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THE NIA NEXUS IMPACT ASSESSMENT (NIA) TOOLKIT

Turning Concepts into Action

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Turning Concepts into Action

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5. WEF Nexus Cost-Benefit Framework

Background

The Water-Energy-Food (WEF) Nexus is an integrated approach for the water, energy and food/agriculture sectors that attempts to reconcile the economic, social, ecological and political interests these compete for the same scarce resources by addressing the trade-offs while building intersectoral synergies that lead to win-win-situations. Designing, evaluating, and promoting effective WEF Nexus projects requires a strong understanding of each project's economic and financial case.

Cost-Benefit-Analysis (CBA) is a tool that can serve a variety of purposes when applied to WEF Nexus projects. CBA, which is a structured method for comparing the benefits and costs of alternative investments, can be used during the entire life cycle of a WEF project. The process of conducting a CBA as discussed in this framework is formulaic and simple, but CBA is a rich and nuanced topic that can hardly be summarised in a short document like this. Instead, the goal of the framework is to provide WEF decision makers, whether they are secretariate staff of an Non-Governmental Organisation (NGO) or on-the-ground project staff, with a brief document describing what CBA is, the steps required to conduct a CBA of a WEF project, examples of how this has been done, and methods, strategies, and guidance on how to use this framework to conduct CBA on other WEF projects at any stage of project development.

The framework presented in this report is intended for prioritising investments in Water-Energy-Food Nexus projects (WEF Nexus) across a variety of criteria, including: Net Present Value (NPV), Return on Investment (ROI), and multi-criteria decision-making. This information is useful for policymakers, restoration professionals, and natural resource managers who are interested in understanding more about the economic opportunities and trade-offs of making investments in WEF Nexus projects.

Using this framework in conjunction with the other tools of the Nexus Impact Assessment (NIA) Toolkit will make the application of the nine steps easier and more straightforward than applying it alone. For example, the information needed by the WEF Nexus Safeguards, which is used to pre-screen potential projects, can help identify the most important aspects of a project for CBA to focus on. The Safeguards Tool answers many of the questions necessary for conducting a CBA, like defining a project's primary benefits and beneficiaries in addition to documenting its potential negative impacts.

It is important to remember that CBA is a complex and rich topic. This framework, while simple, is sufficient to create reasonable analyses of project costs and benefits. However, as projects grow in scale and complexity, additional economic resources should be consulted to ensure appropriate methods and data are used. These resources could include academic textbooks, peer-reviewed journal articles, and discussions with economic consultants and other experts.

The remainder of this framework provides a brief overview of CBA, including its conceptual foundations, before discussing and demonstrating the nine steps to conducting a CBA. Each step includes a discussion on background, tools, methods, and guidance, in addition to examples from CBA's conducted as part of existing WEF projects. The framework concludes by provide discussion and guidance for using CBA results to appeal to different types of decision makers.

Introduction to Cost-Benefit Analysis

At its core, Cost-Benefit Analysis (CBA) is a method for systemically cataloguing positive impacts as benefits and negative impacts as costs, valuing these impacts in terms of currency, whether it is Dollars, Euros, or other local monetary units of exchange and estimating the net benefits (benefits – costs) of a project relative to the baseline situation (Figure 1). As humans, we tend to only value our own benefits and costs when making decisions, but CBA attempts to consider all of the costs and benefits to society as a whole. In this way, CBA is a weighing tool that quantifies and values all consequences of a project to all members of society.

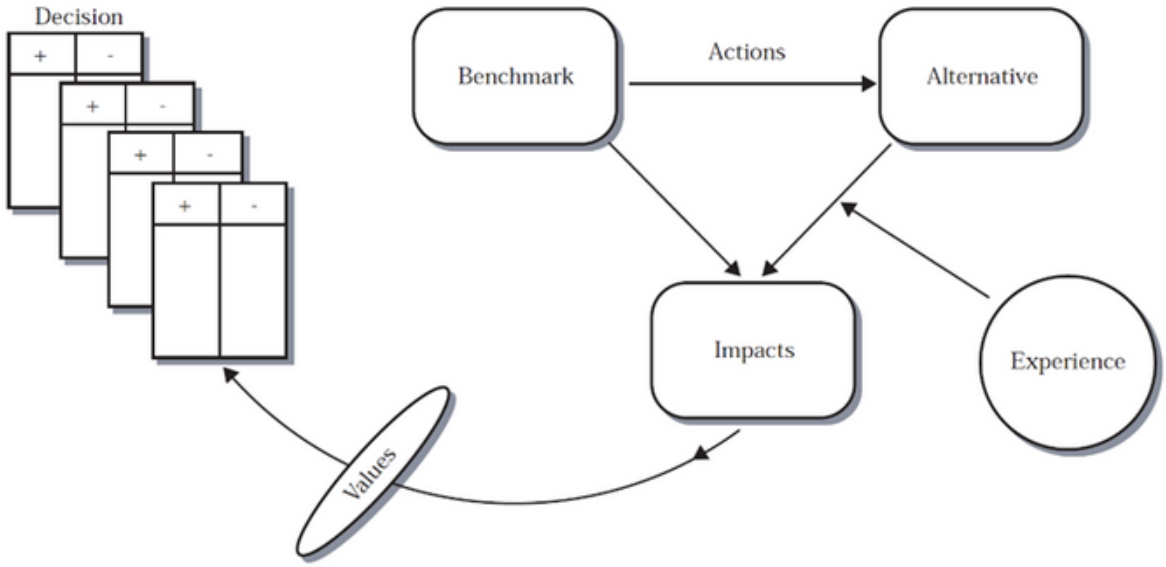


Figure 1: Process of Conducting a Cost-Benefit Analysis

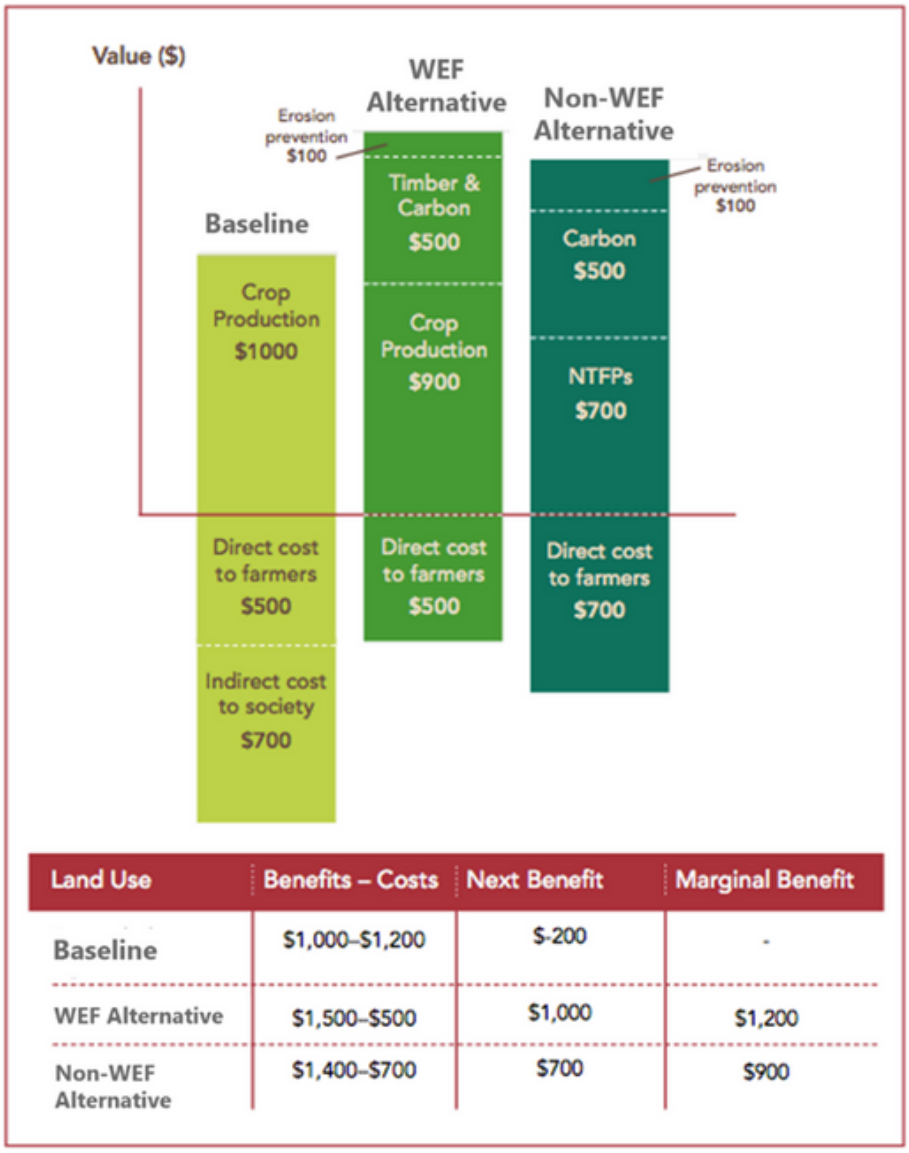
CBA can and should be applied at different stages of a project cycle (ex-ante, inception, as a mid-term evaluation or ex-post) in order to determine the long-term net monetary value of project. In the design and development phase, CBA can be used as a tool to assess the economic and financial feasibility of a project or to help inform decision-makers about the value of the planned activities. In the early stages of project development, there is considerable uncertainty about a project's actual benefits and costs, and thus, its impact on social benefits. Conducting a CBA during the project design phase can help to make sure the project is designed in a way that it creates the highest probability of success.

Once a project reaches the operational phase, CBA can be used as a monitoring and evaluation tool to assess project impacts compared to initial expectations. CBA can also be used to highlight project impacts on local, regional, and national economies in addition to making a business or financial case for specific WEF activities. These types of backward-looking analyses are powerful because they not only show the impacts of a particular project, but their results can also be generalised to approximate the impact of similar projects.

Conceptual Foundations of Cost-Benefit Analysis

The objective of CBA is to make sure that scarce natural, human, and financial resources are being allocated efficiently. When thinking about a WEF Nexus project, for example, CBA is attempting to ask: Over a period of years and decades, will a given project generate sufficient benefits to justify the initial and ongoing investments required to sustain itself? In other words, CBA is a framework for measuring efficiency. It asks if resources invested in a WEF Nexus project are being used in their highest valued use.

Figure 2 shows the result of a CBA for three land use alternatives. In the figure, the benefits and costs of each alternative are added up, discounted, and compared to each other to determine which alternative creates the most benefits per dollar of cost. Benefits in the example include crop, timber, and non-timber (NTFP) production, carbon sequestration, and erosion prevention. Costs include the direct costs of the alternative as well as the indirect costs faced by society. As the figure shows, the WEF alternative creates more benefits per dollar of cost than the baseline and non-WEF alternatives.



Land Use	Benefits – Costs	Next Benefit	Marginal Benefit
Baseline	$1,000–$1,200	$-200	-
WEF Alternative	$1,500–$500	$1,000	$1,200
Non-WEF Alternative	$1,400–$700	$700	$900

Figure 2: Illustrative Comparison of Benefits and Costs for Three Land-Use Alternatives

To better understand the logic of CBA, the concepts of willingness-to-pay and opportunity cost have to be understood. Willingness-to-pay (WTP) represents the amount of money stakeholders would pay or would have to receive to make them indifferent between the status quo or baseline and the proposed WEF Nexus project. The sum of each stakeholder's WTP is the gross benefit of the project. For example, if a WEF Nexus project would impact three people and two of those people were willing to pay $100 each to participate in the project, but the third person does not like the impacts of the proposed project and would have to receive $100 to make them indifferent between it and the status quo, the gross benefit of the project would be $100 + $100 - $100 = $100. That is, the gross benefit is the WTP of all three stakeholders.

WEF projects also require inputs, which include land, labour, materials, and equipment. These inputs have an opportunity cost, which is to say by using them in a WEF project, they are not available to be used for other opportunities. Opportunity cost measures the value of goods and services that society must give to implement a WEF project. The opportunity cost of inputs is generally measured by their market prices.

Once a project's benefits have been valued in terms of WTP and inputs have been valued in terms of opportunity costs, then its net benefits can be calculated to determine if the project is a good investment of society's scarce resources. This logic leads to the CBA decision rule: adopt all projects whose benefits are greater than their costs and reject all projects whose benefits are less than their costs. The logic is simple: WEF Nexus projects that create more benefits than costs are improving societal welfare and WEF projects that create more costs than benefits are reducing it.

While a straight comparison between benefits and costs is enough to justify investing in a project, it is not enough information to choose between different project alternatives. For that, the benefit-cost-ratio (BCR) is used. The BCR measures the value of benefits created by every dollar invested in a project. The BCR is always greater than or equal to zero and higher BCRs always indicate that a project is more beneficial than alternative projects with lower BCRs.

Steps in Process

Conducting a CBA is a nine-step process as shown in Figure 3.

1: Specify set of alternative projects	• Define the baseline and all alternative projects • What is currently happening and what is being proposed?
2: Decide whose benefits and whose costs count	• Project stakeholders could include everyone from locals to society in general • Knowing who counts helps identify what counts
3: Catalogue impacts and select indicators	• Define project impacts as either benefits or costs • Select appropriate measurement indicators
4: Predict impacts quantitatively over life of project	• Quantify impacts for each alternative, for each year • Use appropriate methods and data
5: Value all impacts	• Identify types of goods are being valued • Select appropriate valuation methods and data
6: Discount benefits and costs	• Benefits and costs occur at different points in time, often years apart • Discounting puts benefits and costs in terms of present values
7: Calculate net present values of each alternative	• Net present value (NPV) is the difference between present value costs and benefits • Positive NPV indicates the creation of value; negative NPV indicates value destruction
8: Perform sensitivity analysis	• Projections about the future are prone to risk and uncertainty • Sensitivity analysis shows how sensitive BCA results are to risk and uncertainty
9: Make recommendations	• Based on the results, decide if the project should be funded • Recommend and changes to increase the project's benefit-cost-ratio (BCR)

Figure 3: Nine Steps in Conducting a Cost-Benefit Analysis (CBA)

The accuracy of CBA depends on how well each step in the process is carried out. Each step is prone to uncertainty and error, particularly the steps 3, 4, and 5, but foresight and planning can mitigate this. Each step in the process will be discussed below using a WEF Nexus project in Niger to illustrate the process. The project, located in the Tillaberi region of the country, is a WEF Nexus project designed to improve food, water, and energy security on a plot of land farmed by a local woman's group.

Step 1: Specify Set of Alternative Projects

The first step in conducting a CBA of WEF Nexus projects is to define the set of project alternatives to be analysed in terms of their impacts to water, energy, food, and other resources. For example, the comparison could be between the status quo or baseline situation and one project alternative. However, the comparison could also be made between the status quo or baseline situation and multiple alternative projects, each with their own set of costs and benefits.

Figure 4 shows the alternatives used to evaluate the benefits of taking a WEF Nexus approach to enhance water, energy, and food security at the Kollo Women's Garden. Under the baseline conditions, the garden has two water sources. During the dry season a petrol-powered pump is used to extract ground water for the parcel two times per week. During the rainy season, the garden is irregularly irrigated by spill over from adjacent rice fields. However, this water supply is not controlled by the women and is not reliable water supply. Overall, the garden, which is currently used to grow potatoes and onions, does not produce as much food as it could because it does not have a secure supply of water or energy.

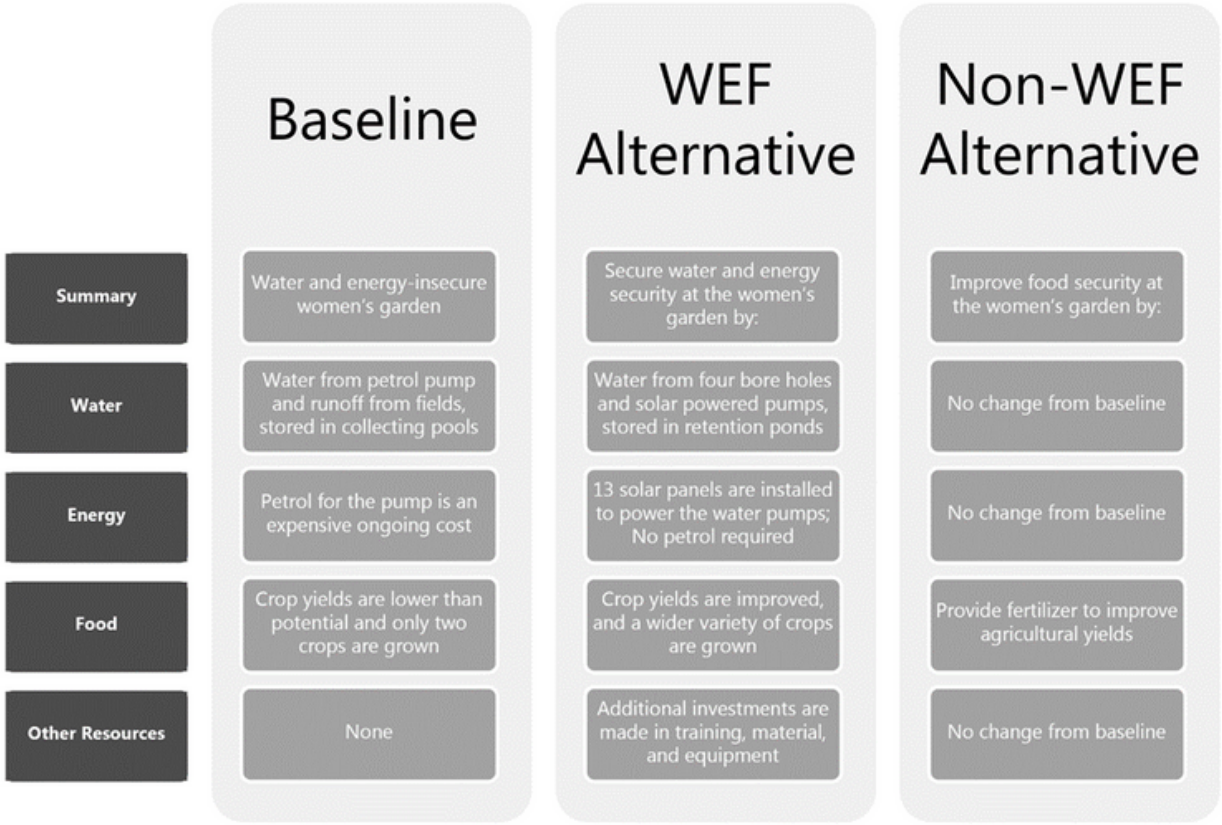


Figure 4: Specifying Alternative Projects

Under the proposed WEF Alternative, the productivity and food security of the garden would be improved by improving water and energy security. Four boreholes would be drilled at various points around the garden. Solar panels would power water pumps that would be used to supply the garden with irrigation water year-round. Additional investments of training, material, and equipment would further improve productivity.

With a more secure water and energy supply, the garden could produce more output and a wider variety of crops compared to the baseline. The increased agricultural output would increase food security for the households participating in the project. The investments would result in higher levels of water use due to higher crop diversification favouring crops that require more water than the crops grown under the baseline. The use of solar panels and electric motors in place of petrol-powered pumps would also reduce greenhouse gas emissions.

To show the value of the WEF Nexus approach, a single-sector alternative could be developed as a point of comparison as shown in Figure 4. Under the Non-WEF Alternative, food security would be improved by providing fertiliser to the women's garden with no further changes made to other resources as compared to the baseline situation.

Guidance

Economic analysis plays a critical role in the systematic formulation of alternative plans for WEF projects. Each alternative plan may consist of a system of structural and/or non-structural measures, land treatment, and other strategies or programmes. These strategies or programs will help to alleviate specific problems or take advantage of specific opportunities associated with water, energy, and food-related challenges in the project area. An alternative plan is developed to improve the security of at least two resources without damaging the third resource. Other alternatives can also be formulated to help understand the advantage of using a WEF approach as compared to a single sector approach. These additional plans should be formulated so that the decisionmaker can judge each alternative in a consistent manner. To do this, each plan requires an economic analysis.

Step 2: Decide Whose Benefits and Costs Count

In the second step of the CBA, the analyst must decide which stakeholder's benefits and costs will be included in the analysis. This is an important step because knowing who counts often tells you what counts. For example, if the CBA was focused on local stakeholders only, the primary benefits of the project would include impacts that directly benefit local stakeholders. This might include changes in crop output, and water and energy availability, quality, and reliability. Taking a broader perspective that includes local and global stakeholders would expand the types of costs and benefits that are accounted for.

In the example of the Kollo women's garden, a primary and secondary set of stakeholders were defined. The primary set of stakeholders are the women from the local community directly participating in the project. They are the project's primary beneficiaries as well as its main contributors. The women manage the daily activities in the garden and supply most of the project's labour. In a broader view, the project also benefits society as a whole by reducing greenhouse gas emissions.

Guidance

Answering the questions below can help identify which stakeholders to include in the analysis:

- What scale is the project primarily designed to impact (i.e., local, regional, national, global)?
- Who primarily benefits from the project (i.e., project participants, local communities, society in general, or a combination of all of these)?

For example, knowing that a project is designed to create impacts at a local level that primarily benefit project participants and the surrounding community helps place a geographic boundary around the CBA. When identifying stakeholders raises difficult issues, it is often useful to report the results at different levels instead of trying to fully resolve these issues prior to conducting the analysis. For example, the results could be reported for a specific village, for a region as a whole, and at the country level, or for society as a whole.

Step 3: Catalogue Impacts and Select Measurement Indicators

This step requires the analyst to make a list of each alternative's physical impacts and classify them in terms of costs and benefits and define measurement indicators. Impacts refer to both inputs and outputs. Inputs generally show up as cost and outputs generally show up as a benefit. Explained differently, all desirable impacts of the project are benefits and all the undesirable impacts are costs.

Costs: Every WEF project requires inputs like land, labour, equipment, and materials. These costs are incurred directly through the physical process of implementing the project and indirectly through foregone production and negotiation as well as planning processes. The costs of each WEF Nexus project can be placed into one of three categories (see Figure 5):

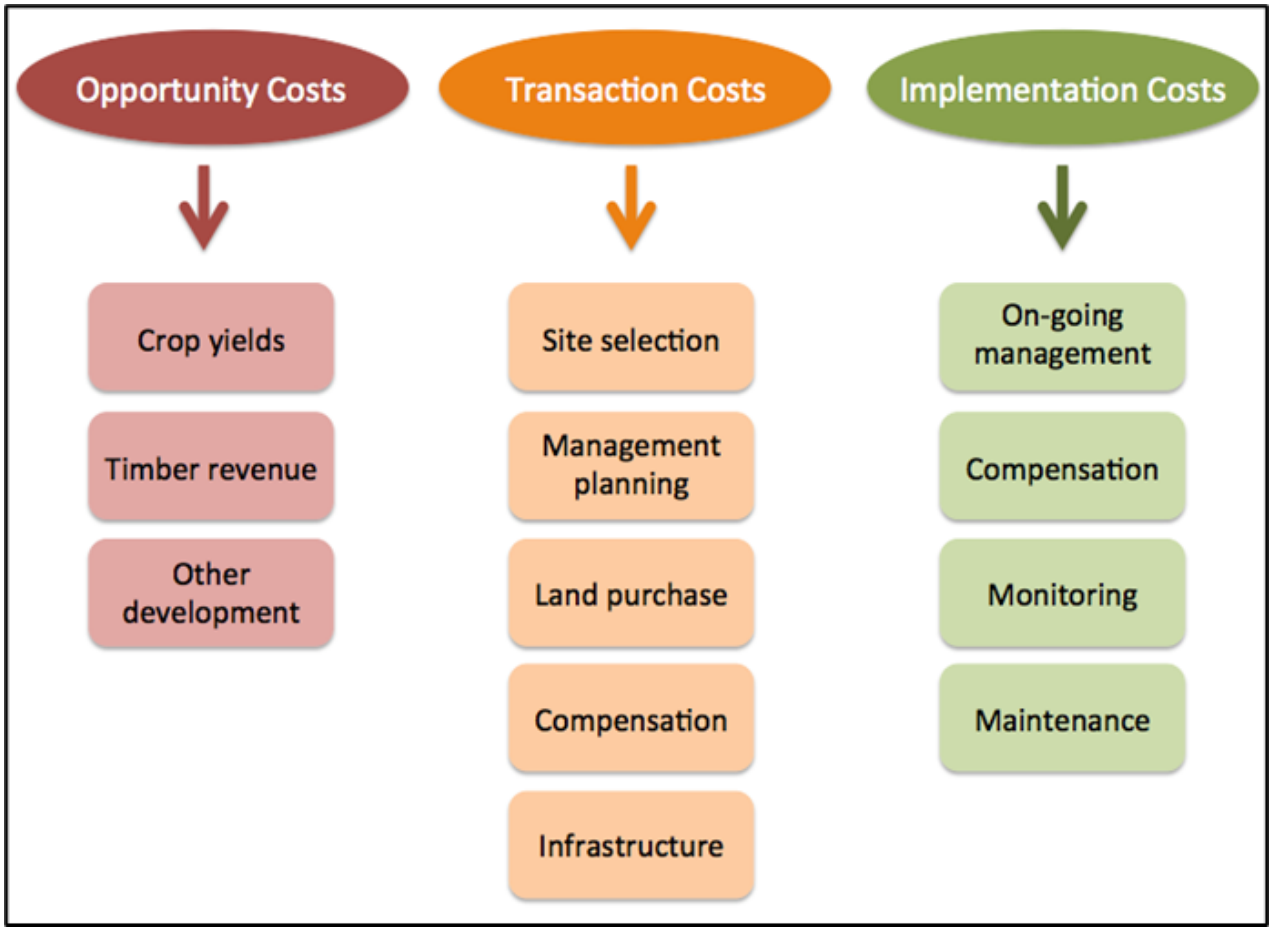


Figure 5: Three Categories of Cost Used in Cost-Benefit Analysis

Transaction costs and implementation costs are the only costs that are directly accounted for in the benefit-cost ledger, discussed in more detail below. Opportunity costs are accounted for in step 1, where each project alternative is defined.

Benefits: Since WEF Nexus projects are interested in improving resource security, most of the beneficial impacts from WEF Nexus projects will come from changes to output of commodities like crops, water, and energy, or in changes to the quality of those commodities. By changes in quality, we mean that projects can change the attributes of crop, water, and energy resources without changing the total amount of the resource that is available. Such changes in quality could be reflected in changes to reliability, price, or other indicators.[1]

The simplest way to account for benefits is to use an ecosystem services framework (see Figure 6).

Figure 6: The Four Types of Ecosystem Services

The Millennium Ecosystem Assessment (MEA (Millennium Ecosystem Assessment), 2005) defined four categories of ecosystem services; each category of services can impact different groups of stakeholders:

- **Supporting services** – Services that are necessary for the functioning of all other services.

- **Provisioning services** – The benefits from products, like food, fuel, fibre, and water that are obtained directly from nature. Private landowners and companies can harvest commodities directly from restored land like fuelwood, crops, or timber. Downstream stakeholders, such as fishing communities or water users, can also benefit if restoration improves the productivity of a fishery or enhances water quality.

- **Regulating services** – The benefits from processes like carbon sequestration, nutrient cycling, and water and air purification that regulate the functioning of ecosystems. While regulating services are generated at a parcel or landscape scale, they can provide benefits to local, national, regional, and international stakeholders alike. For example, carbon sequestrations effects on regulating the global climate everyone equally, although other regulating services like flood control may only benefit stakeholders within specific areas of a watershed.

[[1] Energy: Introduction of renewable energy (RE) would mean that energy supply is more reliable and cleaner (but maybe that means that there is not more energy than before); Water: Through water treatment one increases the water quality, however not the quantity; Crops: One can increase the crop quality without increasing the overall yield by introducing more nutrient-dense irrigation water, better temperature regulations, etc.

- **Cultural services** – The nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and scenic beauty. These types of services are also improved by restoration at different spatial scales and therefore impact different groups of stakeholders. Local residents benefit from restoration through the enhancement of aesthetic, cultural, and natural quality of ecosystems. Eco-tourism is becoming an increasingly popular benefit for local communities, national and local governments, and international tourists. It is important to note that the value of cultural services depends on the cultural backgrounds of each stakeholder group and for that reason restorations impact on cultural values is often left out of cost-benefit analysis despite being an important impact.

Guidance

A useful approach for cataloguing impacts is to use a simple benefit and cost ledger, as shown in Figure 7 below. The ledger contains a benefit column and a cost column. The ledger is filled out by people familiar with the project and the types of impacts it will create. Recalling the previous step, the goal of this step is not to catalogue every possible impact of the project. Instead, it is to catalogue the impacts that will affect the project stakeholders positively (benefits) and negatively (costs).

Impacts	
Benefits	**Costs**
Additional crop output	Equipment and materials
Reduced emissions	Personnel
Avoided fuel costs	Monitoring
	Trainings
Other	Other
A	A
B	B
C	C

Figure 7: Example of Benefit-Cost Ledger

In the case of the Kollo Women's Garden, there are three primary benefits of the project: the project will create additional crop output, thereby enhancing food security, reduce emissions from the burning of petrol, and reduce expenditures on petrol.

The project costs include expenditures on equipment and materials like solar panels, irrigation pipe, electric pumps, pesticides, and gardening equipment in addition to expenditures to pay personnel, set up monitoring frameworks, and conduct trainings.

Step 4: Predict Impacts Quantitatively Over Life of the Project

Step 4 of the framework is to quantify all the impacts for each alternative over the lifetime of the project in terms of the impact indicators identified in Step 3. This can be the most challenging aspect of CBA because there is not always complete data or sound methods for making projections. Projections must be made for each year and for each impact of each project alternative. Project time horizons are generally selected based on the expected life of the project, which could range from a few years to several decades. The correct time horizon for analysis will vary with each project.

In general, there are three ways to quantify the impact of each alternative as shown in Figure 8.

Approach	Strengths	Weaknesses	Tools
Expert opinion	Flexible, intuitive, simple, timely, not data intensive	Opinion-based, errors of judgement, prone to bias, experts may disagree	Delphi method, expert surveys, expert interviews, literature reviews
Mathematical prediction	Data-driven, transparent, objective, accepted methods	Data intensive, may require assumptions, time-intensive, uncertainty,	Ecosystem service models (e.g. INVEST), mathematical equations, statistical analysis, enterprise budgets
Field measurement	Greatest validity to real world, less prone to bias than other methods	Must wait for observations to be measurable, expensive and time consuming, no control over external factors	Field measurements, household surveys, benefit-transfer

Figure 8: Approaches for Quantifying Impacts of WEF Projects

In the expert opinion approach, experts are asked to evaluate the expected impacts of the project on the benefits identified in the previous step. In the prediction approach, mathematical models are used to predict project impacts. And in the measuring approach, the actual impacts of the project are measured and projected into the future. For most WEF projects, one or more of the above approaches will be used. For more information on modelling tools, see Christin et al. (2016).

Guidance

The correct approach depends on the context within which the CBA is being conducted. However, a few simple rules of thumb may be useful. The approach can be selected based on the state of the project. Expert opinion and mathematical prediction are best suited to pre-feasibility studies of a project's potential impacts. Once a project has been active, field measurements will be the most accurate approach to quantifying benefits and costs.

Step 5: Value All Impacts

Economic valuation places monetary value on changes in ecosystem goods and services and puts ecological and biodiversity values on an equal footing with other economic benefits and costs. Not all values of ecosystem goods and services can be measured because they may be intrinsic or religious nature, but they need to be recognised, nonetheless. Other ecosystem goods and service, like the existence value people place on knowing a certain species exists even though they may never actually see it in person, can be valued but are difficult to turn into real flows of financial values. Finally, there are ecosystem goods and services, like carbon storage or water yield, that can be both valued and monetised. Choosing a valuation technique generally depends on the impact to be valued and the availability of resources, time and data for the study.

Economists have proposed several methods for valuing ecosystem goods and services depending on the nature of the good or service in question and the methods can be classified into one of three broad categories:

- **Revealed preference.** These methods use human behaviour to value ecosystem goods and services. For example, crop and timber production can be valued by observing the market prices people are able and willing to pay for different quantities and qualities of crop and timber.

- **Stated preference.** These methods rely upon hypothetical human behaviour to value ecosystem goods and services that are not bought or sold in markets. These methods elicit valuations by asking people, either through surveys or questionnaires, how much they would be willing to pay for a change in the amount and quality of an ecosystem good or services.

- **Benefit transfer.** These methods value specific ecosystem goods and services by transferring the results of valuation studies of the same goods and services from other locations. Benefit transfer methods are useful when valuation information is needed, but time and funding are not available to implement more rigorous valuation methods. The main drawback of using benefit transfer is that studies from other areas are likely to be less accurate in new settings.

Guidance

Revealed preference and benefit-transfer approaches are the simplest methods to implement for most WEF Nexus projects. Most revealed preference methods rely directly on market prices to value the benefits of WEF Nexus projects. For example, if a WEF Nexus project increased crop production by five tons compared to the baseline, the additional production can be valued simply by multiplying it by the market price for the crop. In most cases, this will be the method used to value most benefits of WEF Nexus projects.

Benefit-transfer is likely to be the second most useful method for valuing the benefits of WEF Nexus projects. The method is useful for valuing non-market benefits in a timely manner that does not require a great deal of data. The drawback of this method is that values are being transferred from study sites that may not be similar in any way to the site where the values are being projected, introducing errors and uncertainty. For more information on implementing benefit-transfer, see the following resource (USGS, 2022).[2]

Stated-preference approaches, while useful for valuing certain types of goods and services, requires preparing and conducting surveys and statistically analysing the results. Of the three methods discussed above, it is the most expensive and time-intensive valuation approach.

Step 6: Discount benefits and costs to present values

WEF projects create impacts that occur over times, sometimes for periods of several years and decades. Discounting makes it possible to compare events that occur at different points in time by assigning a weight to future events based on society's preference. While the concept of discounting is not contentious, the choice of which discount rate to use, is. This is because the discount has large influences on which projects are approved and which are not, and it also reflects the way current generations think about future generations.

[2] https://sciencebase.usgs.gov/benefit-transfer/activityCalc/index

The equation used to discount costs and benefits is shown below:

$$PV(X) = \sum_{t=0}^{T} X_t * (\frac{1}{1-r})^t \qquad [1]$$

Where:

PV(X) = the present value of a stream of benefits or costs
X = flow of benefits and costs over time according to Xt.
T = the time horizon
r = the discount rate

$\left(\frac{1}{1-r}\right)^t$ = the discount factor; its value is bounded between 0 and 1.

The larger the value of t, that is the further into the future something happens, the smaller the discount factor is and the less weight that event has. The opposite is also true.

Private Discount Rate. While the streams of benefits and costs are estimated in Step 4 and are empirical problems, the choice of the appropriate discount rate is a conceptual problem. Discounting goods and services reflects the fact that financial capital has an opportunity cost because it can be spent on other investments that could yield returns earlier. This sort of discounting is often referred to as the opportunity cost of capital and it is measured by observing the market yields on government bonds and other low risk investments.

Social Discount Rate. The other type of discounting reflects the different weight society places on the welfare of current and future generations and is commonly referred to as the rate of social time preference. Unlike the opportunity cost of capital, which discounts the consumption of goods and services at different points in time, the rate of social time preference discounts the welfare of aggregate welfare of generations at different points time. It is the tension between these two concepts that leads to disagreement over the appropriate rate of discount to apply to environmental decisions.

These issues are still being debating in the academic and policy literature because of the profound role the discount rate plays in environmental decision-making. Without a clear consensus, analysts must come up with their own rationale for which rate to use. Most environmental CBAs use discount rates of between 0 to 4 percent, but national and global oversight agencies generally give their own recommendations for appropriate discount rates to apply to projects in their jurisdictions.

Guidance

There is no correct discount rate to use for an analysis. The general guidance would be to use social rather than private discount rates for most CBAs applied to WEF projects. This is because WEF projects are based on improving societal wellbeing. While social discount rates are highly debated, each WEF project should consult the central bank or development banks of the region where the project is located to see if the banks recommend a social discount rate. If this information is not available, a discount in the range of 0 to 4 percent should be used.

Step 7: Compute the NPV of Each Alternative

Local communities, regional and national governments, and conservation organisations must decide whether to invest scarce human and physical resources into WEF projects. CBA helps inform these decisions by looking to see if sum of the discounted flow of benefits is greater than the sum of the discounted flow of costs. The net present value (NPV) concept formalises this logic and allows discounted flows of benefits and costs to be compared on equal terms across alternative projects.

The NPV for each alternative is calculated following:

$$NPV = \sum_{t=0}^{T} \delta^t (B_t - C_t) \quad [2]$$

Where:

B_t = is the annual benefit received from the degraded land use or restoration activity,

C_t = is the annual cost associated with that revenue, and

δ^t = is the discount factor.

The decision rule for the NPV concept is straightforward. A NPV less than zero suggests a WEF project will generate fewer benefits than costs, while a positive NPV suggests the opposite.

Step 8: Perform Sensitivity Analysis

The costs and benefits of WEF projects depend on random economic and ecological variables, including market prices, interest rates, precipitation, and tree growth rates. Lingering uncertainty over these values introduces an element of risk into the CBA.

Sensitivity analysis is a systematic method for examining how the outcome of cost-benefit analysis changes with variations in inputs, assumptions, or the structure of analysis. Sensitivity analysis can be performed by varying the value of a single variable at a time and observing the effects on the results of the CBA.

Guidance

There are limits to the amount of sensitivity analysis that can be conducted. Theoretically, every model parameter can be tested with an infinite range of values. However, in application, judgement has to be used to decided which variables are of most interest and/or most uncertain and the sensitivity analysis should focus on understanding how the result vary when the value of these variables changes.

There are also more rigorous methods of sensitivity analysis like Monte Carlo simulations, but for most purposes, simple and straightforward sensitivity analysis will be sufficient to understand how the model reacts to different values and assumptions.

Step 9: Make a Recommendation

Once the CBA is complete, a decision must be made about funding the project. The general rule is that the WEF Alternative with the largest NPV should be selected. Of course, other factors, both qualitative and quantitative, will influence the final decision, but projects with larger NPVs are preferred to projects with smaller NPVs, all else equal.

The output from the CBA can also be used to create other decision-making metrics, like Return on Investment (ROI) and the benefit-cost-ratio (BCR). ROI and BCR metrics are functionally the same and measure the percentage return on each dollar invested into a WEF project. ROIs and BCRs greater than one suggest that each dollar invested into a WEF project generates more than one dollar in societal benefits.

In some cases, it will be important to present other metrics depicting the trade-offs between different alternatives. These trade-offs could merely be different sets of benefits created by different alternatives, but trade-offs may also represent externalities, or negative impacts of an alternative. Graphically illustrating the benefits, costs, and externalities of an alternative, as shown in Figure 2 above, is the simplest way to display each alternative's trade-offs in a side-by-side comparison. Rose diagrams can also be useful for showing how a particular project impacts different types of benefits and costs in a comparative manner.

In other cases, decision makers may want to use the CBA results to make a business case for a project. When people refer to making a business case, they are often referring to a project's financial benefits and costs only. Benefits that cannot be bought or sold in currency are not included in the business case analysis.

A simple business case is showing that a project would produce a certain value of food for a given upfront investment and the recurring costs required to continuously grow the food. It would show what the upfront investment is, the annual stream of benefits that would result from the investment, and the amount of time required to recoup the project costs. Investors are also notoriously averse to risk, so information about how a project will reduce uncertainty will complement the CBA results when making a business pitch for a project.

Guidance

In general, it is useful to report many different metrics as part of a CBA of WEF projects. NPV, BCR, and ROI are all useful metrics to help understand how a project generates benefits. Still, recommendations should be based on the project that creates the largest NPV. Projects with higher BCRs and ROIs are more cost-effective than projects with lower metrics, but projects with higher NPVs create the most benefits for society even if they are not the most cost effective. As a result, the guidance of this section is always to recommend the project with the largest NPV.