costs	Positive	Yes, to investment and maintenance costs and the market price of yield	Private
30	Wiskerke et al. (2010) [41]	Tanzania	A small-scale forestation project for carbon sequestration, a short rotation woodlot and a Jatropha plantation	Primary data (expert opinions and field survey) and secondary data	7	Direct benefits (wood fuel, electricity from jatropha, etc.) and indirect benefits (avoided deforestation, improved health, indirect economic benefits)	Production costs and opportunity costs	Positive for woodlots and jatropha for electrification and soap production, negative for forestation for C credits	No	Private and communal
31	Onduru and Muchena (2011) [57]	Kenya	SWC practices, such as mulching, zero tillage, stone lines, contour ridges, micro catchments with bananas, terracing, and others	Primary data	15	Incremental yield benefits from the adoption of SWC practices	Investment and maintenance costs	Positive	Yes, to discount rates	Private

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