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BRIEFING NOTE
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Cost-benefit analysis for climate change adaptation policies and investments in the agriculture sectors

Overview

This briefing note illustrates the role and logic of Cost-Benefit Analysis (CBA) in the evaluation of climate change adaptation policies and projects in the agriculture sectors and describes the main analytical steps for conducting it, providing practical examples. The note describes the standard CBA methodology but highlights the peculiarities related to its implementation in the context of climate change adaptation in the agriculture sectors.

Key messages

1. CBA is a methodology and decision-making tool, which helps identify solutions (either policy options or investment projects) for an efficient allocation of scarce financial resources. It is usually conducted with reference to a project that is under consideration, but has not yet begun.[i] It also plays an important role in the NAP process in estimating the costs and benefits of different climate change adaptation options.

2. CBA consists of a series of analytical steps. It relies on a set of assumptions, which anticipate the expected outcomes of climate change adaptation interventions and policies.

3. The application of standard CBA should be complemented by specific analytical elements in order to properly consider impacts of climatic changes on the agriculture sectors and related risks; uncertainty of climate scenarios; climate change adaptation policies; and long-term adaptation interventions and investments.

Integrating Agriculture in National Adaptation Plans Programme (NAP–Ag)

CBA of climate change adaptation options

CBA is listed among the methodologies to be used within the preparatory elements of the National Adaptation Plans (NAPs) in order to rank and prioritize adaptation options in light of their costs and benefits to society (see UNFCCC 2012, section B.3).

CBA is an assessment method that quantifies in monetary terms the value of all consequences of a project to all members of society. It is a technique for measuring whether the benefits of a project are larger than the costs, judged from the viewpoint of society as a whole. A *financial analysis* aims at evaluating the costs and the benefits generated by a single entity, such as an organization or a company. Conversely, the *economic analysis* of CBA tries to consider all costs and benefits accrued to society as a whole, such as the social costs and benefits to various beneficiaries. If benefits completely offset costs, then the project makes society better off as a whole as various studies demonstrate (Boardman *et al.*, 2014 and Hanley and Barbier, 2009).[ii]

The goal of CBA is to ensure efficient allocation of society's resources by informing policy-makers and public sector stakeholders on the economic efficiency of alternative projects, interventions and policy options (Boardman *et al.*, 2014; Zerbe and Dively, 1994).[iii] It can assist the public sector in deciding whether financial resources should be allocated to a specific project or not. Within the NAP process, results from CBA are applied to evaluate and rank different adaptation options as part of the implementation of the NAP. The results of CBA can be integrated by a large number of screening criteria including political, social and other considerations.[iv]

Table 1

The major steps of CBA for agriculture adaptation projects

1	Define scope and boundaries of the analysis of the adaptation project
2	Describe the 'with and without adaptation project' (WP and WOP) scenarios
3	Quantify and monetize adaptation benefits and costs every year over the duration of the project.
4	Estimate the annual flow of net benefits of agriculture adaptation projects
5	Compute selected indicators for agriculture adaptation projects
6	Perform sensitivity analysis with reference to climate change scenarios
7	Make recommendations

Source: adapted from Boardman et al. 2014

CBA of agriculture adaptation options: the basic steps

Performing CBA of adaptation projects in the agriculture sectors might require a significant amount of data, information and skills from a multidisciplinary team of experts. The basic CBA steps are listed in **Table 1** and summarized below.

Step 1 aims at defining the scope and boundaries of the analysis in order to decide which and whose benefits and costs should be included. This will help outline all sets of available alternatives, including whose benefits and costs are valid. Project developers usually refer to the general location of the project area within the country (project area boundaries) and CBA would consider projects' costs and benefits to local communities (local boundaries). However, several considerations should be made to acquire a broader perspective such as environmental impacts falling outside project boundaries. Government funded investment projects may consider the area or jurisdiction under their national authority at which point CBA would be conducted within the national boundaries.

CBA compares the benefits and costs of investing resources in the adaptation project with what would have happened in the absence of project interventions (i.e. the counterfactual or baseline scenario). CBA is conducted in both 'with project' (WP) and 'without project' (WOP) cases which are described in the analytical step 2. Due to the probability of spontaneous adaptation taking place in a given project area even when the project is not implemented, particular attention must be paid to the definition of the counterfactual scenario (i.e. the WOP scenario is not static and a baseline in which nothing happens is unrealistic). Predictions are difficult when projects are unique, have long time horizons, or relationships among variables are complex. Modelling work (e.g. crops, livestock or farm models) is often used to simulate project impacts and take into account the heterogeneity of the agriculture sectors at different levels such as geographical and agro-climatic context, productivity, capital and labour availability, technology levels, community and market access. In the application to climate change adaptation projects, climate modelling is used in order to define climate scenarios as wewll as additional benefits or costs related to the adaptation options. For example, benefits can be defined as avoided damage costs of climate change, whereas costs are related to the actual investments in implementing the adaptation action.

On the basis of the project and counterfactual scenario description, step 3 consists in quantifying and monetizing all project benefits and costs over project life, in both WP and WOP cases. This implies the need to:

- identify the project's tangible inputs and outputs;
- identify project impacts through a cause-and-effect relationship within the boundary of analysis;
- catalogue them as benefits or costs; and
- assign a monetary value to each benefit or cost.

Technical inputs and outputs are valued at market prices to construct the financial accounts on the basis of the assumption that prices reflect value as demonstrated by Gittinger (1995). This financial analysis will assess the financial effects the project will have on farmers, public and private firms, government agencies and other participants.[v]

A monetary value to each project input, output or impact can easily be assigned where markets exist and work well.[vi] Problems arise when market prices are no longer a good guide to social costs and benefits, for example where markets such as environmental goods do not exist or do not work well, as is the case in many developing countries. In such cases, specific methods can be used to measure "non market" values[vii] or to adjust financial prices of tangible items to reflect economic values known as shadow pricing.[viii] As shown by Gittinger, when the market price is changed to more closely represent the opportunity cost[ix] to the society, the new value assigned becomes the *shadow price*. This part of CBA is also called 'economic analysis', as opposed to 'financial analysis'. In CBA of adaptation options, intangible factors like environmental externalities should be considered besides estimates of tangible cost-benefit factors and social costs and benefits.

Step 4 takes into account that project impacts occur over years. Future benefits and costs are discounted relative to present benefits and costs in order to obtain their Present Values (PV). This is necessary since it is not possible to compare values which occur at different points in time.[x] Discounting implies that resources available in the future are worth less than the same amount available at present. This reflects the opportunity cost of resources: a given amount of resources today can be transformed into a greater amount in the future due to alternative investments to the project. (Boardman *et al.*, 2014). There is ample debate about the choice of the appropriate social discount rate (Arrow *et al.*, 2013; Gollier, 2002; Weitzman, 1998; Campos *et al.*, 2015; IMF, 2013).[xi]

As shown in step 5, a critical stage towards understanding the benefit of the project to the society is the estimation of its aggregate impact. To do so the Net Present Value (NPV) of each alternative must be computed. NPV equals the difference between the PV of the benefits (B) and costs (C): NPV = PV(B) – PV(C). The basic decision rule for a single project, relative to the counterfactual, is to adopt the project if its NPV is positive. When mutually-exclusive alternatives are compared, the rule will be to select the project with the largest NPV. Also, the Internal Rate of Return (IRR) of proposed investments is computed. The IRR is the value of the discount rate for which the NPV is zero. The IRR may be used for selecting projects when there is only one alternative under consideration. If the IRR of a project is greater than the prevailing discount rate, then one should proceed with the project (Boardman *et al.*, 2014).[xii]

Step 6 deals with the considerable uncertainty about both the predicted impacts, due to the many changing dynamics that could eventually affect the results of interventions, and the appropriate monetary valuation of each unit of the impact such as price volatility or variations in crop and livestock productivity. Every assumption in CBA can be potentially varied, even if sensitivity should only focus on the most important assumptions and parameters key to the outcome of the analysis.

A fundamental issue in conducting CBA of adaptation options is the treatment of uncertainty pertaining to climate change and the handling of multiple climate projections. In particular, the conduct of sensitivity analysis in the context of climate change is significantly different to the conduct of 'traditional' sensitivity analysis. Climate change and risk prevent the use of expected values and must be based on scenario-based analysis, which would consider risk assessments and future climate projections. Long-term adaptation investments in agriculture require assigning probability distributions to different climate change scenarios in order to possibly further analyse the sensitivity of the results. In addition, costs or benefits of slow-onset adaptation options, occurring in long-term time horizons (e.g. 25, 50 and 100 years) are difficult to quantify and the choice of the discount rate affects the NPV outcomes. As a consequence, limitations of *ex ante* CBA in light of weather unpredictability should be considered and estimated costs and benefits will necessarily be approximate.

Relying on the analysis conducted following the steps highlighted above and on the basis of concrete and elaborate information generated through the CBA, it will be possible to make recommendations about the project and the eventual alternatives as iterated in step 7. It is worth noting that CBA is a rigorous analytical process, which provides the decision-maker with objective information and results. Assumptions made in the analysis should be based on empirical data, supported by strong evidence, validated with key experts and described in a transparent manner. A summary of the key definitions related to CBA is provided in **Box 1** below.

Box 1

Definitions

Discount rate: the rate at which future benefits and costs are discounted to make them comparable with benefits and costs at the present time. If an annual rate of 10 percent is applied, USD 1 of costs or benefits in one year's time is equal to 91 cents today and USD 1 of costs or benefits two years from now is equal to 83 cents today.

Present value (PV) of costs: the sum of all costs, present and future, with each year's costs discounted at the selected rate.

Present value (PV) of benefits: the sum of all benefits, present and future, with each year's benefits discounted at the selected rate.

Net Present Value (NPV): the difference between the PV of the benefits (B) and costs (C): NPV = PV(B) – PV(C). The basic decision rule for a single project, relative to the counterfactual, is to adopt the project if its NPV is positive.

Example: CBA of adaptation options for Arabica coffee production in Uganda

This section summarizes a practical example on the use of CBA for agricultural adaptation options for coffee production in the Mount Elgon region of Uganda according to a recent survey (FAO, 2016).

Climate change projections in Uganda indicate a slight decrease in total annual rainfall and an increase of temperature, which might negatively affect Arabica coffee production in particular at lower altitude ranges. Extreme events, such as heavy rainfall and/or droughts, are also likely to increase in frequency and intensity. Climate projections suggest that the impacts of climate change could further affect coffee production in the area. The adoption of agricultural adaptation practices could help farmers deal with current climate variability and adapt to climate change.

The CBA analysis focused on the Bududa district, an area extending over 4 340 hectares in the Mount Elgon region, and well covered by coffee cooperatives and private companies. 'Conventional' coffee production would represent the baseline or counterfactual (WOP case). With climate change, under WOP, yields are projected to decline by 10-50 percent by 2050, with the mean loss at 30 percent by 2050. The WP case consists of agricultural adaptation options in the project area such as soil and water conservation techniques (e.g. conservation tillage, erosion bunds or terracing) together with agroforestry at the farm scale. Costs of such adaptation measures include the costs per hectare of coffee plantation land on which to adopt the selected practices and the costs of the support measures per farmer. As demonstrated by Baastel (2015), based on detailed estimates collected in the field, expected benefits of the adaptation practices would consist of increased yields per tree by a factor of 3.4 over the 15 years, compared to the baseline (WOP). This would translate in on-farm increased revenues from the sale of higher yields of Arabica dried beans.

Planting shade trees may not only increase the productivity of coffee trees, but it may also reduce the risk of floods and, consequently, its economic and social costs. The reported study (FAO, 2016) accounts for on-farm private benefits but not for such environmental benefits, and lacks in information on flood recurrence and the avoided costs of floods. To add up costs and benefits in different years a standard discount rate of 10 percent has been used, with results shown in **Table 2**. Computed NPV is positive in both WP and WOP scenarios. Nevertheless, NPV is higher in the WP case indicating that the proposed project investments will be advantageous.

In the sensitivity analysis, the authors of the study also found that under the climate change scenarios, profitability will drop under both WOP and WP scenarios, but that profitability will still be higher in the WP scenario – even with climate change, than in the WOP case. However, even under the WP scenario, coffee profitability drops when climate change projections are taken into account; by the second 15-year cycle it is barely profitable. Finally, significant income fluctuations over the years are recorded when droughts or floods occur (FAO, 2016).

Table 2

Costs and returns of adaptation options for Arabica coffee production in Uganda in a 15 year period

	Unit of measure	WP	WOP
Cost per Tree (15 years)	USD	21.4	8.3
Cost per Tree per Year	USD	1.4	0.6
Return/Tree (15 years)	%	41.1	12
Return/Tree/Year	%	2.7	0.8
Profit per Tree	USD	19.7	3.7
Profit per Tree per Year	USD	1.3	0.2
Total Project Area	Ha	4340	4340
Total Costs (15 years)	000 USD	139 505	54 228
Total Revenue (15 Years)	USD	267 466	78 415
NPV	000 USD	64 885	12 264

Source: adapted from FAO 2016

Conclusions

CBA is a decision-aiding methodology which assesses how resources should be allocated among different alter-natives in order to reach economic efficiency. CBA is selected as a fundamental methodology within the NAP preparation, representing a key input to the planning process. CBA allows to compute the NPVs of adaptation options under different climate scenarios. As demonstrated by Hallegatte (2009), uncertainties of climate change pose new challenges for decision-makers and, as shown by Pindyck (2007), seriously complicate CBA, which should rely on climate-change related models, data and factors.

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Notes

[i] More generally, CBA applies to projects, programmes, investments, policies, regulations. For the sake of simplicity only the term "project" is used here. Standard CBA is generally conducted ex ante, while a policy or a project is under consideration, before it is started or implemented. CBA could be conducted ex post, too. Given the objectives of the present note, this is not taken into account here.

[ii] Social CBA does not explicitly consider the distributional aspect of any extra worth generated by the project. The underpinning assumption in welfare economics is that in a better-off society, the government will adequately redistribute resources so as to compensate those who incur losses, and that society would still be in a more efficient and equitable equilibrium where social welfare is maximized.

[iii] Efficiency can be thought of as a situation in which resources such as land, labour and capital are deployed in their highest value in terms of the goods and services they create. This is intended as allocative Pareto efficiency, which means an allocation of goods which cannot make at least one person better off without making anyone else worse off (see Boardman *et al.*, 2014).

[iv] For example, multicriteria analysis (MCA) allows project options to be ranked against a number of criteria, including economic efficiency. MCA does not act as an alternative to CBA, but uses the outcome of CBA as a measure of the economic efficiency of the proposed project. Using the weighting system, MCA determines an overall score for each alternative option thus helping to make a decision on the option to be prioritized.

[v] When conducting financial analysis of agricultural adaptation projects, partial budgets are usually built and on-farm costs and revenues are estimated. Results could also be used to: compute economic performance indicators such as net incomes or returns to factors (e.g. labour, land, capital); provide farmers with useful data about on-farm economic results; and eventually orient farmers toward more productive crops, technologies and farming systems, also contributing to the development of more business-oriented ways of thinking and skills.

[vi] In well-functioning competitive markets, the willingness to pay (WTP) for a specific good or service can be determined from the appropriate market demand curve and prices of goods and services correctly reflecting their value. In this case, social and private costs (and social and private benefits) are the same thing, meaning that market price simultaneously reveal both marginal social and private costs (and benefits) (Hanley and Barbier, 2009).

[vii] Different approaches to putting monetary values on changing environmental quality include: stated preference methods, revealed preference approaches and the evaluation of ecosystem services (e.g. see Hanley and Barbier, 2009).

[viii] Examples include: adjustments for direct transfer payments (e.g. government interventions in markets through taxes, direct subsidies, credit transactions) and adjustments for price distortions in traded and non-traded items (Gittinger, 1995).

[ix] The opportunity cost is the value of a good or service to its next best alternative use. Opportunity cost measures the value of what society must forgo to use the input to implement the project (Boardman *et al.*, 2014). For example, the opportunity cost of land is the net value of production forgone when the use of land is changed from its WOP to its WP use. In estimating the opportunity cost of labour, wage rates in many developing countries do not accurately reflect it and should be appropriately reduced (Gittinger, 1995).

[x] A cost or benefit that occurs in year t is converted to its present value by dividing it by $(1 + s)^t$, where s is the social discount rate. Suppose a project has a life of n years and let Bt and Ct denote the benefits and costs in year (t), respectively. The PV of the benefits and the costs will be respectively: $PV(B) = \sum[Bt/(1+s)^t]$ and $PV(C) = \sum[Ct/(1+s)^t]$.

[xi] The choice of appropriate social discount rates is anchored in welfare economics which assumes that the marginal value of an additional dollar of net benefits is smaller when the recipients of those benefits are richer. If an economy is growing over time, the recipients of future benefits of a project will be richer. As a result, future benefits are valued less than those that occur in the present, when recipients are worse-off. Thus, if growth is expected to be positive over the life of the project, future beneficiaries will be richer than current individuals, and future benefits should be discounted accordingly. Where no country-specific growth projections are available, the World Bank suggests using 3 percent as a rough estimate for expected long-term growth rate in developing countries, yielding a discount rate of 6 percent. Where there is reason to expect a higher (or lower) growth rate, a higher (or lower) discount rate should be chosen (World Bank, 2015).

[xii] Problems associated with using the IRR for decision making include: i. no existence of IRR; ii. existence of multiple IRRs as more than one discount rate would render a zero NPV; iii. IRR is a percentage and cannot be used in comparing projects which are different in size (Boardman *et al.*, 2014).

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Integrating agriculture in National Adaptation Plans

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