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MAKING IRRIGATION PROJECTS VIABLE AND SUSTAINABLE
A GUIDE TO USING ECONOMIC ANALYSIS

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ACRONYMS & ABBREVIATIONS

AFD	French Development Agency
AFEID	French Association for Sustainable Agricultural Water, Irrigation and Drainage
AI	Agricultural income
CBA	Cost-benefit analysis
COSTEA	Agricultural Water Scientific and Technical Committee
EA	Economic analysis
GVA	Gross Value Added
IFC	International Finance Corporation (World Bank Group)
IRR	Internal rate of return
LCA	Life cycle analysis
MCA	Multi-criteria analysis
NPV	Net Present Value
OC	Operating costs
PPP	Private public partnership
PROPARCO	Promotion and Participation for Economic Cooperation (an entity within the AFD Group)
PSD	Public Service Delegation

INTRODUCTION

1.1 Why a guide to using ex-ante economic analysis of irrigation projects?

While economic analysis is typically presented as a decision-making tool, it is often poorly or hardly used when appraising irrigation and agricultural development projects.

In most cases, investment decisions are made both by project owners and by donors based on criteria other than the expected economic outcomes. This approach may not be questionable per se given that the objectives of irrigation projects usually involve much more than economic stakes.[1] What could be questioned, however, is the role to which economic analysis is limited, i.e., justifying, a posteriori, investment decisions by highlighting the economic indicators targeted by decision-makers.

As noted by a group of researchers and practitioners working together under COSTEA: "*In practice, economic analyses are often given secondary consideration compared to other dimensions underpinning projects and investments that are more technical or political. Economic analyses are sometimes conducted in a summary manner and very often as a mere formality to justify choices that have already been made. In those cases, they too often are disconnected from the project thinking and development phases, which ultimately raises the issue of their relevance or even their usefulness*."[2]

In this context, the economic analysis of irrigation projects generally boils down to two indicators, the Net Present Value (NPV) and the Internal Rate of Return (IRR). Furthermore, the values of these indicators are misinterpreted by the various actors. The indicators are used mainly in discussions between the Ministry of Finance of the countries contracting a loan and their donors. They are seldom reviewed with the content of projects and the expected outcomes (whether economic or else), such outcomes being discussed with the ministries having technical competence over the projects.[3]

In line with this limited interest in economic analysis, it is carried out in parallel or after technical studies, with no link to the various study components and consistently with inadequate resources.

As a result, there is minimal - yet actual - possibility of using ex-ante economic analysis not only as a decision-making tool (to move forward with the project or not) but also, perhaps more importantly, as a tool to support design.

Groundwater-based irrigation - Province of Prey Veng, Cambodia © J-P. Venot

Thus, economic analyses should allow for assessing stakeholders' interest and buy-in (by precisely reviewing their situation, capacities and expectations) andidentifying conditions under which projects are feasible and, as needed, for restructuring or abandoning projects if the conditions cannot be met.

In the case of irrigation projects:

- by reviewing agricultural systems, the analysis allows for identifying under which conditions producers will benefit from participating in the project and for defining the components to support producers;
- by specifying the conditions required to achieve financial balance in the management of collective hydro-agricultural infrastructure, where applicable, it supports the selection of institutional and funding arrangements that will ensure the sustainability of investments;
- more generally, by integrating all the dimensions of an irrigation project (technical, social, environmental, institutional, economic and financial), it feeds into the thinking and decision-making on all project components.

1.2 Presentation of the guide

This guide results from an initiative of the Scientific and Technical Committee for Agricultural Water (COSTEA) motivated by two observations: (i) in projects, economic analysis is hardly used or misused, and (ii) the specificities

1 Irrigation projects pursue several objectives, as explained in Chapter 2.

2 Malerbe, Florence, Pierre Strosser, Frédéric Bazin, Samir El Ouaamari, Béatrice De Abreu, Jean-François Amen, and Jérémie Dulioust. «*Éclairages sur l'analyse économique des projets d'irrigation* ». COSTEA, February 2019, page 7. www.comite-costea.fr/wp-content/uploads/AC-Analyses-Economiques-rapport-eclairage-economie-1.pdf

3 When projects are funded through a grant, little attention is given to economic analysis in most cases.

of irrigation projects are not considered in economic analyses (see box).[4]

The guide's objective is to contribute to improving the way economic analyses are performed in the context of irrigation projects with public financing at the feasibility stage. As such, it focuses exclusively on ex-ante analyses and attempts to identify irrigation specific problems (see box below). The approaches and methods presented here were explicitly developed in this context, but one should keep in mind that they can be useful at other stages in the life of a project, in particular for monitoring its implementation and in ex post evaluation.[5]

WHAT CHARACTERIZES IRRIGATION PROJECTS

- Construction of individual or collective infrastructures that may be costly;
- Need for a "management structure" that ensures proper use of the collective infrastructure and serves as an interface between the various actors (additional level of governance);
- Obligation to fund long-term operation and maintenance of infrastructure and to ensure the difficult task of reconciling individual interests and collective obligations, in particular when there is a significant diversity of irrigators;
- Use of natural resources (land and water) shared with other consumptive uses (livestock, rain-fed agriculture, drinking water, industry, local authorities, etc.) or non-consumptive uses (hydroelectricity, navigation, leisure, etc.);
- Overlapping and/or combinations of rights relative to allocation, transfer, and uses (cultivated land, pastoral, forestry, access to water), involving a large number of actors (State, local authorities, communities, owners, operators, users, investors, etc.);
- Structural modification of the territory;
- Significant change (that may be gradual or not) in production systems and agricultural practices, as well as upstream and downstream sectors;
- The time to develop irrigation systems, which is often proportional to the scale of the works and the magnitude of the changes occurring in the territories and production systems;
- high variability and uncertainty caused by climate change can impact water resources and demand.

Adapted from COSTEA, 2019, « *Éclairages sur l'analyse économique des projets d'irrigation* », op. cit.

The assumption underlying the methodological approach presented in this guide is that when economic analyses are conducted according to an approach adapted to the nature of projects, it can provide much more than the value of IRR:

- It can feed into and contribute to shaping the dialogue between donors and project developers or owners, whether public or private, on project design and on decisions at the various stages (including the decision to move forward with projects or not);
- It allows to integrate the different dimensions of projects (technical, economic, financial, social, and environmental) and thus provides key inputs into the design and sizing of projects;
- It should be an opportunity to involve farmers and all stakeholder on the ground in the project design and analysis process, which is rarely the case;
- Finally, it can contribute to defining the contents of communication and information to all stakeholders.

The purpose of this guide is to convince public project owners and donors the usefulnes of a well-done economic analysis in the design and implementation of sustainable irrigation projects.

This guide is a methodological tool intended for:

- decision-makers, who will use it to better mainstream economic analysis into the process of defining irrigation projects and to specify the contents of their requests for economic analyses,
- practitioners who will draw inspiration from it to meet the expectations of public authorities carrying out irrigation projects.

Olive trees and irrigated annual crops - Kairouan region, Tunisia © F. Deram Malerbe

4 COSTEA was created in 2013 with funding from the French Development Agency (AFD) and is implemented by AFEID (www.comite-costea.fr)

5 This guide pertains only to projects implemented on public funding and benefiting a set of farmers, regardless of the type of farm. Irrigation projects implemented by private investors are not considered insofar as they do not involve the same issues.

CHAPTER 2

GENERAL PRINCIPLES OF THE PROPOSED APPROACH

2.1 An approach by successive questions

The approach proposed in this guide is based on the idea that there is no standard method that can be applied to all irrigation projects, but rather a set of principles that should be translated into an economic analysis approach adapted to each situation to be reviewed.

To determine the appropriate approach to the ex-ante economic analysis for a given irrigation project, one has to go through a series of questions, as illustrated in Figure 1.

The approach will depend on the type of project, its objectives, the typology of the irrigated perimeters, and finally, the objectives of the economic analysis. In any case, three levels of analysis will be needed to assess the economic sustainability of a project: the producers-irrigators, the irrigated system, and the territory. Depending on the type of project and infrastructure, the importance of each of these three levels of analysis varies and therefore should be questioned. For each level of analysis, specific methods will be used to assess the relevant indicators from data available or to be collected. Depending on the situation, there will be large variations in the means and resources to be mobilized.

2.2 Typology of projects and irrigated perimeters

2.2.1 Projects

Table 1 makes a distinction between four main types of projects, based in particular on the following:

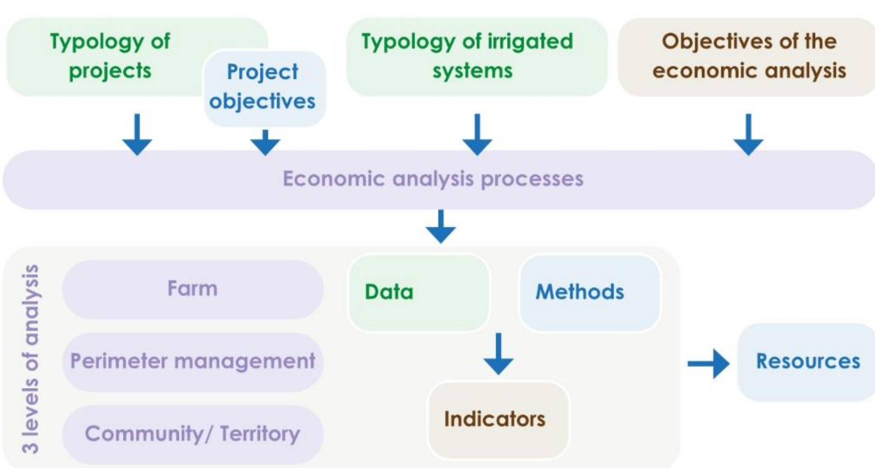
- the nature of the infrastructure targeted by the project (major structure or development of irrigated areas);
- the nature and diversity of project components;
- and finally, the project's geographical scope (local, multi-site, territorial, or national).

Table 1: The four types of projects considered

Development of an irrigated scheme
• Construction or rehabilitation of a hydro-agricultural scheme with support to users (in general management of the schemes and agricultural development). • It may be a sub-project of the following two types.
• Local scale
Irrigation development program
• Multi-component project • Investments in several schemes, support for the management and development of schemes, • This is often supplemented by microfinance activities, support for irrigated sectors, institutional support, etc.
• Multisite
Large multi-use infrastructure
• Dam and/or transfer or transport infrastructure with irrigation being one use of the infrastructure (often irrigation is a small users for dams whose main purpose is energy production). • Project with several technical components (or sub-projects).
• Territorial scale
Public policy
• Institutional technical assistance for the construction and/or promotion of an irrigation policy. • And/or funding for the implementation of a public policy.
• National scale

The objectives defined for projects are also an important element to distinguish between types of project.

Figure 1: Approach by successive questions to select the appropriate economic analysis approach



Four main types of projects are identified at this stage:

- Projects aimed at increasing agricultural production on a large scale (national or regional);
- Rural development projects aimed at improving farmers' incomes and living conditions (local level);
- Projects aimed at optimizing the use of water resources (network upgrade, resources substitution, for example), this objective often going hand in hand with that of improving system management (manager's organization and resources, collection costs, in particular);
- Projects aimed at climate change adaptation or climate impact reduction (resilience).

Two other objectives promoted by projects should also be mentioned, which rather correspond to the methods applied for achieving the objectives mentioned above (productivity, export, income, development, climate):

- Call for private investment;
- Innovation.

Table 2: Projects main objectives

Objective	Characteristics
Increased production/productivity	• National or regional impact project • Local consumption products • Includes sub-sector development
Production for export	• Export products • May include sub-sector development
Improved farmers' incomes	• Project of a more local dimension • Sustainable increase in production and farmers' incomes (and resource conservation)
Rural development	• Local socio-economic development • Settlement of rural populations
Adaptation to climate change	• Resilience of agricultural systems • Long term vision
Climate impact reduction	• Reduction of greenhouse gas emissions
Optimization of the use of water resources	• Project of local or national scale • Modernization of infrastructure • Resource substitution or input of additional water resource • Improved management (cost recovery, operation and maintenance, etc.)

All these objectives are encountered in most irrigation projects, with variations as regards to their relative importance. Many of the existing projects combine three objectives: climate, optimization of the water resources use, and increase in agricultural production, whether at a national or local scale.

Thus, the main objective of an irrigated scheme development project of local scope (or of regional scope in the case of a large system) may be to build resilience of agricultural systems to climatic shocks, and its "secondary" objective may be to increase the income of agricultural households directly linked to it.

2.2.2 Irrigated schemes

Irrigated schemes are very diverse, and the characteristics of the schemes targeted by irrigation projects (whether for creation, rehabilitation, extension, or support) must be considered in selecting the economic analysis approach and methods.

This is especially true regarding the scheme management arrangements (the manager's nature and missions). For instance:

- For a perimeter managed by a professional structure (employing salaried administrative and technical staff), a detailed financial analysis must be performed. In the case of a company that is privately owned (in whole or in part), the financial analysis must consider the return on the private capital invested. In all cases, the pricing of the service should also be based on the analysis of users' willingness and ability to pay (as part of the analysis of agricultural systems) for the service rendered;
- In the case of a scheme managed by a users organization and whose members contribute by paying a fee, a financial analysis of the organization should be performed, and users' willingness and ability to pay should be assessed;
- In the case of a scheme managed by its users, whose only contribution is working time for the operation and maintenance of canals, the analysis should focus on assessing the farmers' willingness and ability to play a role (mainly in terms of available time).

The nature of the infrastructure, its complexity, and its operating mode will also determine which methods should be applied or calculations made. For instance:

- The assessment of operation and maintenance tasks will differ based on whether the networks are open surface or pressurized and based on the type of organization put in place to perform these tasks;

- When the infrastructure operates with one or several pumping levels, it would be essential to ensure the reliability of the related costs.

The farming methods is also a decisive aspect in economic analyses. For instance:

- The economic assessment of agricultural systems that are very diversified will mobilize tools other than a monoculture scheme. In particular, it will be necessary to be more precise in the analysis of agricultural systems and the typology of farms;
- Self-consumption (food crops) and production for marketing will not be valued in the same way;
- Waged labor and family labor are not considered at the same level in the financial analysis of farms.

The reliance of farming activities on collective networks should also be considered, notably by assessing the importance of irrigated agriculture and the existence of alternative water resources.

The table below groups the main elements that account for the diversity of irrigated schemes into three groups: each of the features mentioned will have to be reviewed in a more detailed analysis under the economic analysis of the project.

Table 3: Criteria for a simplified typology of irrigated schemes

Institutional arrangement
• Project management - Investment • Operation-Water distribution • Maintenance • Renewal

Perimeter and infrastructure
• Size • Water management • Collective/individual • Resource • Water supply infrastructure • Distribution network

Agricultural system
• Crops • Reliance on networks • Farm size • Type of operator • Land status

2.3 The three levels of economic analysis

Under ex-ante project appraisals, the term "economic analysis" includes the actual economic analysis and financial analysis. Though this guide uses the generic term "economic analysis" for the sake of simplicity, it is important to make a clear distinction between "financial evaluation" (or analysis) and "economic evaluation" (or analysis). Financial evaluations take the perspective of those actors that will participate in the project and aims to verify that each type of actor will have an interest in participating in the project and will be in a position to do so, in particular, and that they will have the material and financial resources required. Financial evaluations allow for foreseeing, where applicable, the financial conditions to ensure the participation of these actors, including subsidies, credits, tax exemptions, etc. Economic evaluations, on the other hand, take a perspective of general interest (at the level of the Government, the community or the territory impacted), by analyzing the advantages and disadvantages for society as a whole. They allow for choosing to fund and implement those projects that are the most beneficial to society or for choosing between several variants of the same project. In this latter case, they contribute to defining the technical and organizational characteristics of the project.

Well for market gardening - Mauritania © F. Bazin

IMPORTANT NOTE:
DIFFERENCES BETWEEN AN ECONOMIC ANALYSIS AND A FINANCIAL ANALYSIS

The methods used to analyze project outcomes for producers or a territory are similar, which can lead to confusion. However, there are substantial differences to keep in mind when doing the analyses:

- Effects (positive or negative) differ according to whether one takes the perspective of producers or the community. For example, the use of nitrogenous fertilizers can be considered an advantage by producers because it results in better yields for them, whereas it can be negative for the community if their excessive or inappropriate use causes groundwater pollution and eutrophication of surface waters.
- The prices considered for economic and financial analyses are different. Market prices used in the financial analysis do not necessarily reflect the actual value of the goods or services produced or consumed during the project. For example, use by an energy producer at a subsidized price for irrigation will be accounted for at its actual price (paid by the producer) in the financial analysis, while in the economic analysis, the energy reference price at the national level (which is non-subsidized) will be used. Similarly, rice production, whose consumer price is subsidized by the Government, may have an economic price higher than the market price.

In any case, one should start by analyzing the effects in physical terms by comparing the projected "with project' situation with the "no project" situation that would occur for each period. Two methods may be used to translate these physical effects into monetary terms:

1. the reference price method, which attributes to the goods and services used and produced by the project shadow prices that better reflect the actual advantages and disadvantages generated for society;
2. the effects method, which uses market prices to calculate the project's contribution to creating national wealth by deducting external transfers from the project's net added value, both direct and indirect.

These two methods (see Annex 3) yield similar results (NPV and IRR), provided the reference prices reflect the effects not captured by the market prices and all the direct and indirect effects are adequately measured.

Financial analysis considers all the economic agents involved in the project: farmers, landowners, traders, public or private companies, etc. This guide focus specifically on two categories of agents: irrigating farmers (producers) and managers of irrigation networks (operators). The method can be applied to all categories of economic agents.

Farmers who irrigate or produce

To assess the interest and ability of farmers to develop a scheme, very good knowledge is required of the various production systems and the rationale of the different types of producers. For example, producers who seek to ensure their family's food security may favor less profitable but less risky crops to avoid having years in which they cannot feed their family, to the detriment of cash crops proposed by a project. Others may have be interested in enhancing their labor force's value by working on rainfed crops rather than on the irrigated scheme. Finally, some may not have the material and financial resources needed to grow two crops a year without efficient credit and marketing systems.

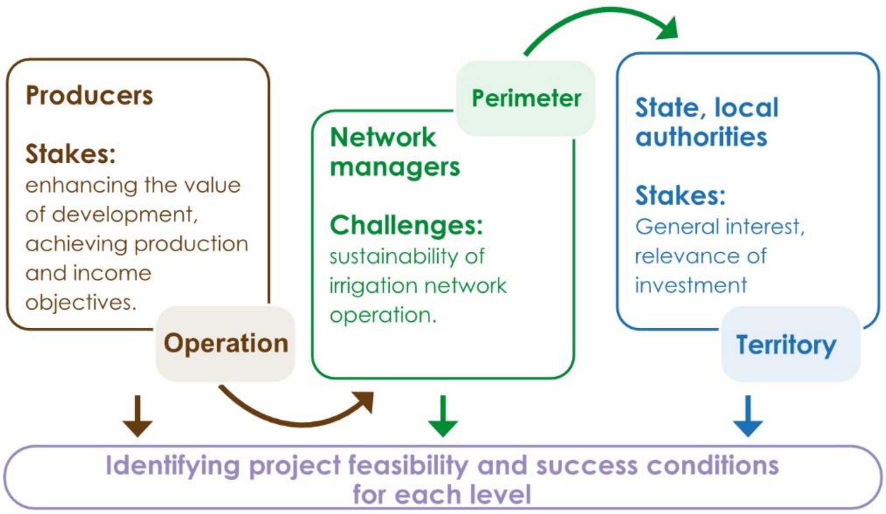
The assumptions underlying the profitability analysis for each type of producer - such as assumptions on price, yields, and development rates - must be clearly explained, as well as the technical, economic, and financial conditions that must be met for these assumptions to hold. Producers who do not have the necessary (financial, human) resources may, therefore, not have the interest or the ability to implement the surface areas envisaged or to work to achieve the expected results, unless the project provides support measures such as credit, subsidy, technical support, mechanization, etc. This is where the producer level analysis allows to identify the required support measures.

Irrigation network managers or operators

In the case of collective irrigation systems, managers of irrigation networks are key actors in ensuring project sustainability. Many irrigation projects show poor performance due to the lack of effective management and maintenance of collective infrastructure at all levels (dams, canals, pumps, etc.). Various types of institutions manage irrigation networks, such as farmers' organizations (associations, groups, and federations of irrigators), administrations, public companies, private companies, or even semi-public companies. Under more or less complex systems, the responsibility for managing and maintaining irrigation systems may be split between several actors of different types. The financial balance of the management function must be ensured for network managers to be able to provide satisfactory services to their users in the long term.[6] This balance depends, on the one hand, on the cost of operating and maintaining the network and, on the other, on the capacity of the different actors to contribute to its funding. More generally, the institutional arrangement also depends on the local legal and

Figure 2: The three levels of economic analyses

[6] This guide does not discuss the financial interest for a potential private investor. The point here is not to develop methods to compare different types of investments.



regulatory frameworks (existing statutes, rights and duties of institutions, etc.).

To achieve the objectives presented above, an irrigation project's economic and financial analysis is broken down into three levels. The analysis process must consider the specific expectations and stakes at each level, which also depend on the project type, as discussed in Chapter 3.

Canals of Arcahaie, Haiti © F. Deram Malerbe

CHAPTER 3

PROCESS OF AN ECONOMIC ANALYSIS FOR IRRIGATION PROJECTS

The process of an ex-ante economic analysis refers to defining the different stages of an economic analysis in the first stages of the project process, based on the type of project and irrigated scheme.

For each major type of project defined earlier, the task will consist in specifying when and why the economic analysis plays a role, i.e., which discussions and which decisions it must feed into at each stage of the project development process and before project implementation.

Each situation is illustrated by a summary diagram of the project process (from identification to inception), allowing to visualize where the ex-ante economic analysis occurs. The diagrams also specify whether the analysis is to be performed in several stages (during project identification, feasibility study and/or detailed studies) and indicate for each of the stages:

- The type of analysis to perform, including the levels of analysis required (producers, operator, and territory);
- The main inputs to decision-making regarding the project that can be drawn from the analysis.

What is meant by the "first stages of the project process" should be specified here. These include:

- Project identification study - this is the phase before the launch of studies, during which the project features are broadly defined between the local authorities and the donors. This step allows for validating the project's overall relevance;
- Pre-feasibility study - this is an intermediate step that may be conducted in some cases and corresponds to a summary feasibility study limited to some aspects. It can also be part of the identification study;
- Feasibility study - it consists of all the studies (technical, economic, social, environmental, etc.) that will identify project feasibility conditions, i.e., conditions under which the project will be feasible, efficient, and sustainable. When investments are planned, the summary design of infrastructures is carried out at this stage.

- Detailed technical studies (and other complementary studies) - they serve to deepen studies based on the options selected at the end of the feasibility stage. They include at least the final technical project but should also cover all the dimensions of the project (technical, economic, social, and environmental), especially when it comes to complex projects.

IMPORTANT NOTE:
MONITORING-EVALUATION SYSTEM

The diagrams also include the project's monitoring and evaluation system to remind that economic analysis is an approach that must take place over the entire project duration - though this aspect is not covered here. The objectives vary depending on the project stage, but consistency should be ensured overall. In particular, how ex-ante economic analyses are performed determines what can be done in terms of monitoring and evaluation, and impact study. Therefore, it is very important to have future expectations in mind when carrying out an ex-ante analysis and to structure work in line with these expectations in particulare to have a usable baseline at later stages.
Monitoring and evaluation must also allow for validating the assumptions made during the economic analysis as the implementation of projects progresses. To this end, monitoring and evaluation must include indicators relating to the main assumptions.

3.1 For an irrigated scheme development project

3.1.1 Role of economic analysis in the project process

The project has an irrigated scheme as its scope and may consist in rehabilitating, upgrading, extending, or even creating a perimeter. It is, in a way, the "basic" irrigation project and, therefore, the "simplest" project process in terms of approach.[7]

The project generally includes an investment component for infrastructure works and one or several support components to provide support for scheme management and agricultural development.

The process explained here will apply to more complex projects, namely irrigation development programs and major multi-use infrastructure projects.

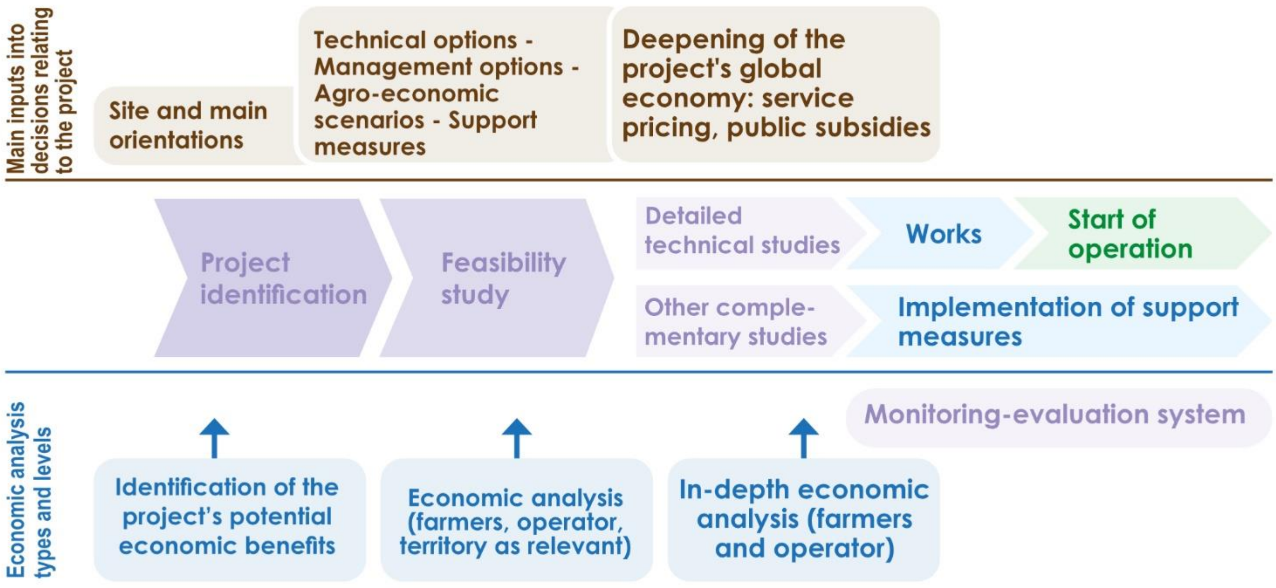
There are three stages in an ex-ante economic analysis, which correspond to the first three stages of project appraisal:
- Identification;
- Feasibility study;
- Detailed studies.

3.1.2 The different stages and levels of economic analysis

In the project identification phase

The project identification stage consists in characterizing in a qualitative way the expected benefits based on the main orientations (general and specific objectives) and the site. It also allows for validating the overall relevance

Figure 3: For an irrigated scheme development project – Project process and role of an economic analysis



7Projects to create irrigated schemes have become rare. Most of the projects aim to upgrade or rehabilitate existing perimeters.

of the project, i.e., that the activities planned and the objectives sought respond to needs and expectations at the project territory level regarding economic, social, and environmental aspects.

At this stage, the project's primary data can be specified and quantified, with further deepening planned later. These may include areas targeted, types of hydro-agricultural infrastructure, main cost components, main crops, main markets (food crops or cash crops), number of farms, and population concerned.

In the feasibility study phase

At the feasibility stage, an economic analysis must provide inputs for:

- Choosing among different options (technical, management) when such options exist;
- Specifying the relevant agro-economic scenarios (agricultural development);
- Defining the support measures required (for farmers and scheme management structures).

Analysis at the producer level: this analysis must be systematic because it allows assessing the farmers' a priori interest in the project, while simultaneously allowing for including them in the project design and thus preparing them to take part in it (as long as it is carried out in a participatory way, which is generally recommended).

> **IMPORTANT NOTE**
>
> An analysis of the farming budgets of the planned productions is not sufficient to assess farmers' interest in a project. The potential importance of these productions in the farmers' income should also be assessed. For example, if the productions have secondary importance for the farmers' income, even a large improvement in the value added will remain of little interest to the farmers, especially if the projected productions consume resources (such as labor) that are normally used for other productions. This is why it is essential to study each type of farm.

The analysis must include developing a typology of producers and the financial modeling of their farms to check whether each type of producer is interested and can participate in the project. It also allows the definition of measures, i.e., all the actions to be carried out, so producers can participate in the project and benefit from it.

The means to be mobilized for an assessment at the farmer level may vary according to the stakes and the data available (as well as the available means for the economist).

Quantitative work would allow producing the data needed for the economic assessment at the territorial level (in terms of value creation):

- if the analysis at the territory level is essential, it will be necessary to perform a financial assessment at the farmer level to have an accurate assessment of the value generated by modifying the production systems;
- if the territorial analysis is not necessary or without particular interest, it is possible to reduce the expectations in terms of quantitative results, provided the analysis allows to check the farmers' interest in the project and their ability to participate in the project, in particular their ability to pay the irrigation fee (if any). This work can be limited to a few farms representative of the diversity of producers.

Qualitative work must be done in addition to (and in support of) the quantitative analysis and would take the form of surveys and focus groups to understand farmers' expectations and the project relevance, and to suggest the measures needed.

The methods to analyze at the producer level are discussed in Chapter 4 (4.1- Farmer level).

Analysis at the manager level: it is essential to analyze at the manager level in the case of a collective infrastructure. The analysis will take various forms depending on the nature of the management structure and the existence of a fee (water service tariff) paid by users to the manager.
For instance:

- For a small irrigated scheme relying on a simple canal infrastructure, it is likely that no fee is to be paid by users who will contribute only their time for the operation and maintenance of the network. This is the case with some old networks whose proper functioning relies on establishing genuine irrigation commons (as defined by Elinor Ostrom[8]). In theory, there would be no actual financial analysis of the management but rather work to facilitate the co-construction of operating rules (to draw closer to the concept of commons). This case, however, is rare.
- For a simple, small-scale infrastructure managed by a users association, the key will be to assess the ability and willingness of producers to contribute (in time and fees) to the management of their shared infrastructure.
- For a large-scale infrastructure managed by an operator (who has employees and with no consideration of its status - associative, public, private or semi-public), a financial analysis is necessary to set pricing for the water service and, if necessary, to assess needs for public subsidies (for capital and operating expenditures), or other income-generating activities (such as the sale of equipment, advisory services, etc.).

The methods to analyze at the operator level are discussed in Chapter 4 (4.2 - Manager or operator level).

[8]Cf. Bibliographical references in Annex 1.

Harvesting rice - Nakai region, Laos © F. Bazin

Analysis at the territory level: The need for and usefulness of an economic analysis at the territory will be mainly determined by the scope of the territory and the likelihood of a significant territorial (regional or national) impact.
For example:

- For a scheme of a few tens to hundreds of hectares of food production, the territory level will not be of particular interest; it will therefore suffice to analyze project sustainability at the farm level and to explain the conditions for managing the irrigated system.
- For a scheme of several thousand hectares with one or more crops of strategic importance for food security or for export, the economic analysis at the territory level is important.

The economic analysis at the territory level is traditionally done by a cost-benefit analysis (CBA), according to a method described in Chapter 4 under "Territory level". Depending on the importance of the non-monetary effects and impacts, which are difficult to monetize, it can be supplemented or replaced by a multi-criteria analysis (MCA), also discussed in Chapter 4.

IMPORTANT NOTE

In all cases, an analysis of the social and environmental impacts on the project area must be conducted in addition because these impacts may determine the sustainability of the project and its acceptability to the populations. These will be addressed through the multi-criteria analysis

If several options are explored as part of the feasibility analysis, an economic analysis must be performed for each of them. This will not necessarily involve an in-depth economic assessment of all the options. Depending on the stakes and the nature of the options, the analysis may be limited to a comparison based on several economic criteria, provided that these allow for discriminating between the options regarding relevant dimensions and therefore to make a rational choice. The economic analysis of the option selected will have to be deepened under detailed technical studies.

When the technical options refer to the development aspect (such as the type of water intake, the type of network), it is usually sufficient to assess the costs of the various options (capital and operating expenditures) without having to consider the expected benefits, these being most often identical or at least similar. A cost-effectiveness analysis may suffice in that case rather than conducting a cost-benefit analysis (see Annex 3 for the differences between these two types of analyses).

IMPORTANT NOTE

When the scope of the project (surface area to develop) is determined by the technical options and/or when the technical options have an impact on the methods of agricultural development and therefore the different agro-economic scenarios (for example, network under pressure/network with open surface), the assessment cannot be limited to investments. It must also include:

- the operation-maintenance methods and the associated costs;
- agricultural development (crops, production costs and value produced).

Therefore, a full economic analysis must be conducted addressing costs and benefits to compare the technical options envisaged.

Under detailed studies

If the feasibility study highlights very different technical or management options (with strong impacts on the irrigation cost, or even on the agro-economic scenarios), the economic analysis of the project that is ultimately selected will have to be deepened during the detailed studies, especially if the economic analyses performed for the different scenarios in the feasibility study were summary ones.

Though the scoping of the project may have been fully completed in the feasibility stage (no options) and the economic analysis was carried out in the feasibility study, it is essential at the detailed studies stage to check that the assumptions and data that were used in the feasibility study remain valid. In particular, it should be checked that no revision was made to the investment and no change was made to the organization of management that would justify revising fees or subsidies.

Pricing is specified (amount of water service fees) at this stage as well as the arrangements for funding the service (need for technical support, subsidy, etc.).

Table 4: Summary of the approaches proposed for an irrigated scheme development project

Analysis level	Farm	Scheme	Territory
Main actor	**Producer**	**Infrastructure manager**	**State, local communities**
Large scheme managed by a public institution	Interests of producers (income, food security, resilience) Ability to participate in the project (investments, means of production, technical knowledge, etc.) Ability and willingness to pay irrigation fees (tariffs)	Financial analysis to assess the balance conditions of the management of the system: - irrigation service pricing - possible public contribution (capital and operation)	Level of analysis necessary given the project's a priori scope Economic analysis approach covering all the project's effects (direct, indirect, induced) (CBA and MCA), including environmental and social impacts
Large scheme managed by a semi-public or private company (public service delegation or public private partnership)		Financial analysis to assess the balance conditions for the management of the system, ensuring the targeted profitability for the management company: - irrigation service pricing - public contribution to capital costs and, where applicable, to operating costs.	
Small or medium scheme managed by an organization of irrigators		Analysis of operation and maintenance tasks entrusted to users and verification whether they are compatible with the farming tasks calendar and the availability of labor. Financial analysis to assess the balance conditions of the system management for the organization: - level of fees to cover the expenses allocated to the management structure - public contribution (capital and operating expenditures)	Non-essential level of analysis (relevance and scope to be assessed on a case-by-case basis) Systematic analysis of environmental and social impacts (including land)

3.1.3 Synthesis

See Table 4 above.

3.2 For an irrigation development program

3.2.1 Place of economic analysis in the project process

An irrigation development program differs from an irrigated scheme project on two main aspects:

- An irrigation development program generally includes an investment component aimed at rehabilitating/upgrading, or more rarely creating, a set of irrigated schemes considered in this case as of small to medium size (most likely);
- It provides for activities that go beyond support for agricultural development and the management of the schemes targeted; these activities can be institutional support (local or national administrations), support for sectors, setting up credit, etc.

A distinction is also made here among the three stages in an ex-ante economic analysis, which correspond to the first three stages of project appraisal: identification, feasibility, and detailed studies.

The main difference with the previous case as regards conducting the economic analysis is that it will be done successively at two levels:

- Initially, on the scale of the project as a whole, by integrating all the components. This will consist in an analysis of a territory level[9] that is performed during the project's feasibility study and will often consider global indicators such as the surface area developed or rehabilitated,[10] while being based on actual data obtained on one or more perimeters similar to those targeted by the project, to the extent possible;
- Then, at the level of each scheme (analysis at the farmer and operator levels), during the project implementation and before any intervention on the schemes.

If the targeted schemes are identified from the start under the program, the economic analysis of the project can be done by combining the results of the analyses carried out at the level of each of the schemes, according to the approach developed in Chapter 3.1.

3.2.2 The different stages and levels of economic analysis

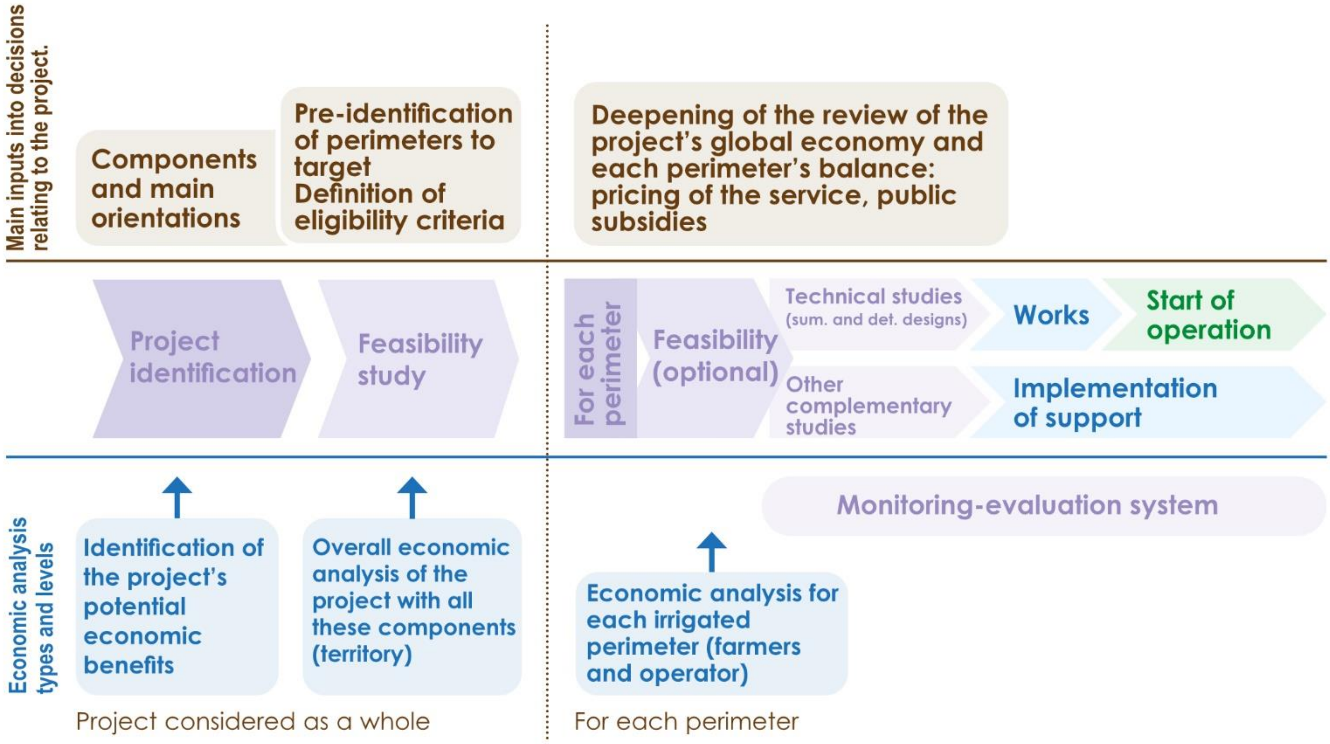
On the project as a whole (territory)

The economic analysis of a project should be done during its feasibility study. It will be used to specify the expected benefits of the project components. The elements of the project and its main orientations will have been predefined during the identification phase, along with the potential economic benefits.

[9]. We are talking here about the level of analysis and not about the territories (or areas of intervention) of the project, which can be multiple.

[10]. In many projects of this type, the schemes which will be the subject of interventions are not all defined at the outset. The global economic analysis of the project is done only at the territorial level (by accumulating all the expected effects based on global objectives such as surface areas, production volumes, and not on elements specific to the areas of intervention).

Figure 4: For an irrigation development program - Project process and role of an economic analysis



This analysis must be conducted at the territorial level (regional or national depending on the surface areas targeted and the scope of the actions planned) and will include an assessment of the economic costs and benefits of all project components. As this is an irrigation development project, the various components will be related to irrigation (support for development, sub-sector, institutional strengthening, etc.) and the benefits of the project will a priori occur at the level of irrigated schemes: increase in irrigated agricultural production, better production development or even optimization of the water resources use.

IMPORTANT NOTE

A national or even regional action (for example, on the sectors) can have impacts on schemes or agricultural areas other than those directly targeted by the project's investment component. These impacts must be considered in the analysis.

When a program is likely to have a significant impact on the volumes produced, an analysis of the capacity to sell production (sub-sector analysis) is needed.

Three situations may occur:

- From the outset, the project precisely identifies the schemes targeted and an economic analysis process similar to the one described in Chapter 3.1 may be conducted for each of the parameters;
- The project specifies a total surface area to be developed/rehabilitated and the scheme in which investments will be made are selected at the stage of project implementation;
- Some schemes have already been identified and studies may have even been completed for these while others remain to be selected to achieve the surface area targets.

In the second and third cases:

- The economic analysis at the project feasibility study stage must allow for establishing the economic criteria to be used for selecting the schemes to be targeted for the developments. The analysis can be based on the schemes already identified and/or on similar schemes (the analysis approach described in Chapter 4.1 may be applied in that case);
- A detailed study at the farmer and operator levels must be conducted as part of the studies specific to each scheme.

To ensure that the project will meet its economic objectives, the criteria for selecting schemes must be defined to be aligned with these objectives. From an economic point of view, the criteria may pertain to the following aspects:

- Investment (for example, defining an average or maximum investment per hectare, with schemes beyond the thresholds excluded);
- Operating costs (for example, with a given management arrangement and only infrastructures of a certain type);
- Agricultural value produced or type of production expected (the schemes favored being those where the value added generated will be at the expected level or those that allow for developing the crops sought);
- Ability/willingness of farmers to participate (either through a qualitative approach via surveys or through at least partial financial analysis at the farm level).

Table 5: Summary of the approaches proposed for an irrigation development program

Analysis level	Farm	Schemer	Territory
Main actor	**Producer**	**Infrastructure manager**	**State, local communities**
Small or medium scheme managed by an organization of irrigators	Interests of producers (income, food security, resilience) Ability to participate in the project (investments, means of production, technical knowledge, etc.) Ability and willingness to pay irrigation fees (tariffs)	Analysis of operation and maintenance tasks entrusted to users and verification whether they are compatible with the farming tasks calendar and the availability of labor. Financial analysis to assess the balance conditions of the system management for the organization: - level of fees to cover the expenses allocated to the management structure - public contribution (capital and operating expenditures)	Analysis to be conducted to assess the benefits of all project components (investments, institutional support, subsidies, support for sectors, etc.) To be conducted at the regional or national level depending on the surface areas targeted and the scope of the actions planned Non-essential level of analysis at the scale of each perimeter (subject to the analysis of environmental and social impacts)

The assumptions made for the economic analysis at the territory level will allow for specifying the investment per hectare, the value added generated, etc.

For each scheme

In the second step, a specific economic analysis must be conducted for each scheme. The analysis will address at least the farmer level (in detail compared to the previous stage) and, where applicable, the operator level,[11] according to the procedures specified in Chapter 3.1.

In the same way as for a scheme development project, its content will depend on the schemes' characteristics. However, it may also depend on the level of detail of the analysis conducted during the project evaluation as a whole. If this evaluation has been already well detailed for each scheme, the remaining tasks will consist in deepening the evaluation to finalize the last aspects relating to pricing, identifying the level of subsidy required, etc.

3.2.3 Synthesis

See Table 5 above.

3.3 For a large multi-use infrastructure project

3.3.1 Role of an economic analysis in the project process

A project that pertains to a large multi-use infrastructure (such as dams, transfer and transport structures) is typically made of several sub-projects that respectively pertain to the infrastructure and the developments required for the various uses, including irrigation.

In the project process, as for the previous case (irrigation development program), a distinction should be made between what falls in the project as a whole and what falls specifically in each sub-project. This is shown in the diagram below that is broken down into two successive parts:

- In the first part, the project is considered as a whole (identification and feasibility);
- In the second part, each sub-project is considered separately and specific studies are performed for each of them, possibly from feasibility studies (depending on how far the definition of the project went in the first stage) to detailed studies. Sub-projects relating to irrigation (namely the development of one or more irrigated schemes) are the only ones represented here.

The decision to move forward with project or not, as with the design choices, will consider all project components. This decision step regarding the project as whole is not included in Figure 5, nor in the explanations.

Only one aspect needs to be considered in addition to the approach relating to the economic analysis of the irrigation development program: the share of irrigation in the investment and operation of the basic infrastructure (in particular to assess its contribution).

3.3.2 The different stages and levels of an economic analysis

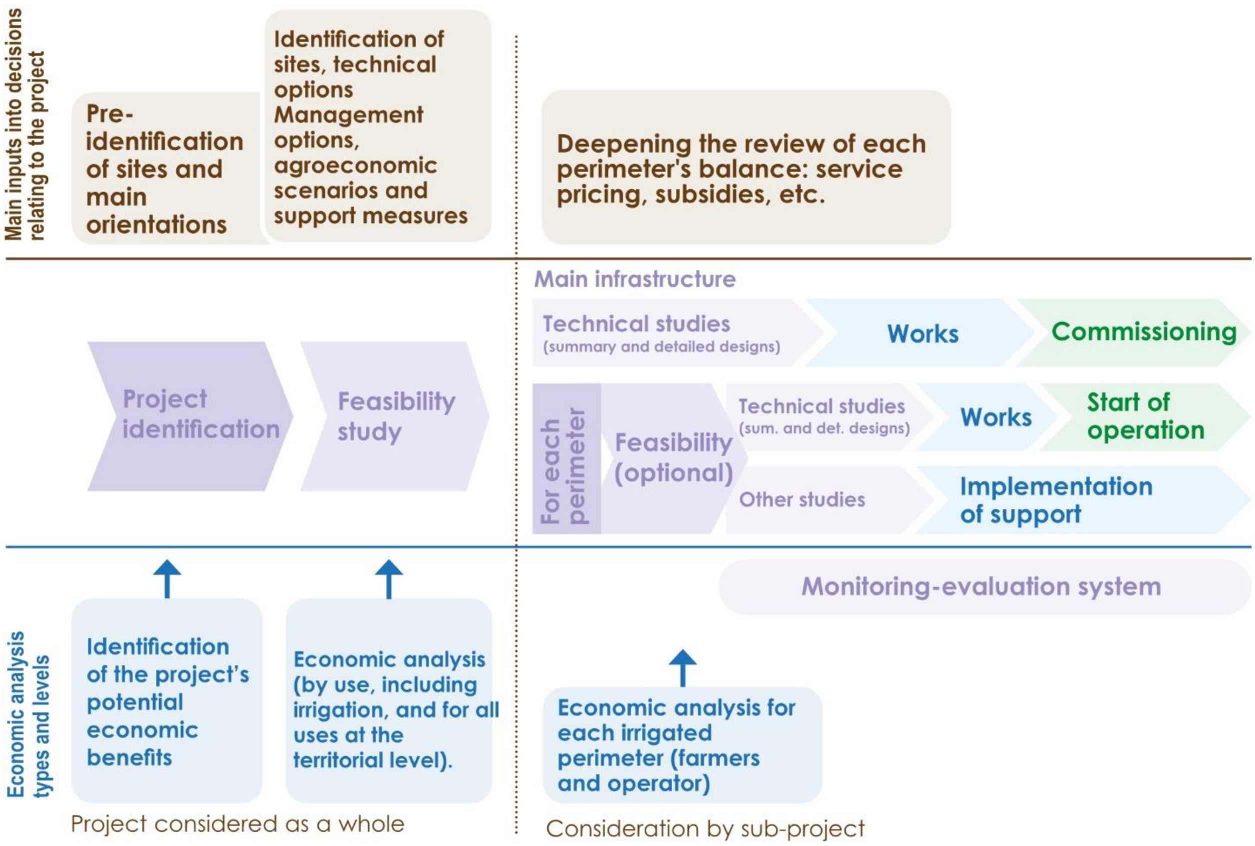
The project as a whole

In the first stage, in a multi-use dam project,[12] the economic analysis will focus on the territory and will endeavor to assess the expected benefits of each use, so as to be able to compare the overall benefit to the cost of the project. The different uses to be considered can be energy production, regulation, drinking water supply, irrigation, fishing, navigation, natural environments, etc.

11As the territory level has already been addressed and the expected benefits estimated during the feasibility study, a territory analysis for each scheme is no longer useful once the scheme selected meet the selection criteria. Moreover, in this type of project, the targeted schemes are often medium-sized ones that are located in the same region.

12The issue is the same for a transfer of water between basins or a major transport infrastructure. The uses are the only elements that may vary.

Figure 5: For a large multi-use infrastructure project - Project process and role of economic analysis



For irrigation, this first level of analysis will generally be limited to an estimate of the future irrigated area to be multiplied by the additional income per hectare, compared to a "without project" situation. In the case of a hydroelectric dam, for example, irrigation is often insignificant in economic terms compared to energy production and the evaluation can be summary without impacting the decision on the project as a whole.

PARTICULAR CASE

When irrigation is the main use or one of the main uses, an overall approach of this type is not sufficient and a detailed analysis must be carried out for each of the schemes that will be supplied (see Chapter 3.1) from the feasibility study. [13]

For each irrigation sub-project[14]

In the second step, whether irrigation is the main use of the infrastructure or not, a specific economic analysis must imperatively be conducted for each scheme. This analysis will include at least the farmer level and, where applicable, the operator level, according to the procedures specified in Chapter 3.1, in order to determine the feasibility conditions for each perimeter (and the support measures required). The territory level is considered as already processed in the previous step.

In the same way as for a scheme development project, its content will depend on the schemes' characteristics. However, it may also depend on the level of detail of the analysis conducted during the evaluation of the project as a whole. If this evaluation has been already well detailed for each scheme, the remaining tasks will consist in deepening the evaluation to finalize the last aspects relating to pricing, identifying the level of subsidy required, etc.

Contribution of irrigation to main infrastructure maintenance

It is often useful/necessary to conduct the economic analysis of irrigation taken separately, for example to set up a fee (contribution) from the irrigated schemes to the headend infrastructure.

The main issue consists in identifying which portion of the capital costs of the multi-use infrastructure (dam, transfer, etc.) and of its operating-maintenance costs, should be allocated to irrigation use. There is no rule in this matter. A first option would be to allocate the costs proportionally to the water consumption of each use. However, in many cases, the value generated by the different

[13] If irrigation is the main use, schemes should be defined before feasibility.

[14] The economic analysis of other non-irrigation uses and sub-projects is not addressed here.

Table 6: Summary of the approaches proposed for a large multi-use infrastructure project

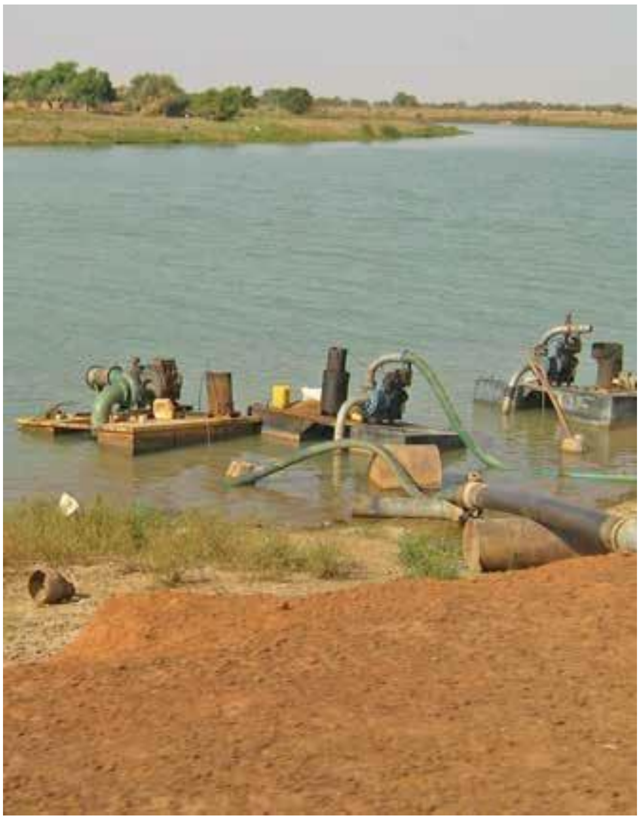
Analysis level	**Farm**	**Scheme**	**Territory**
Main actor	**Producer**	**Infrastructure manager**	**State, local communities**
For all types of schemes.	Farmer interests (income, food security, resilience). Ability to participate in the project (investments, means of production, technical knowledge, etc.) Ability and willingness to pay irrigation fees (tariffs).	What portion of the costs of the multi-use infrastructure is allocated to the “irrigation” use?	Level of analysis required given the project’s a priori scope. Economic analysis approach covering all the effects (direct, indirect, induced) of the project (CBA and MCA), including the environmental and social impacts. Important issues in terms of methods and sensitivity analysis (addressing uncertainties at the scale of the territory).
Large scheme managed by a public institution.		Financial analysis to assess the balance conditions of the management of the system: - irrigation service pricing - possible public contribution (capital and operating expenditures)	
Large scheme managed by a private company or through a PPP.		Financial analysis to assess the balance conditions for the management of the system, ensuring the targeted profitability for the private company: - irrigation service pricing - public contribution to capital costs and, where applicable, to operating costs (in the case of a PPP)	
One or more perimeters managed by irrigating producers’ organizations.		Analysis of operation and maintenance tasks entrusted to users and verification whether they are compatible with the farming tasks calendar and the availability of labor. Financial analysis to assess the balance conditions of the system management for the organization: - level of fees to cover the expenses allocated to the management structure - public contribution (capital and operating expenditures)	

uses is very variable and this type of calculation tends to favor those water uses, such as agriculture, that generates the lowest value while mobilizing large volumes – even if they also provide important social and environmental services. Another option to correct this bias is to weight the volumes used by the value produced per m³. However, it happens that the same volume of water goes successively through different uses, and as a result it may be a complex task to estimate the water consumption by the different uses. To simplify, the costs may be distributed in proportion only to the values generated by the different uses, this approach having the merit of solving the issues of uses that do not generate financial value (for example, a low water flow intended to maintain environmental functions).

However, especially when irrigation is a minor use, it may be decided not to allocate infrastructure costs to irrigation. This is justified especially when the irrigated schemes come as a compensation measure for populations displaced to allow for building the infrastructure (this aspect being of special importance in the case of dam construction).

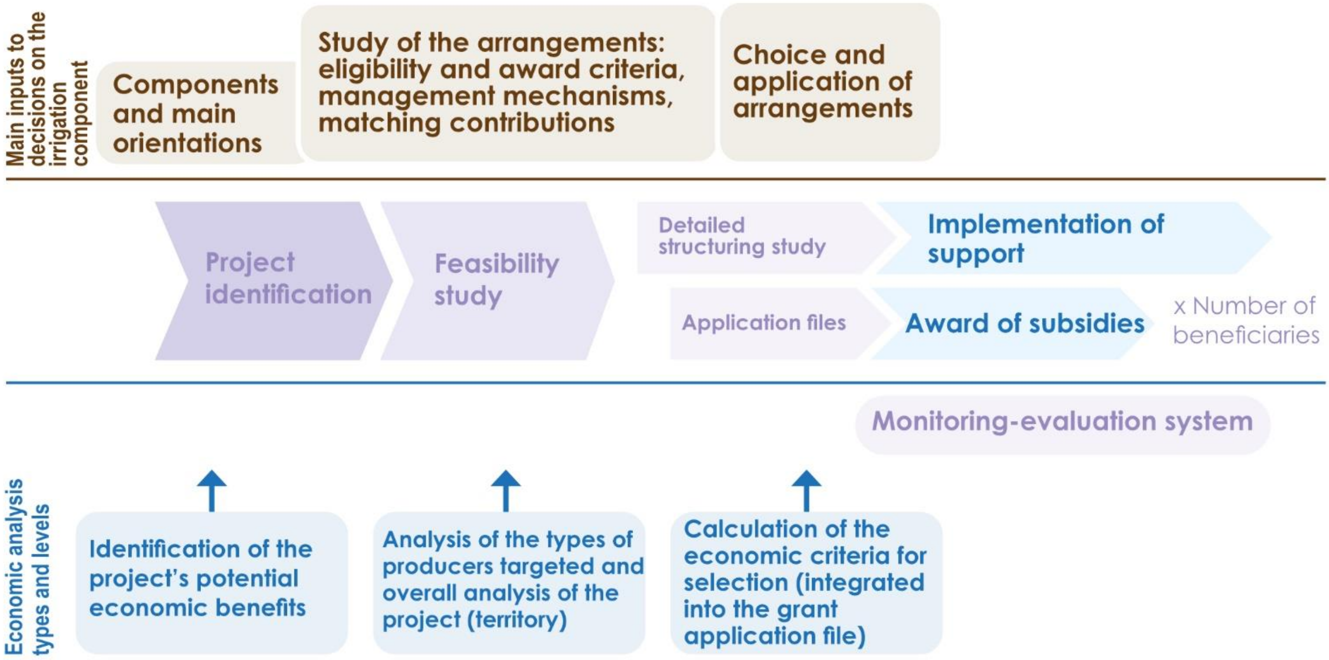
3.3.3 Summary

See Table 6 above.



Small private pumping systems in the Senegal River Valley (Podor) © B. Vennat

Figure 6: For a public policy project - Project process and role of economic analysis



3.4 For a public policy project

3.4.1 Role of an economic analysis in the project process

The case considered here is that of a public policy project that consists in subsidizing the provision of irrigation equipment to producers, either to develop individual irrigation, or to promote upgraded practices in collective schemes (for example to develop drip irrigation).

As in the two previous types of project, three stages and two levels must be considered in this case:

- At the project identification level, expected benefits and risks should be listed, without quantifying them at this stage, which will allow for specifying the project's main orientations;
- Under the feasibility study, the economic analysis should be done at two levels:
- at the level of the project as a whole, by integrating all project components and in particular the objectives in terms of development of areas irrigated through individual systems and/or better use of water resources, in order to define the implementation arrangements and, if necessary, to justify the project;
- at the level of the farmers targeted by the program to set the criteria for eligibility and for the allocation of grants as well, and above all, the amounts and ceilings of subsidies.
- Then, at the level of each applications, during the analysis of the subsidy applications.

3.4.2 The different stages and levels of economic analyses

During the feasibility study

Beyond project justification, the study of the **project as a whole**, combined with the analysis of the types of producers targeted (below), must allow for defining the arrangements for implementing the policy, i.e.:

- What structure will manage the distribution of grants (public administration, microfinance institution, bank, etc.)?
- How, with what means and at what cost?
- What materials will be approved and what will be the distribution channels?

The management mechanism must be simple (to be effective and accessible to the target populations) while avoiding windfall effects (through control mechanisms).

In general, agricultural equipment subsidy policies define subsidy rates over the total investment, sometimes with several levels depending on the nature of applicants. More rarely, these mechanisms provide for a ceiling amount.

To set subsidy rates and ceilings, it is important to have good knowledge of the targeted producers and to study the effects of these rates and ceilings on their activity according to the objectives of public policy (see below).

IMPORTANT NOTE: CONTROL AND QUANTIFICATION OF EXTERNALITIES

Regarding the effects of the project and its externalities in particular, it should be noted that these will be very scattered in spatial terms and potentially difficult to control. This will be the case in particular for the control of water resources withdrawal if the project's effect is to develop individual irrigation.

An economic analysis **at the producer level** would be essential in order to characterize and choose the types of farms (and contexts) targeted by the policy and to define the arrangements for implementing the policy.

Tillage in the Sélingué area, Mali © F. Bazin

The arrangements include:

- The criteria for eligibility of producers and for the allocation of subsidies;
- Rate levels and ceilings according to the types of producers (who are we targeting?). Rates and ceilings will also depend on the objectives of the policy: supporting small farms, increasing surface area irrigated regardless of the nature of producers, etc.;
- The implementation channels (by whom?) and whether the subsidies should be associated with a credit mechanism (this will be the case in particular if the subsidy is aimed at small farms but do not cover the entire investment);
- Any matching contributions requested from subsidized producers (particularly as regards water resources management).

The purpose of the criteria will be to verify applicants' ability to capitalize on the investment that subsidies allow for (to increase their food resources and income, and potentially contribute to national production), as well as their ability to maintain and develop their production system over time. When subsidies are backed with credit, the criteria should take into account producers' repayment capacity.

The subsidy rates will also have to be defined according to the types of producers. Ceilings on the total amount of the subsidy per farm should, in turn, allow for preventing capture of subsidies by large farms mainly.

The criteria, rates and ceilings will be set based on an analysis of the interest of each type of producer targeted, similar to the analysis discussed in Chapter 4.1.

When processing subsidy applications

The economic analysis at the application level will be simple, at the level of individual projects. It will be based on one or more criteria set during the feasibility study and that will be informed in the subsidy applications.

CHAPTER 4

ECONOMIC ANALYSIS METHODS

4.1 Farmer level

The analysis at the farm level must allow for establishing whether - and under which conditions, developing irrigated crops and, more broadly, participating in the project is advantageous for producers. Depending on whether the project consists in rehabilitating, upgrading or creating a scheme, or even substituting a water resource, the analysis must identify the specific determinants of producers' involvement in the project, i.e., the factors that will make them decide to develop irrigated areas, change the crops they farm, or switch to an alternative water resource.

The analysis is a financial one conducted at the level of the farms located in the perimeter being studied.

IMPORTANT NOTE

The analyses whose scope is limited to estimating "profitability" per crop (by calculating the added value or margins per hectare) are not analyses at the farm level as meant here because they do not allow for assessing the farmers' interest for the crops.

This type of analysis could be useful as part of a very summary approach at the territory level or as inputs in calculations that will feed in the financial analysis per type of farm.

It should be noted that the circumstances of producers are diverse: some, for example, may own their plots, while others are tenant farmers; some may grow other (rainfed) crops or breed livestock out of the irrigated scheme, while others cultivate only irrigated plots; some may have plenty of labor or can recruit, while others must develop their plot with a single family worker; some may have a large plot, while others do not; some may work on a family farm, while others are entrepreneurial farmers; etc.

Obviously, it is impossible for the financial analysis to cover all the producers that will participate in the project, especially since they are not yet identified at the feasibility study stage in most cases. Consequently, financial analyses are generally conducted in reference to a producer typology or modeling that is as representative as possible of the diversity of the farmers that will participate in the project. The access to production means (labor, land, capital) is generally the characteristic that determines the typology. To fit its intended use, a typology must include a limited number of types (four to six).

It is traditionally considered that a project will be advantageous to a producer if it offers prospects of higher income, as compared to the income they would derive from allocating their current production resources to other activities. Therefore, the point is not just to ascertain that producers will be able to generate positive or sufficient income to feed their family, for example. There is also a need to ensure that other productive options are not preferable.

**IMPORTANT NOTE:
PROFITABILITY PER TYPE OF PRODUCER**

Profitability does not find the same expressions across all types of producers. An entrepreneurial producer who has capital and can recruit labor, will likely consider that investing in an irrigated plot is profitable if the return on the capital invested is higher than if it had been invested in another sector (e.g., trade) or productive activity (e.g., livestock farming).

For a family producer, the main objective will often be to provide family labor with as good a compensation as possible, in consideration of the other employment opportunities that may arise. Still, because of their precarious situation, some producers will prioritize the family's food security, mainly giving preference to low-risk productions intended for self-consumption, even if they are less gainful.

Since the expression of profitability varies according to producer type, the methods for calculating it must also vary and be adapted to the producers' rationale.

- For example, in the case of an entrepreneurial producer, a project's profitability can be measured against its profit rate and a comparison of its profit rates with the ones that could be achieved by investing in other projects.
- In the case of a family producer, profitability may be measured in terms of income per worker, which could be compared to the income that could be derived from assigning family labor to other opportunities.

In addition to ascertaining whether the development of a given type of irrigated production is advantageous for producers, there is also need to ensure that they will have the means to do so, i.e., 1) they will have the technical means to implement the planned irrigated crops and achieve the intended outcomes; 2) they will have enough family labor and/or can recruit from the local labor market to attend to the period where additional labor is needed; 3) they will have the financial means needed to support operating and capital expenditures throughout the project – and beyond. For a project proposing water resource substitution (e.g., replacing an individual borehole with a connection to a collective network), there is also a need to ensure that the new, alternative resource is *at least* as accessible and reliable as the existing one, without being more expensive (or that the extra cost is justified by better access to irrigation).

Survey with a market gardener - Anambé, Senegal © F. Bazin

The approach used to conduct the analysis at the producer level involves the following key steps:

- Establishing a production system typology and collecting technical and economic data on each type identified;
- Formulating the project's technical choices, including irrigation options and development scenarios (choice of crop rotations, sub-sectors, yields, etc.);
- Performing a financial evaluation of an average year to understand the advantage of participating in the project for each type of producer and/or establish the options that are most profitable;
- Performing a flow analysis to establish the financial conditions that need to be met for producers to implement the irrigated systems contemplated; and
- Conducting a sensitivity analysis of the most sensitive parameters.

4.1.1 Production system typology

Opportunities to access production inputs vary among farmers:

- land will not be equally available to all of them (in terms of quantity, quality, and location in the different parts of the ecosystem);
- the labor they can mobilize (family members or people external to the farm) will vary from farm to farm; and
- lastly, their access to production capital (tools, inputs, cash) will also vary according to their production units.

Farms with similar access to production factors tend to have similar production rationales and implement the same combinations of productions and production factors, i.e., the same production systems. Accordingly, the multiplicity of farms found in a given region can generally be classified into a limited number of types.

For some regions, studies with established production system typologies exist. Although they are seldom specific or precise enough to identify or characterize the project area's production systems, they often provide a suitable basis for developing a preliminary typology from which the sample of farms that will be used to conduct production system characterization surveys can be built. From there, depending on the time and means available, detailed surveys relying on interviewers, or rapid but more participatory focus group-based characterizations may be conducted. If the systems are complex and the stakes high, it is recommended to conduct both the surveys on a representative sample and the participatory component.

4.1.2 Determining the irrigation project's technical options

Determining a project's technical options is a tricky step where economic analyses can and must play an important role. It is not uncommon for part of the technical choices to be predetermined by the project's objectives; for example, the purpose of many irrigation projects is to contribute to national food security and, more or less explicitly, to produce rice to meet the country's needs. These choices will determine the type of irrigation network and, very often, the type of crop and crop rotation options. The technical choices made with respect to the network (gravity, pressurized, etc.) often restrict the range of crops that producers can farm and therefore, the agricultural systems' long-term potential for adaptation and resilience. This is particularly the case for rehabilitation projects.

However, the producers' current systems can also be used as a starting point for determining the changes they wish to make, and could make, if they had access to irrigation or improved access to irrigation (more reliable, more regular, more flexible, etc.). From there, several scenarios can be tested to determine the one most relevant to each type of producer identified in the context of the project and discuss the options they prefer with producers' representatives. Having a good understanding of the farmers' strategies allows for defining relevant assumptions; for family farms, for example, it could be advantageous to propose diversified production systems, whereby farmers can simultaneously produce food for self-consumption and invest in a commercial production.[15]

4.1.3 Financial analysis of an average year

A farm's agricultural income is equal to the average annual value of plant and animal products (sold or self-consumed), minus the value of the goods and services used to produce them. These goods and services can be classified in two types, namely intermediate consumption (seeds, fertilizer, veterinary costs, animal feed and other inputs, services paid to third parties, water fees, etc.) and the annual depreciation and maintenance costs of farm buildings and equipment. Calculating the operating revenue involves several stages that begin with the calculation of the farm's value added[16].

Gross value added:
The farm's gross value added (GVA) is equal to the sum of the values added of the different crop and livestock farming systems making up the farm.

$$GAV = \sum_{1}^{n}(GAVc) + \sum_{1}^{m}(GAVl)$$

Where GAVl = Gross value added of a livestock farming system and GVAc = Gross value added of a crop farming system

The gross value of any crop farming subsystem is calculated as follows:

GVAc = GP – IC

Where

GP = annual final production x unit price

And

IC = ∑(quantities of goods x unit price of each good)

+ ∑ (quantities of services x price of each service)

In the same way, GVAl is determined by calculating the gross value added per animal and year and multiplying the resulting value by the average number of animals in the herd (in the case of breeders, calculations are matrix-based).

Net value added:
The net value added (NVA) is obtained by deducting the annual cost of depreciation and maintenance of the buildings and equipment used from the gross value added.

NVA = GVA - depreciation

Agricultural income (AI) of the farm:
The agricultural income is calculated by deducting the wages of permanent employees, rents, interest on borrowed capital, as well as taxes and duties from the net value added.

AI = NVA - wages - rent - interests - taxes

When the number of family workers is known, the income per agricultural worker from the family can be calculated and compared with the potential income from other locally available work opportunities (opportunity cost of labor). The income derived from the system proposed by

15. In this regard, see Chapter Q3 - Which production systems do the development aim to put in place and how will previous systems evolve? in: Malerbe, Florence, Pierre Strosser, Frédéric Bazin, Samir El Ouaamari, Béatrice De Abreu, Jean-François Amen, et Jérémie Dulioust. "*Éclairages sur l'analyse économique des projets d'irrigation*". COSTEA, February 2019.

16. The method suggested hereunder, which consists in calculating the value added, then the income, allows for separating the evaluation of wealth creation from its distribution among the various production means holders. Another common method is to calculate the Gross margin [GM = PB - (IC + salaries)] then the net margin [NM = GM – Depreciation] and lastly, the agricultural income [AI = NM – (rent + interest + taxes)]. The result is the same.

the project can also be compared with the ones derived from the other systems that the individual types of producers can implement with their respective production means, to make sure that the proposed system is indeed the most advantageous one.

IMPORTANT NOTE:

Care should be taken not to confuse the analysis of the value added per worker - which allows for analyzing the value generated according to the selected crop rotation systems - with the calculation of the value added per hectare of the different irrigated crops. Indeed, a crop can generate a very high value added per hectare but require a lot of work, which will limit the surface areas that can be developed and therefore, the total income. Furthermore, it is important to bear in mind that family farmers generally have diversified production systems as a way to mitigate risks through the development of the different environments and diversification of the productions; and their strategies aim, above all, to optimize the overall income across the entire farm, instead of maximizing income on irrigated plots alone.

4.1.4 Flow analysis over several years

When producers make transformations on their farms, expenditures are generally concentrated in the first years when investments need to be made, then at the times when equipment needs to be renewed, while revenues tend to increase gradually with the development of the production systems. The detailed financial analysis consists in establishing a multi-year statement of income and expenditures (that includes investments and the renewal of materials and equipment) for each type of producer, to verify, on one hand, that the total cumulative profit is positive, while also assessing, on the other hand, the potential for financing difficulties during the project.

The detailed financial analysis consists in establishing a statement of income and expenditures (that cover investments and the renewal of materials and equipment) for each type of producer over a period that will be determined according to the type of investment, with the aim of verifying that project-related modifications are beneficial to producers.

- Regarding family farmers, the activity will consist in monitoring the series of agricultural campaigns that will span the investment period, as well as the period where the production system will be modified, to ensure that they do not encounter any particular difficulty at any point (financing, availability of labor, renewal of equipment);
- Entrepreneurial farmers will rather be interested in verifying the profitability of their investments and will, therefore, consider the period of return on investment (which is closer to a medium-term business plan).

The results from the different crop rotation systems in irrigated farming can also be compared to determine the one that would be the most advantageous.
For this purpose, a statement of income and expenditures is generally drawn up on annual basis; nevertheless, it may be interesting to draw up a statement of income and expenditure for shorter periods. For example, if a scheme is developed for two rice harvests per year, a statement of income and expenditures should be drawn up for each growing cycle to verify that the financial conditions for having two harvests are actually met (e.g., the income from the first season arrives in time to finance the next one or a bridge financing mechanism is available).

The analysis is conducted for two major categories of expenditures:
1) operating expenditures (OPEX), which represent intermediate consumption and wages actually paid (which exclude inputs from the farm or family labor); 2) capital expenditures (CAPEX) to invest in or renew materials or equipment, which must be accounted for when they are actually made. To have the Income (In), the final productions that are sold or self-consumed by the farmer are accounted for (but not those used as intermediate consumption).

This allows for calculating the cash flow (B) for each of the periods considered:

$$B_i = In_i - CAPEXI_i - OPEX_i$$

Where for a given period i, B is the balance, and I the income, CAPEX the capital expenditures and OPEX the operating expenditures. A balance B_i that is not positive means that, unless specific financing mechanisms are put in place, the farm will encounter cash flow difficulties that might prevent it from supporting the operating expenditures or necessary investments (CAPEX).

4.2 Manager or operator level

The objective of the analysis at the operator level is to determine whether, and under what conditions, operators will have the means to properly perform the operating and maintenance tasks for their irrigation system. The point is to verify through a financial analysis that management balance is achievable.

Of course, the analysis applies only to irrigated systems that include an infrastructure or resource that requires collective management.

The financial analysis will vary according to the management system put in place and the nature of the structures involved.

Where the irrigation system's management is the responsibility of several distinct operators, a separate financial analysis needs to be performed for each of the operators (for convenience, they will hereinafter be referred to in the singular as "the operator"). In the same way as with irrigation users, the calculation should take into account the specific economic rationales of the respective actors (association of irrigation users, administration or public company, private company). For instance, a private company will seek to generate profit, often proportional to the amount of its capital investment, whereas a public company can limit itself to simply achieving financial balance (or staying within the budget allocated by the State, in the case of an administration).

For a simple and small infrastructure managed by an users association and whose resources include a farmers' fees and sometimes users' working time (especially made responsible for the maintenance of the canals serving their plots), the most important aspect will be to correctly assess the association's costs (by defining the tasks that should be covered by the fees) and farmers' ability to pay (linking back to the analysis at the farmer level), as well as their availability (and willingness) to perform certain tasks directly (compatibility with farming calendars and labor availability especially).

Rehabilitation of self-supporting canals - Region of Marrakech, Morocco © F. Deram Malerbe

A business-like operator or professionalized association (that has employees) will require a detailed financial analysis, as described hereafter.

4.2.1 Identification of the irrigation infrastructure's Management arrangement

The model used to manage the irrigation infrastructure is a factor that determines the sustainability of the irrigation system put in place. It can be fully or partially determined by the public policies in force. Whether the model is predetermined or yet to be defined in full, there will always be elements that will need to be specified during the feasibility study.

To start with, the needs relating to the infrastructure's management must be identified, followed by the structures that will ensure such management: it may require one or several structures, depending on the complexity of the infrastructures to be managed and the distribution of roles between the different organizations. For example, a dam can be managed by the company in charge of producing electricity; main irrigation infrastructure (intakes, primary and secondary canals, pumps, etc.), by a public company; and the distribution to parcels, by users associations. While the distribution of responsibilities will be overwhelmingly determined by the complexity of the infrastructure's maintenance and operating activities, the existence of local institutions/organizations and their level of skills will also play a role.

Relatively simple systems (farm dams, small-scale irrigation using shared pumping, spreading weirs, etc.) could probably be managed by community organizations, provided they receive training and support over a sufficiently long period of time to be able to develop and test their operating rules and tackle management and maintenance challenges.

Technically simple irrigated systems, or portions of systems, can also be fully supported by water users organizations. This practice is widespread around the world and many countries have specific by-laws for these organizations (often similar to those applicable to associations).

The advantage with irrigation users organizations is that the irrigation users themselves can manage the infrastructure of which they are beneficiaries. If management is transparent, this can limit reluctances to pay the applicable fees - although it is not always the case[17], and costs can generally also be limited, to the extent that part of the work can be performed by the irrigation users themselves.

IMPORTANT NOTE

It should not be assumed that irrigation users organizations will operate on a solely volunteer basis, especially when it comes to organization, representation, financial management, water policing, or conflict management tasks. These time-consuming tasks are at risk of being poorly performed if the people in charge are not compensated for the time spent on them and taken away from their farm.

For large-scale and/or highly technical systems, it might be more effective to resort to a professional operator that has the specialized human and material resources to handle the technical and financial challenges associated with the irrigated scheme. This operator could be a public, private, or public-private entity. In most cases, it will be a public or semi-public structure, as rural development and irrigation are often considered to be the State's mandate. Furthermore, when irrigated systems require large-scale infrastructure (dams, transfer and transport infrastructure, etc.), the time it takes to secure a return on investment is often incompatible with the private sector's expectations.

Beyond the institutional organization - and therefore the definition of the tasks falling to the respective stakeholders - the distribution of operating and maintenance costs also needs to be addressed. With open networks, for example, it is common for irrigation users to contribute to the maintenance of tertiary or quaternary canals in labor, while also paying a fee to finance an operator in charge of the maintenance of primary and secondary infrastructure. This payment may cover the costs in full or only in part. In this case, the commitment of other institutions (government, local authorities, watershed agencies, etc.) to finance the remaining costs should be secured to guarantee the system's overall balance. Analyzing the irrigation users' contribution capacity is critical to determining the way costs will be distributed among the irrigated system's different actors. The analysis should allow for establishing the irrigation service's pricing at a relevant level (affordable to users and consistent with

[17]. Collecting fees is sometimes easier for an independent structure, rather than community members.

the benefits they derive from it). The financial analysis at the operator level will allow for establishing whether further income is needed or not, and where needed, they may be public subsidies.

4.2.2 Which costs should be included in the analysis?

Figure 7 provides a breakdown of the types of costs making up what is usually called the cost of water. They include the following major cost categories:

1. **The system's technical and administrative operating costs,** which include the organization's operating costs (coordination, administration, accounting, planning, fee management, conflict management, etc.), operating costs (handling of structures, etc.), water policing, as well as the routine maintenance conducted at least once a year (e.g., cleaning of canals);
2. **Infrastructure and equipment maintenance and renewal costs** which may be incurred on a scheduled (renewal of a pump) or unexpected (repair) basis, as well as any financial costs relating to any necessary investment;
3. **Repayment of initial investments** that allowed for making the developments, as well as any related financial expenses; and
4. **Other costs,** linked, for example, to the irrigated system's impacts on other sectors (negative externalities on the environment, water's opportunity cost).

The different costs that need to be reflected in the calculation depend on the operator's mandate and the agreement entered into with the contracting authority.
In general, other costs (opportunity cost, environmental cost) are included in the economic analysis but not in the financial analysis at the operator level, except in the particular case where such costs would be reflected in their accounts as actual expenses (e.g., a tax is levied by the government with respect to them).

As for the costs linked to the initial investments, they need to be considered if they are actually borne by the operator, which is often the case in the context of public-private partnerships. In the very frequent cases where they are borne by the State, they are not necessarily accounted for in the operator's balance sheet[18].

As a general rule, the costs to be included therefore come in two types: 1) operating costs, and 2) maintenance and renewal costs.

4.2.3 Financial analysis at the operator level

The financial analysis follows the same process as the analysis relating to irrigation users, taking into account two main categories of expenditure[19]: 1) operating costs (OCs), which represent the salaries, expenditures on consumables, services used, and different taxes and duties; 2) investment or renewal expenditures (I), which include maintenance works, repair works, renewals of material or equipment and any financial costs.

Income (In) includes the fees paid by irrigation users, subsidies received from the government, and any other income.

Figure 7: Cost of the water resource and cost of irrigation service (Source: Tardieu and Préfol, 2002.)

Types of costs				
System's technical and administrative operation	Infrastructure operation	Sustainable cost	Full cost (technical and financial)	Total cost (economic)
	Water policing			
	Administration of management or Administrative and financial management			
	Routine infrastructure maintenance			
Maintenance (non-day-to-day)	Preventive maintenance			
	Corrective maintenance			
Renewal	Renewal			
Initial investment	Principal repayment			
	Financial expenses (LT debts)			
Water resource	Opportunity cost	Opportunity cost of resource		
Environment	Impacts and externalities	Environmental cost		

18. The way initial investments are accounted for at the level of the public operator depends on its status, national accounting rules, and whether the infrastructure has been transferred to the public operator. A transfer of ownership may be effected in the case of a public service delegation, for example, but not if the operator's mandate is restricted to management.

19. Depending on to their bylaws, operators will have a specific chart of accounts. The different variants are not detailed here. The different ways maintenance expenditures can be classified are also not specified. Depending on their nature, they can be considered as day-to-day operating costs or investments.

Figure 8: Levels of balance of an irrigation infrastructure's management

Balance of the management system through the rates/fees collected from irrigation users			
		Payment of day-to-day operating costs (operation and routine maintenance) by irrigation users	
		<100%	> or = 100%
Payment by irrigation users: costs of operation, maintenance and renewal works = Sustainable cost (Tardieu-Préfol, 2002)	<100%	Day-to-day operating costs must be subsidized, and other resources must be mobilized to cover the (non-day-to-day) maintenance and renewal of infrastructure.	The service fee allows for financing day-to-day operating costs, while other resources must be mobilized to support the (non-day-to-day) maintenance and renewal of the infrastructure.
	> or = 100%		The service fee paid by irrigation users allows for financing the costs of operations, maintenance, and renewal of the infrastructure.

The total profit over the period considered is the sum of the balances of each project period:

$$P = \sum_{i=0}^{i=d} Bi$$

Where for each year i:

$$B_i = I_i - CAPEX_i - OPEX_i$$

This calculation allows for checking that the operator makes at least zero profit (case of a public company or associative structure), or a positive profit in the case of a private company. In the latter case, profit P can be carried over to the project's total fixed capital ($\Sigma 1$) to compare the operator's profitability to other types of investment. In any case, the calculation allows for establishing whether the operator has the capacity to use its own funds to make the necessary investments or it will need to resort to loans, whose repayments must then be included in the operator's financial statements.

For private operators, it may be necessary to calculate the discounted profit, which allows for calculating the present value of the future income that will be generated by the project, while taking the capital's opportunity cost (*a*)[20] into account. It is calculated as follows:

$$B' = \sum_{i=0}^{d} \frac{S_i}{(1+a)^i}$$

4.2.4 Notion of management balance of an irrigation infrastructure

As part of irrigation projects and even more generally, at the stage of their identification or feasibility analysis, the irrigation service's tariff (i.e., the price paid by irrigation users, regardless of its form) must cover all service costs. However, experience shows that when major collective infrastructure is involved, it is seldom possible to cover all costs with tariffs. This is one of the reasons many projects struggle.

It is essential to remember that achieving balance in an irrigation infrastructure's management (see Figure 8) depends, first of all, on having a (technical, financial and social) strategy. This strategy must be developed from project inception, with all stakeholders. A comprehensive analysis of its feasibility must be conducted as it will determine the project's utility and overall feasibility.

As such, it is often more relevant to realistically analyze the ability to pay of different categories of irrigation users by considering their own needs for investment in their production system, as well as the gradual changes in irrigation income that happen as the technical and organizational improvements contemplated are implemented (water control, improvement of yields, development of sub-sectors, etc.).

The irrigation users' ability to pay can then be compared to the operating and investment costs considered by the manager, which will bring to light the additional financing needs that must be met to achieve management system balance (see Figure 8).

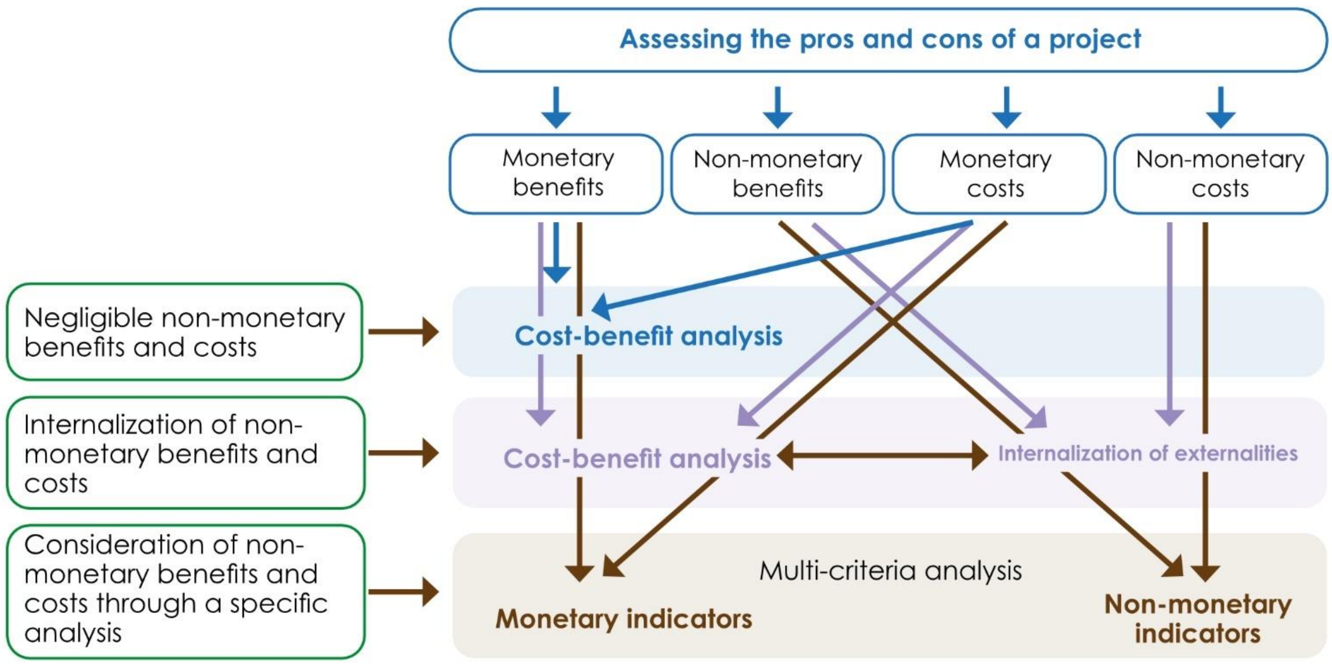
4.3 Territory level

4.3.1 Objectives and methods

Unlike previous analyses, the analysis at the territory level does not focus on a specific actor but rather on all actors in a given territory. Its purpose is to compare the pros and cons of implementing the contemplated irrigation project for society. It must at least allow for preventing the implementation of projects that result in more negative impacts than positive ones. Where several projects can be financed, it must allow for identifying the one that benefits society the most.

[20]. The discount rate generally represents the marginal cost of money for the operator considered, i.e., the rate at which the company can borrow money. For further detail, see: Gittinger, James Price. Analyse économique des projets agricoles. 2nd ed. rev. and Augm. Paris: Economica, 1985, page 355.

Figure 9: Methods for including non-monetary costs in an economic analysis



The comparison of pros and cons across widely diverse areas is one major difficulty with this analysis. Beyond the transformations that agriculture and value chains are expected to induce in terms of wealth generated, the development of irrigation can have numerous impacts on employment, social differentiation, health, nutrition, ecosystems, etc. How can one decide between a project that creates more wealth and a project that creates more jobs? How can benefits in terms of human nutrition be compared with adverse impacts such as loss of biodiversity? Figure 9 provides an overview of the different methods that can be used.

Banana plantation – Scheme of Saint-Marc, Haiti © F. Deram Malerbe

One solution consists in converting all pros and cons into monetary units to allow for comparing the sum of the benefits with the sum of costs over a reference period to be determined (see box hereafter): this forms the basis of a **cost-benefit analysis (CBA).** This method is very effective when the expected benefits and costs are for the most part monetary, e.g., the value added resulting from irrigated crops, the costs of building irrigation infrastructure, etc. However, some pros and cons cannot be directly converted into cost or monetary benefit, or this process involves some difficulty.

IMPORTANT NOTE

Defining the time horizon for an analysis pertaining to infrastructure projects is not an easy task as infrastructure can last 20, 30 or 40 years. It is generally accepted that the project duration used for the economic analysis must at least cover: (i) the investment phase; (ii) the production ramp-up phase; (ii) the phase when production is deemed stabilized. This third phase generally includes the renewal of part of the equipment, rarely that of main infrastructure such as dams or primary irrigation canals.[21]

Economic methods for monetizing certain costs or benefits exist. For example, the costs expected from an increase in the incidence of a waterborne disease can be estimated on the basis of the increase in number of the people affected and costs of treating illnesses, the number of working days lost, etc. The carbon footprint is also increasingly integrated directly into the CBA by valuing the amount of CO_2. However, some costs (or benefits) are much harder to quantify - for example, this is the case of

[21]. On this subject, see Q7 – Quelle(s) dimension(s) temporelle(s) du projet intégrer dans l'analyse économique? in: Malerbe, Florence, Pierre Strosser, Frédéric Bazin, Samir El Ouaamari, Béatrice De Abreu, Jean-François Amen, et Jérémie Dulioust. « Éclairages sur l'analyse économique des projets d'irrigation ». COSTEA, février 2019.

biodiversity loss for which there is no market price. Methods that allow for "internalizing externalities" are often complex

and difficult to implement as part of a project's economic analysis because they require conducting comprehensive studies that cannot be systematically conducted (due to time and resource constraints). However, it is noted that the body of references is growing, and it is gradually becoming easier to find directly usable indices and references.

Furthermore, the fact that the economic analysis, which generally uses discounting techniques to compare costs and benefits falling in different timeframes, tends to give less weight to future events than more immediate events, even if they are important. As such, the discount will downplay the negative consequences of using techniques liable to cause serious illnesses in the long run if they also offer short-term economic benefits.

A multi-criteria analysis (MCA) offers an alternative to the cost-benefit analysis' valuation of non-market costs by considering aspects such as human health, the environment, social issues, or assets in addition to the economy. It therefore allows for judging the relevance of a project on the basis of non-monetary or non-monetizable elements as well. To do so, MCA proposes to analyze the pros and cons of a project through a series of criteria against which it will be assessed and rated. The process is even more valuable if it is participatory and opens a dialogue among project stakeholders that enables them to choose and rate the criteria that they deem most important.

A weight can then be assigned to these different criteria to represent their relative importance for the actors, which subsequently allows for aggregating them in such a way as to obtain an overall assessment and decide between several options.

Another alternative that works for certain indicators is to assign threshold values below or above which a project must be dismissed. This will generally apply to projects whose net present value (NPV) is negative. For other indicators that allow for assessing the project's impact on health, social cohesion or the environment, similar threshold values could be set to dismiss the implementation of a project.

MCA is actually complementary to CBA. If we consider that all projects with a positive NPV can be financed, then the additional criteria defined under MCA can be used to decide between two projects or options. For example, the project retained could be the one that has a positive NPV, generates the least negative effects on biodiversity, has the best carbon footprint or leads to the creation of the biggest number of local jobs.

As such, this type of analysis can inform the project's technical, economic, and organizational choices by allowing for comparing several project implementation options or variants, for example. This is why it is important to put in competition the different criteria that will actually be used to assess the projects.

4.3.2 Approach used for the analysis at the territory level

Identification of project effects:

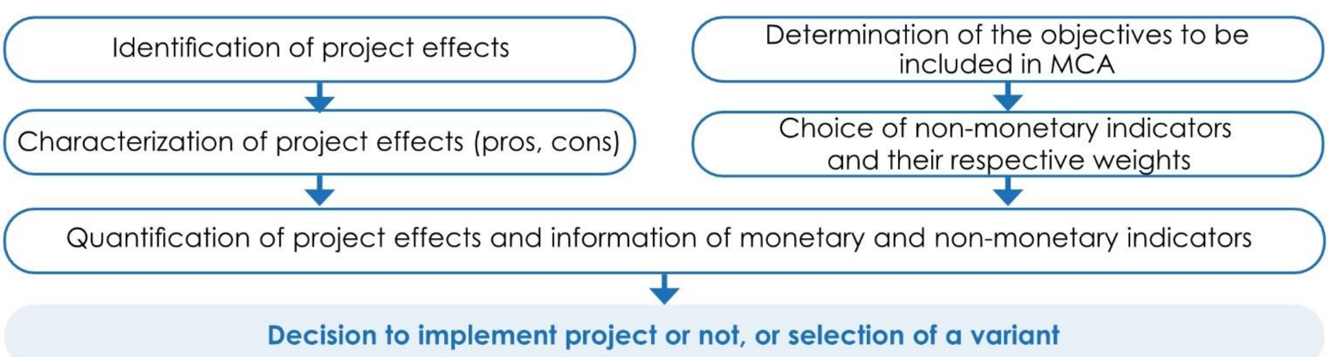
The first step consists in identifying the project's expected effects. It is traditionally considered that there are three types of effects: direct effects, which directly ensue from the activities implemented as part of the project; indirect effects, which ensue from behavior changes of agents directly affected by the project (e.g., upstream and downstream effects in agricultural sub-sectors); and lastly, induced effects, which ensue from the use of the income generated by the direct and indirect effects. Project effect analyses often omit the latter as they are difficult to assess.

Identifying effects requires good prior knowledge of the environment – which is also required on the financial analysis at the level of individual types of actor – as well as good knowledge of the changes that can generally be observed on similar projects to predict the potential behaviors of the actors directly and indirectly impacted over the project's duration.

Characterization of project effects

Determining which project effects should be considered as pros or cons is not always an easy task. An increase in the price of rice can be seen as beneficial from the producer's perspective, but detrimental from the consumer's.

Figure 10: Summary description of the approach used for the analysis at the territory level



How should this effect be classified from a general interest perspective? Generally speaking, effects that constitute financial transfers within society are considered neutral from the project's perspective and are therefore not considered. Nevertheless, financial transfers that would improve the situation of the poorest within a given society could be considered as a pro, provided such improvement constitutes a public policy objective.[22]

On the other hand, when new land is put under cultivation, the additional production can be considered a pro, while at the same time, the resulting modification of the natural environment would be a con.

It is important to remember that project effects are established in relation to a "without project" situation, which necessarily factors in the likely changes that would have occurred in the absence of the project. Therefore, if an irrigation project presents the advantage of limiting deforestation on rainfed land, when compared to the variant without the project, this reduced deforestation will be considered as a project benefit.[23]

Quantification of project effects

Effect quantification consists in comparing the changes expected to happen in a variant with the project with those expected in a variant without the project. For example, it will track the changes in irrigated areas and agricultural production induced in the areas developed or rehabilitated/upgraded by the project, as well as out of them, if the implementation of the project causes changes in the production systems in rainfed areas. This underscores the importance of clearly defining the geographic area that the project effects analysis will consider.

The assumptions on the potential changes that will occur under the variants with and without the project are crucial to the quality of the findings of the analysis. The more realistic they are and the more they are based on solid references and, preferably, production systems equivalent to the ones considered by the project, the more reliable the findings of the analysis will be. It is essential to clarify these assumptions for the purpose of sharing the analyses and enabling informed decisions.

The project's effects beyond the developed areas where irrigated agriculture is being developed also need to be taken into account:

- Project effects on all production systems: the development of irrigation can cause a decrease in rainfed crops by diverting labor, resources, or investments to irrigated crops, for example. It follows that some systems can be strongly impacted: for instance, this would be the case of pastoral systems whose access to water and fodder sources could be reduced by the monopolization of lowlands and water resources for irrigated crops. On the other hand, the dam lakes often allow for developing a new sector linked to fishing.

Individual gas-powered pumping - Saïss Plain, Morocco © F. Deram Malerbe

- Indirect effects of the project on all sub-sectors, including the upstream sector (supply of inputs and delivery of services) and the downstream sector (processing, transport, marketing).
- Effects of the project on social differentiation dynamics, solidarity and social cohesion mechanisms, social ties and reciprocity mechanisms, employee development, climate and economic risk management, etc.
- Effects on ecosystems and the environment: soil fertility and salinization, deforestation, biodiversity, development of diseases for human beings, animals and plants, pesticide pollution, changes in water regimes and water quality, carbon emission or storage in soils and plants, etc.

Some of the effects are quite difficult to assess on an *a priori* basis, especially when they occur in the medium/long term, and there are few data and studies on the social, economic and ecological conditions of the project's intervention area. This is especially the case for environmental effects.[24]

Moreover, the process of classifying effects into "pros" or "cons" is often more complex than it looks. For example, while replacing a system by another may create more wealth, it may require eliminating a large number of jobs. Clearing forests for cultivation may generate additional production but will also reduce biodiversity and carbon storage. In practice, care should be taken to duly characterize effects in physical terms and avoid limiting such characterization to their quantification in monetary terms as this would restrict the process for uncovering the project's specific issues.

22. The "effects method", which is sometimes used for the project's cost-benefit analysis, allows for highlighting project-induced financial transfers between different groups of actors (cf. Appendix 3).

23. On this subject, see Chapter Q2–Comment caractériser le scénario de référence? in: Malerbe, Florence, Pierre Strosser, Frédéric Bazin, Samir El Ouaamari, Béatrice De Abreu, Jean-François Amen, et Jérémie Dulioust. "*Éclairages sur l'analyse économique des projets d'irrigation*". COSTEA, février 2019.

24. See on this subject: "La difficile évaluation des effets environnementaux", in Dufumier, Marc "Les projets de développement agricoles – Manuel d'expertise" CTA – Kharthala, 1996

4.3.2 Summary indicators of the cost-benefit analysis

The indicators produced by the cost-benefit analysis are monetary indicators that are intended to compare the increase in wealth enabled by the project over its duration, with the increase in wealth that would have occurred in a situation without the project. First of all, it allows for verifying that the project actually enables an increase in wealth production over the territory.

Value produced over the territory

The increase in value V induced by the project is conventionally calculated as the sum of the balances of each project period:

$$V = \sum_{i=0}^{i=d} P_i - C_i$$

Where

P_i is the economic value of the net profits generated by the project over period i

C_i is the economic value of the net project costs over period i

The methods used to calculate the baseline prices intended to determine economic values are in line with traditional methods that are described in numerous manuals and not reproduced here.

It is possible to compare the increase in value created by several projects or different variants of a same project. If the projects do not have the same duration, the increase in annual values $v=V/d$, where d is the duration of the project, can be calculated and used to compare them.

Discount

Deferred benefits are traditionally considered to have less social value than immediate ones, because the latter can be reinvested in the economy to produce further positive effects. To allow for comparing costs and benefits that involve different timeframes, annual balances will be converted into a current value (or present value) by correcting them ("discounting" them) by a rate similar to an interest rate, called the discount rate.

The resulting value, called net present value (NPV), is calculated as follows, using a discount rate r and a period of n years:

$$NPV\ (i) = \sum_{k=0}^{n} \frac{Vi}{(1+R)}$$

NPV therefore represents the total collective value generated by the project, which must be positive for the project to be considered economically viable. Like with the value generated, the NPVs of several projects (or variants) could be compared to allow for selecting the one that creates the highest discounted value for society.

However, it should be kept in mind that the preference given to quick benefits, expressed by the discounting of income, is not self-evident and may introduce a bias in the project selection process that is detrimental to projects whose benefits can only materialize in the medium or long term, such as in the case of soil restoration, tree planting, or climate change control projects. This bias can, for example, lead to a preference for annual crops - which are less protective of the soil in the medium term - over perennial crops whose income will take several years to materialize.

A project's present value tends to decrease conversely to the discount rate. At a given rate r, called a project's Internal Rate of Return (IRR), NPV will balance out. IRR represents the maximum interest rate that a project can bear while producing value for society. Where the project is financed by a loan, the IRR is comparable to the interest rates at which the State would take out debts.

Care should be taken not to use this indicator to compare different projects or variants. Indeed, the most important meaning conveyed by a higher IRR is that the project's profitability is not very sensitive to interest rates. However, at a discount rate of 6 percent, it is absolutely possible for a project with an IRR of 12 percent to have an NPV that is lower than that of a project with an IRR of 4 percent.

Irrigation projects, which require significant investments at their beginning and whose return on investment materializes in the medium or even long term, typically have a low IRR, meaning that they are generally profitable only if the discount rate is fairly low (less than 10 percent). This, of course, does not mean that these projects should not be funded.

Choice of discount rate

The choice of the discount rate is therefore a determining factor of NPV that could cause a project, deemed unprofitable, to be dismissed in favor of another. Several methods exist for choosing a discount rate[25]. In practice, discount rates defined by national monetary authorities on the basis of the duration and type of project generally exist. Low discount rates will favor projects with high initial investments and medium- to long-term profitability. This is generally the case of long-term core investment projects (transport, communication and sometimes, also irrigation).

[25]. See AFD: guide to the economic analysis of development projects, version 02.1 of 21/11/2017, 89 pages

Flood irrigation - Marrakech region, Morocco © F. Deram Malerbe

4.3.4 MCA indicators

Choice of relevant indicators

For projects that will be assessed using MCA, selecting the indicators that will be considered to assess the project or its variants is a key step. These indicators must be defined according to project objectives and expected effects, as well as in connection with the policies defined by the government. Ideally, the indicators (and possibly their weighting, see hereafter) should be selected by all stakeholders involved in the project: contracting authority, donors, beneficiary populations' representatives, etc.

For example, in the context of climate policies, one of the objectives could be to avoid financing any project with a net greenhouse gas emitter. When climate change mitigation features among a project's objectives, financing will be restricted to those that are considered carbon sinks. The project's carbon footprint would be a relevant indicator for assessing the project's impact in this area. Climate change resilience indicators could be defined using a similar process.

Projects can also seek to have a neutral or positive impact in terms of biodiversity and sustainable management of natural resources, reduction in inequalities and social cohesion, gender integration, or local governance strengthening. The life cycle analysis (LCA) is a method that is increasingly used to analyze environmental impacts (see box hereafter) nowadays.

LIFE CYCLE ANALYSIS (LCA), A TOOL FOR ASSESSING A PROJECT'S ENVIRONMENTAL IMPACTS[26]

LCA is a tool that allows to measure the environmental impacts of a product, agricultural system, or territory. In the case of agricultural systems, LCA allows for assessing not only the agricultural production process, but also its impacts upstream and downstream of the sector, including those generated outside the study territory (e.g., input production).

LCA allows for doing more than a carbon balance analysis of an agricultural system and generally includes information on the consumption of non-renewable energies, water eutrophication, soil and water acidification, biodiversity, and land use.

However, because of the large amount of data that it requires, its implementation is still challenging, especially the *ex-ante* evaluation of projects in contexts where little research has been made. Some impacts may be difficult to quantify (variations in soil carbon, nitrates propagation in water and soil, loss of biodiversity, ecotoxicity linked to pesticides, etc.).

Methodological developments are underway to adapt the LCA approach (initially designed for product analysis) to the environmental assessment of a territory as a whole.

Feeding MCA indicators

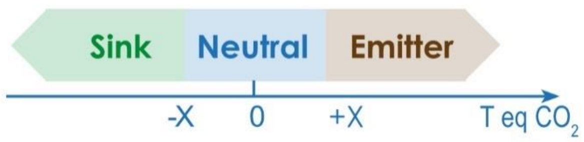
There are different potential types of MCA indicators:

1. basic indicators that represent gross, monetary or non-monetary values: T CO_2, value generated in EUR, number of jobs, etc.;
2. summary indicators that can be used as a basis for decision-making. This requires having threshold values or indicators that allow project analysis a project and comparing variants.

For example, a project can be classified into different classes according to its carbon footprint. In the example illustrated on the figure hereafter, this amounts to defining a value X that allows for differentiating a carbon neutral project from a project that is considered a carbon emitter or sink. More complex scales can be defined in order to classify projects into a larger number of categories (e.g., neutral, low emitter, high emitter, low carbon sink, significant carbon sink).

26. See the works of the ELSA-PACT Chair (www.elsa-pact.fr)

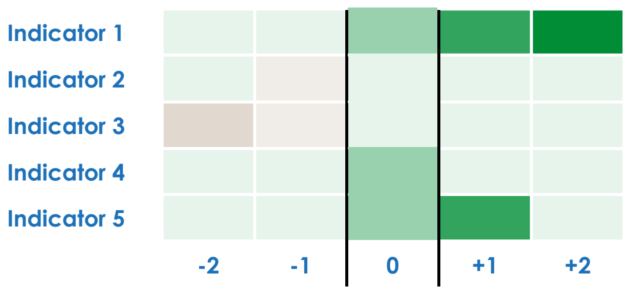
Figure 11: Sample definition of categories for an indicator relating to GHG emissions



As such, a limited number of categories can be defined for each indicator and used to classify the project in relation with all indicators. This allows checking the project's alignment with public policies, and donor strategies.

In the example hereafter (Figure 12), the project is analyzed based on five summary indicators that respectively break down into five categories scored on a scale of -2 to +2 matching the following outcome ratings: highly negative, fairly negative, neutral, fairly positive or highly positive. The alignment of the project's expected effects with the objectives that each indicator feeds can then be verified. For example, if one of the indicators represents the project's NPV, it is possible to assess whether this NPV is positive or not. More complex indicators that summarize outcomes in terms of non-discounted and discounted value can also be defined.

Figure 12: Sample feeding of project indicators



Where indicators have negative values, project elements leading to this outcome can be reviewed and the possibility of formulating variants that do not have the same cons can be assessed.

Projects or variants can also be compared across all the indicators, to allow for selecting the one yielding the best potential results. In some cases, to facilitate the comparison, it may prove relevant to assign an overall rating to each of the projects. For this purpose, the weight to be assigned to each of the criteria should be defined on a concerted basis and the weighted average ***N*** of indicators ***i*** should be calculated.

$$N = \sum_{k=1}^{5} ak.ik$$

Where i_k = value of indicator *k*
And a_k = weight of indicator *k* with

For example, for the five indicators on Figure 12, the following overall ratings would be obtained using respective weight assumptions of 20 percent, 30 percent, 10 percent, 15 percent and 25 percent:

Indicator	Weight	Rating
1	20%	2
2	30%	-1
3	100%	-2
4	15%	0
5	25%	1
Total	100%	0,15

4.4 Sensitivity analysis

The findings of the economic analysis are estimates from a number of assumptions developed on the basis of an analysis of existing systems and comparable situations. For example, assumptions are made regarding future returns and the time horizon for generating them; the future selling prices of productions; the annual development rate of the perimeter developed; the costs and duration for setting up facilities; etc.

Using these assumptions involves a certain amount of risk and uncertainty. For example, irrigated production prices may vary within a range of plus to minus 20 percent of the interannual average used in the assessment. To take this variation into account, an analysis of the impact of a 20 percent drop in price on the producers' income and the value produced by the project could be conducted.

This analysis of the trends of a project's economic outcomes according to the variation of certain critical factors is called "sensitivity analysis".

Traditionally, the object of the study is the extent to which the following variables affect the project's expected outcomes:

- implementation delays;
- delays in ramp-up till full production is reached;
- increase in investment costs;
- increase in operating and agricultural production costs (e.g., prices of energy or fertilizers); and
- decrease of expected gross benefits (quantity or price).

For irrigation projects, the sensitivity to water resource availability will also be studied, especially if uncertainties exist in this respect, as is frequently the case[27].

Sensitivity analyses must pertain to the critical assumptions of the system under consideration, i.e., the assumptions presenting a high level of risk or uncertainty. Although they are traditionally performed on monetary indicators, such as NPV's sensitivity to an increase in investment cost, they can also be performed on non-monetary indicators.

[27] Very few countries have reliable hydrological data relating to long periods of time that allow making a relatively precise assessment of available resources. Furthermore, the effects of climate change are hard to quantify.

Whether the analysis is a financial or economic one, the last step of the calculations consists in:

- determining the variables whose values show the highest uncertainty;
- determining their plausible ranges of values; and
- assessing to what extent the results (balances and relevant indicators) of the analysis are sensitive to it:
    - either through calculations based on value ranges,
    - or, where these variations are unknown, by calculating the variables' critical values, i.e., the thresholds above or below which the results will indicate a project's lack of viability or relevance.

Sensitivity analyses direct the attention to the assumptions underlying the findings of the economic analysis and allow for understanding the project's level of risk. They can alter the overall judgment of the project and as such, constitute a critical component of economic analyses.

Market garden - North of Santo Domingo © F. Deram Malerbe

CHAPTER 5

MEANS TO BE IMPLEMENTED

5.1 General framework of the proposed estimates

The means to be implemented at the different stages of the *ex-ante* economic analysis (team, time, and budget) will depend on many factors, including:

- the complexity of the project (complexity of the structures and agricultural systems, scale of the expected effects, existence of technical or organizational options, etc.);
- the stakes of the economic analysis at the territory level, especially the decision to conduct the project or not;
- the availability of baseline data and complexity of the access to data and project sites;
- the size of the scheme and number of farms;
- the range of agricultural systems before the project and the extent of projected changes in terms of sub-sector development and organization.

In any case, the needs of the economic analysis must be considered when preparing the budget for the studies and must be considered at all stages, not just for the feasibility analysis (see the details of the different studies and the role of economic analysis in Chapter 3).

The means to be prepared for the *ex-ante* economic analysis must allow for performing the following tasks.

Diagnostic of agricultural systems and agro-economic analysis at the producer level (pre-project situation and projected scenarios):

- Data collection and production (collection and analysis of documentation, site visits, and surveys, etc.); difficulties in accessing data (which are sometimes non-existent or can hardly be used) are common problems that should not be underestimated;
- As much as possible, use a participatory approach involving farmers and other actors at the local or even national level (consultations through focus groups, organization of working groups, etc.);
- Analysis and processing of the data and information collected to establish a farm typology, produce technical and economic factsheets, model agricultural systems, etc.); and
- Forward-looking work on the changes in agricultural systems (several scenarios).

Financial analysis of perimeter management (at the operator level):

- Data collection and analysis (where operator exists);
- Pricing study of the irrigation service if plans include the levy of a fee or tariffs (concurrently with the assessment of the future irrigation users' ability to pay to be performed on the basis of the agro-economic analysis conducted at the producer level);
- Financial modeling of the future operator (if the operator is to be set up) according to the institutional and financial organization selected for the irrigated system's management (or for each option considered).

Table 7: Standard cases for an *ex-ante* economic analysis (feasibility study)

Standard case		Level of analysis		
		Producers	Manager	Territory
Case 1	Rehabilitation / Upgrading of an existing scheme	Detailed agro-economic analysis (financial analysis per type of producer)	Financial analysis	Economic analysis (where useful)
Case 2	Development of a new scheme	Detailed agro-economic analysis (financial analysis per type of producer)	Financial analysis	Economic analysis (where useful)
Case 3	Project with a target developed surface area(perimeters not identified at the feasibility stage)	Simplified agro-economic analysis (per type of targeted perimeters)	Financial analysis	Economic analysis at the scale of the project territory
Case 4	Public policy project (subsidy for individual equipment)	Simplified agro-economic/financial analysis of the types of producers targeted	N/A	Economic analysis at the scale of the project territory

Territory-wide economic analysis (where applicable) that may include the following, depending on the methods chosen:

- Access to data (exclusive of data collected or established at the producer and operator levels);
- Participatory work (especially in the case of an MCA – see 4.3);
- Analysis and processing of the data and information collected

IMPORTANT NOTE

The resources allocated to the economic analysis and its implementation schedule must also allow for full integration with the other study components (technical, institutional, social, environmental, etc.).

To ensure that the economic analysis is actually used to support the choices to be made at different stages of the project's development, it is imperative to conduct it in iteration with the other components of the feasibility study (design and sizing of irrigation infrastructures, organizational arrangement, farming methods arrangements, associated support measures, etc.). As such, this aspect should be included in the estimate of means to be implemented.

Given the diversity of projects and contexts, it is not possible to evaluate standard budgets for the economic evaluation during *ex-ante* studies. Nevertheless, for the purpose of providing a few benchmarks, several scenarios have been devised and their time requirement estimated.

This estimation process considers:

- the stages of the economic analysis process according to the type of project (see Chapter 3); and
- the three levels of analysis, i.e., producers, irrigation infrastructure operators, and project territory (see Chapter 2.3).

Based on this premise, four scenarios for economic analysis may be considered and are presented in Table 7 along with the analysis methods to be implemented at each of the three levels (producers, operators, and territory).

The estimated time requirements proposed hereafter refer only to the project's feasibility study – they do not include the economic studies that may be recommended during its implementation. It is particularly noted that the detailed economic studies to be performed for each perimeter in the case of irrigation development programs and multi-purpose infrastructure projects are not included in the budgets. They must be added and can be estimated (depending on the size of the perimeters) based on Cases 1 or 2 defined above.

For each of the four cases, budgets estimated in days are proposed along with:

- the minimum level representing a situation where data is available and/or stakes are low;
- and the maximum level representing a situation where there is no data and/or stakes are high.

Stakes refers to the situations developed in Table 8 hereafter.

Lastly, the amount of work to be performed is also linked with the surface area of targeted perimeters, size of the investments, and diversity of the agricultural and producer systems.

5.2 Estimated time requirements of the proposed cases

Each estimate was established for a type of project and scheme. To clearly specify the assumptions underlying these estimates, the characteristics of the sample project are specified in a first table. A second table sets forth a number of days for each level of analysis. The tables detailing all the activities included in the economic analysis process are set forth in Annex 4.

Table 8: Sample high-stakes situations

Types of stakes	Sample situations
Project justification (existence of competing projects)	The counterpart's or donor's decision is conditional on a certain economic result.
Multiplicity of options (technical, financial or institutional)	Several development options potentially resulting in different impacts (more developed areas, more efficient infrastructure, etc.) Economic and financial impact of the type of institution selected (public, private, or public-private)
Ownership by and involvement of producers	The perimeter will be managed by an irrigation users association that is yet to be set up. The project's profitability/success is conditional on significant changes in farming methods. The economic analysis must therefore allow for bringing support/extension needs to light.
Financial (participation of the private sector)	The rate of return for the private sector conditions its participation.
Constraints on water resources	Resource restrictions strongly impact producers' interest for a project and/or the operator's financial balance.
Competition between water resources	The planned network must supplement or replace the resource used to date (often underground): the (financial and technical) interest for producers must be verified.

IMPORTANT NOTE

- The estimates provided in the following paragraphs must be considered in light of all the parameters set out earlier and adapted to each project and local context.
- Some activities needed for the economic analysis relate to other aspects of the feasibility study (technical design of the infrastructure, organization of the scheme, agronomic analyses, etc.). In this case, these activities are costed according to the amount of processing required for the data from other components (without including the work that must be performed under these components) or simply recalled (pm).

5.2.1 Case 1: Rehabilitation/upgrading of an existing perimeter

The costing under this first case refers to a small perimeter developed by family farmers.

Land used as pasture before the next farming season - Sélingué perimeter, Mali © F. Bazin

Table 9: Case 1 – Characteristics of the type of perimeter considered

	Case 1: Rehabilitation of a small associative scheme		
Project characterization	**Project type**		Development of an irrigated scheme
	Project components	Works	Rehabilitation of intake structures and networks
		Other components	Support: irrigation management, farming methods
	Targeted scheme type	Size	500 ha
		Infrastructure	Network of open canals - intake from river
		Management arrangement	Irrigation users association (to be created by the project)
	Farming system	Farms	Very small size to a few exceptions - average of 1 ha
		Main crops	Food crops, fruit trees and market gardening
		Farming systems	Diversified (mixed crop and stock farming, land status, etc.)
	Study conditions	Access to data	No reliable national or regional statistics, no previous studies
		Access to plot	Risky local access
		Access to actors	Easy access

Table 10: Case 1 – Summary of the estimated time requirements

Summary (*number of days excluding travel time*)	Min d	Max d
Agro-economic analysis (producers)	**20**	**40**
economist/engineer	***20***	***26***
surveyor/technician	***0***	***14***
Financial analysis at the operator level	**8**	**18**
Economic analysis at the territory level (with carbon footprint)	**17**	**32**
Total days	**45**	**90**

Pivot on sugar cane plantation - Southeastern Eswatini © B. Vennat

5.2.2 Case 2: Creation of a scheme

Table 11: Case 2 – Characteristics of the type of scheme considered

	Case 2: Creation of a large scheme		
Project characterization	**Project type**		Development of an irrigated scheme
	Project components	Works	Creation of a network for additional irrigation
		Other components	N/A
	Type of targeted scheme	Size	30,000 ha
		Infrastructure	Pressurized – high technicality of main structures
		Management arrangement	Public or private company, providing full service (down to individual farms)
	Farming methods	Farms	Highly variable: from less than 1 to 3,000 ha
		Main crops	(Non-irrigated) grains, fruit trees, market gardening, and mixed crop and livestock farming
		Farming systems	Highly diversified agricultural systems: Large entrepreneurial estates to small family farms – Same for land status (private, collective, long-term leases, etc.)
	Study conditions	Access to data	Statistics at local level – No data specific to the targeted perimeter
		Access to plot	Easy access
		Access to actors	Easy access

Table 12: Case 2 – Summary of the estimated time requirements

Summary (*number of days excluding travel time*)	Min d	Max d
Agro-economic analysis (producers)	33	70
economist/engineer	*33*	*40*
surveyor/technician	*0*	*30*
Financial analysis at the operator level	23	50
Economic analysis at the territory level (with carbon footprint)	29	55
Total days	**85**	**175**

5.2.3 Case 3: Project with a target developed surface area (schemes are not identified at the feasibility stage)

Table 13: Case 3 – Characteristics of the type of scheme considered

	Case 3: Program for the rehabilitation of a set of small associative schemes		
Project	**Project type**		Irrigation development program
	Project components	Works	Creation of new networks – areas unidentified before the feasibility study
		Other components	Support: irrigation management, farming system, support to downstream sub-sectors
	Type of targeted schemes	Size	20,000 ha
		Infrastructure	Networks
		Management arrangement	Associations of irrigating farmers
	Farming system	Farms	Family farming
		Main crops	Rice, fruit trees, market garden
		Farming systems	Mixed crop and livestock farming
	Study conditions	Access to data	Limited data
		Access to plot	Easy access

Table 14: Case 3 – Summary of the estimated time requirements

Summary (*number of days excluding travel time*)	Min d	Max d
Agro-economic analysis (producers)	25	55
economist/engineer	*25*	*55*
surveyor/technician	*0*	*0*
Financial analysis at the operator level	12	20
Economic analysis at the territory level (with carbon footprint)	25	50
Total days	**62**	**125**

5.2.4 Case 4: Public policy project (subsidy for individual equipment)

Table 15: Case 4 – Characteristics of the type of scheme considered

	Case 4: Equipment subsidy for small irrigation		
Project characterization	**Project type**		Public policy
	Project components	Works	No works
		Other components	Subsidies for the individual equipment of producers Technical assistance for setting up
	Type of targeted scheme	Size	
		Infrastructure	Small irrigation by individuals or small groups
		Management arrangement	Mainly individual
	Farming system	Farms	Small-scale farms
		Main crops	Market garden
		Farming systems	
	Study conditions	Access to data	Limited data
		Access to plot	Difficult to access

Table 16: Case 4 – Summary of the estimated time requirements

Summary (*number of days excluding travel time*)	Min d	Max d
Agro-economic analysis (producers)	**20**	**45**
economist/engineer	**20**	**55**
surveyor/technician	**0**	**0**
Financial analysis at the operator level	**12**	**20**
Economic analysis at the territory level (with carbon footprint)	**25**	**50**
Total days	**62**	**125**

Children at the edge of an irrigation canal - Aquin Plain, Haiti © F. Deram Malerbe

ANNEXES

Annex 1: Bibliography

The main resources that can provide further insight into the concepts and methods discussed in this guide are highlighted in the bibliography hereafter.

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Annex 2: Definitions

Economic terminology

Carbon footprint	Various methods for accounting for greenhouse gas emissions have been developed to quantify the contribution of human activities or a territory to climate change. These methods vary according to their subject: territory, organization, product, etc. Organizations use different names to refer to them, the most common ones being "carbon balance" or "carbon footprint".
Cost-benefit analysis	Identifies and evaluates all the costs and benefits (including positive/negative externalities) associated with the implementation of a project, allows for calculating the net present value generated by the project (difference between discounted costs and benefits).
Discount rate	Discounting consists in applying rates - called discount rates, to financial flows that are not directly comparable and involve different timeframes, in order to compare or combine them in various ways.
Economic analysis	An economic analysis takes into consideration an entire system (collectivity, territory, country) with all its actors (see definition of the system and scope of the analysis) and assesses the project's economic relevance to this system by integrating all its direct, indirect, and induced effects. It does not look into the financial flows between actors, such as the taxes and subsidies (and water service) that are (a) paid by some and (b) received by others (accounting for the zero-sum of the economic analysis). The economic analysis of a project allows for determining the additional wealth it creates at the level of the collectivity or territory considered, in comparison with the "without project" situation. Depending on the methods used, it can also help determine the patterns of distribution of the differential in value added between the different agents involved.
Financial analysis	A financial analysis pertains to a given actor (farmer, investor, etc.): it looks into this actor's financial balance by assessing what they pay (costs of inputs including irrigation water, labor costs, taxes, etc.) and what they receive (through the sale of products, subsidies, etc.). Under development projects, this kind of analysis allows for ensuring that the type of actor considered finds the project advantageous (by verifying if the project is advantageous to them and under what conditions). It also allows for producing inputs needed for the economic analysis; for example, assessing the project's effects on the farms allows for assessing the farmers' potential interest in the project and provides baseline data for the economic analysis.
Internal rate of return	The internal rate of return is the discount rate at which the net present value of an investment project is balanced out. Comparing it to the minimum rate required by capital providers, which is generally equal to the weighted average cost of capital, it often allows for determining whether a project will be profitable or not: in trivial cases, NPV will be positive if IRR is greater than the discount rate. However, there are many exceptions to this rule. Moreover, IRR is not a linear function of cash flows and therefore cannot be used to assess project portfolios.
Life cycle analysis (LCA)	A life cycle analysis is a method for assessing a system's environmental impact (product, service, territory, etc.), over its entire life cycle: from the extraction of raw energy and non-energy materials required for manufacturing the product to its disposal towards end-of-life sectors, including distribution, use, as well as all transportation phases.
Multi-criteria analysis	Qualitative and/or quantitative assessment of different criteria that allows for understanding the social, economic, and environmental implications, as well as implementation and organizational challenges, and for aggregating them based on the relative weights assigned to individual criteria.
Net present value	The net present value (NPV) is a measure of an investment's return calculated as the sum of the cash flows generated by the operation, where each one is discounted in such a way that its importance in this sum decreases over time. If the discount rate is properly chosen, the investment will be deemed profitable and therefore selected if and only if its net present value is positive.

Siphon of the LUZIP project - Southeastern Eswatini © B. Vennat

Irrigation terminology

Day-to-day operation (costs)	Routine operating and maintenance (or upkeep) costs of a network
Irrigated system	Social system for managing water that draws on (Sabatier, Ruf & Le Goulven, 1991): - hydraulic and agronomic know-how (assessment of resource, catchment, transfer, network, sharing, application, crops' water needs, work frequency) - a division of labor between the actors in charge of production through irrigation and ones in charge of water conveyance under the best conditions - a hydraulic authority that ensures the performance of water rights registration functions, rights transmission functions, water policing functions, hydraulic maintenance functions, (labor and financial) cost sharing functions. The study of an irrigated system mainly differs from the study of a non-irrigated agrarian system due to the existence of strong and shared constraints linked to the presence of a hydraulic network: the need to make arrangements to ensure the catchment, conveyance, and distribution of water, on the one hand, and to build or maintain network infrastructure, on the other hand, tends to shape different and specific societies or human groups. It is especially appreciated that because water (water management) and irrigated land (land rules) are scarce resources most of the time, arrangements relating to their sharing constitute hotbeds for tension and conflicts that require the development of stringent social rules controlled by a recognized authority. (Molle & Ruf).
Irrigation infrastructure	Set of structures and networks that convey a water resource to an agricultural perimeter for irrigation purposes - this includes the mobilization, transport (transfer) and distribution of water within the perimeter.
Irrigation network	Infrastructure internal to the irrigated agricultural perimeter that includes at least the structures and networks allowing for distributing water among users and farming plots.

Irrigation project	As the subject of the economic analyses, it corresponds to any project to create, develop, or rehabilitate collective infrastructure for mobilizing and/or distributing water for agricultural use, publicly financed in full or in part. (study ToR - §4.1). Project: set of activities implemented in a given framework (own organization) to achieve given objectives. Irrigation projects traditionally include several components relating to specific types of activities/objectives: - Infrastructure component (works to create, develop, or rehabilitate infrastructure + project management + supervision) - Management support component (implementation of and/or support to the management structure, regardless of its nature) - Farming system component (support to farming: technical components, subsidies, support for upstream and downstream sub-sectors, etc.) - Institutional strengthening component (support for project management, support for public policies, capacity building, etc.).
Maintenance	There are several types of maintenance that must be distinguished according to their objectives and time step: - Day-to-day maintenance or upkeep: regular tasks necessary for the proper functioning of the network (e.g., cleaning of channels, lubrication of valves, etc.) - Preventive maintenance: periodic tasks allowing for maintaining the structures in good condition and preventing breakages (e.g., repainting valves) - Corrective/curative maintenance: repair work after a breakage - Long-term maintenance: incorrect term that is sometimes used to refer to renewal
Maintenance strategy	Seeking balance between the different types of maintenance and renewal: two extremes (that significantly impact on the economic rationale, especially the operating costs to investment ratio) - Preventive maintenance to limit curative maintenance and renewal; - Zero preventive maintenance, repairs or replacements are made breakage occurs.
Operation	Includes all operations that allow for distributing water among users (valve handling, pump operation, etc.) and the resulting energy consumption (generally considered separately at the cost analysis level).
Renewal	Full replacement of a structure or equipment with an identical or upgraded version, either because of a breakage or because it is reaching the end of its life (renewal of fountains, pump). Renewal is approached very differently depending on the nature of the infrastructure: for example, a large, paved and properly maintained canal never undergoes renewal.

Mechanized harvesting - Perimeter of Po Pi Deum, Cambodia © F. Deram Malerbe

Annex 3: Main methods of economic analysis, characteristics, and specific objectives

Method	Main characteristics	Contributes to what objectives?
Effects method	Evaluates a project's overall impact in a given territory in terms of direct and indirect effects and flows (among actors of the territory and between the territory and the rest of the world).	How does it contribute to a territory's economic development?
Method of reference prices	Evaluates the wealth differential that a project brings to the community by measuring all values earned and all values lost as a result of its implementation. It uses reference prices to reconstruct the real economic value of the goods and services produced or consumed as a result of the implementation of the project. This value represents their opportunity cost for the collectivity, which is different from the market price of the good or service considered.	How does it contribute to a territory's economic development?
Cost-benefit analysis (CBA)	Identifies and evaluates all the costs and benefits (including positive/negative externalities) associated with the implementation of a project, allows for calculating the net present value generated by the project (difference between discounted costs and benefits).	Which scenario or variant is deemed the best from an economic perspective? Is the project a net producer of value?
Cost-effectiveness analysis (CEA)	Identifies the most profitable option for achieving a predefined objective (for a given actor, generally the project promoter). Goes from the assumption that the objective to achieve is economically viable.	How to achieve a set objective at lesser cost? (Or: how to best use a predefined budget for maximum impact?)
Multi-criteria analysis (MCA)	Qualitative and/or quantitative assessment of different criteria that allows for understanding the social, economic, and environmental implications, as well as implementation and organizational challenges, and for aggregating them based on the relative weights assigned to individual criteria.	Which scenario or variant is deemed "the best" in the light of a range of indicators that allow for understanding the social, economic, and environmental implications, as well as the implementation/organizational challenges? As a tool that allows for conducting consultation processes involving various actors, this method allows for seeking the trade-offs that are needed between the various actors' expectations.
Risk-based analysis	Identifies all types of risk, their severity, and probability of occurrence, establishes an analysis grid, and proposes mitigation measures.	How to minimize risks on a territory for actors?

Source: Malerbe, Florence, Pierre Strosser, Frédéric Bazin, Samir El Ouaamari, Béatrice De Abreu, Jean-François Amen, et Jérémie Dulioust. "*Éclairages sur l'analyse économique des projets d'irrigation*". COSTEA, February 2019, www.comite-costea.fr/wp-content/uploads/AC-Analyses-Economiques-rapport-eclairage-economie-1.pdf

Annex 4: Estimation of resource requirements in four standard cases - detailed tables

Case 1: Rehabilitation/upgrading of an existing perimeter

Case 1 - Estimation of the agro-economic analysis' time requirements – Producers

		Activities	Details	Min d	Max d
Producers	Agro-economic analysis	Main objectives of the agro-economic analysis	**Conditions for producer interest** **Baseline situation**		
		Documentation and data	Collection and analysis	2	4
		GIS	Processing of GIS data to be pooled with other study components	pm	pm
		Focus group (can be pooled with other study components)	3 per perimeter area (all, women, youth) and local authorities	1	2
		Field surveys (including the preparation and analysis of questionnaires)	Min: Limited survey (based on a typology established during the focus groups): 2 farms per type Max: Detailed survey on representative sample	8	18
		Agro-economic analysis (present situation that can be used as baseline situation, provided it is formatted appropriately)	Modeling of farm types: factsheets per crop, analysis of calendars, income per type (including external income)	4	6
		Farming scenario and agro-economic analysis (future situation)	Modeling per farm type: assessment of the increase/diversification of production and income (identical agricultural systems + introduction of new crops based on focus group results)	2	4
		Ability to pay/contribute - Iterative work with pricing	Double analysis: working time (maintenance of canals) and ability to pay fee	2	4
		Ability to invest (material): SFC, availability of suitable credit	Assessment of the local credit offer	1	2
			Total days	**20**	**40**

Case 1 - Estimation of the time requirements of the financial analysis of management – Operator

		Activities	Details	Min d	Max d
Operator	**Financial analysis at the operator level** *Iterative work between the economic component and other components to assess conditions for management balance: investments, costs, pricing, ability to pay and organizational arrangements*	Financial diagnostic of operator (if already in place)	**N/A**		
		Organizational component of the study Impact on costs	Co-construction of organizational arrangement (distribution of tasks [producers, association, State]) and definition of management arrangements between producers (representatives) and other stakeholders	2	5
		Identification and costing of operating and maintenance tasks (with technical component)	Per type of structure: - scheduling of interventions (periodicity) - costing: estimation of working time requirements (tasks performed by producers) or invoices from specialized companies	1	2
		Identification and costing of administrative tasks (with organizational component)	In particular: collection of fees, accounting management, coordination of association and organization of O&M tasks	1	2
		Irrigation fee scenarios/ Pricing	According to organizational arrangements, costs allocated to association and producers' ability to pay	2	5
		Financial analysis	Summary modeling	2	4
			Total days	**8**	**18**

Case 1 - Estimation of the economic analysis' time requirements - Territory

		Activities	Details	Min d	Max d
Territory	Economic analysis	Data collection	Population, employment, environmental issues, etc.	2	4
		Use of GIS	Processing of GIS data to be pooled with other study components	pm	pm
		Estimation of investments	Technical component	1	1
		Public contributions (investments, subsidies)	Provided per technical component and financial analysis of the operator	1	1
		Project management and reinforcement of public services	Definition and costing: project unit, technical assistance, training, etc.	1	2
		Support measures	Service providers (network of technical advisers, additional studies, etc.)	1	2
		Offset or avoidance measures (negative externalities) - ESMP	Costing of ESMP (exclusive of support measures)	1	2
		Impact on agricultural production	Modeling of project impact on the total production and value added generated: evaluation of surface areas before and after the project (identical agricultural systems + introduction of new crops)	2	5
		Other positive project impacts: social, environmental, etc.	Social: reduced precariousness, reduced rural exodus, jobs Environmental: better use of natural resources	2	3
		Negative externalities requiring the setting up of offset or avoidance measures	Eviction of small-scale farmers Land pollution, waste management	1	2
		Carbon Footprint (formerly ACT)	Based on data from previous steps	3	5
		CBA, including sensitivity analyses	Modeling and calculations	2	5
		MCA	N/A		
			Total days	**17**	**32**

Case 2: Creation of a perimeter

Case 2 - Estimation of the agro-economic analysis' time requirements – Producers

		Activities	Details	Min d	Max d
Proroducers	Agro-economic analysis	**Main objectives of the agro-economic analysis**	**Conditions for project to be advantageous to producers (technical and financial)** **Ability to pay tariffs** **Baseline situation**		
		Documentation and data	Collection and analysis of data available on the perimeter	4	6
		GIS	Processing of GIS data to be pooled with other study components	pm	pm
		Focus group (can be pooled with other study components)	Targeted on family farming: 3 per perimeter scope (all, women, youth) + 1 working group per major type of entrepreneurial farm?	3	4
		Field surveys (including the preparation and analysis of questionnaires)	Min: Limited survey (based on a typology established during the focus groups): 2 farms per type Max: detailed survey on representative sample	15	40
		Agro-economic analysis (present situation that can be used as baseline situation provided it is formatted appropriately)	Modeling of farm types: factsheets per crop, analysis of calendars, income per type (including external income)	5	8
		Farming scenario and agro-economic analysis (future situation)	Modeling based on farm type: assessment of the production and income (identical agricultural systems + improved irrigation productivity + introduction of new crops based on focus group results)	3	6
		Ability to pay/contribute - Iterative work with pricing	Ability to pay service rates and invest in suitable irrigation equipment	2	4
		Ability to invest (material): SFC, availability of suitable credit	Assessment of the local credit supply	1	2
			Total days	**33**	**70**

Case 2 - Estimation of the time requirements of the financial analysis of management – Operator

		Activities	Details	Min d	Max d
Operator	**Financial analysis at the operator level** *Iterative work between the economic component and other components to assess conditions for management balance: investments, costs, pricing, ability to pay and organizational arrangements*	Financial diagnostic of operator (if already in place)	Collection and analysis of accounting data: calculation of ratios	5	15
		Organizational component of study - Impact on costs	Definition of the organizational arrangements: -Reflection on the manager's structure and resources (technical, human, financial, etc.) + services accessible with other structures (public or private) -Definition of the maintenance policy	3	6
		Identification and costing of operation and maintenance tasks (with the technical component)	Evaluation of O&M costs by applying appropriate ratios (to the works' amounts - provided per technical component)	1	2
		Identification and costing of administrative tasks (with organizational component)	Costing of other tasks and material resources	1	2
		Irrigation fee scenarios/ Pricing	Pricing study along with definition of a range of services and several pricing, where applicable	5	10
		Financial analysis	Detailed modeling: building a complex financial model integrating operating accounts, financing scenarios (investments and cash), taxation, etc.	8	15
			Total days	**23**	**50**

Case 2 - Estimation of the economic analysis' time requirements - Territory

		Activities	Details	Min d	Max d
Territory	Economic analysis	Data collection	Population, employment, environmental issues, etc.		
		Use of GIS	Processing of GIS data to be pooled with other study components	pm	pm
		Estimation of investments	Technical component	1	1
		Public contributions (investments, subsidies)	Provided per technical component and financial analysis of the operator + Factors of financial/economic conversion	1	3
		Project management and reinforcement of public services	Definition and costing: project unit, technical assistance, training, etc.	1	2
		Support measures	Service providers (network of technical advisers, additional studies, etc.)	1	2
		Offset or avoidance measures (negative externalities) - ESMP	Costing of ESMP (exclusive of support measures)	1	3
		Impact on agricultural production	Modeling of project impact on the total production and value added produced	4	8
		Other positive project impacts: social, environmental, etc.	Social: improved income, reduced rural exodus, job creation Environmental: water "savings" / better water development	2	4
		Negative externalities requiring the implementation of offset or avoidance measures	Social: land concentration (eviction of small-scale farmers) Environmental: carbon footprint, increase in effluents and waste (drip equipment, plastics, etc.)	2	4
		Carbon Footprint (formerly ACT)	Based on data from previous steps	5	8
		CBA including sensitivity analyses	Modeling and calculations	6	10
		MCA	As a tool for consulting and involving stakeholders in the project: definition of support measures, measures / negative externalities, etc.	5	10
			Total days	**29**	**55**

Case 3: Project with a target developed surface area (perimeters are not identified at the feasibility stage)

Case 3 - Estimation of the agro-economic analysis' time requirements – Producers

		Activities	Details	Min d	Max d
Producers	Agro-economic analysis	Main objectives of the agro-economic analysis	**Definition of the agro-economic criteria for choosing the perimeters that will be integrated into the program Analysis of a few typical perimeters**		
		Documentation and data	Data relating to agricultural production and systems in the areas targeted by the program	2	3
		GIS	Processing of GIS data to be pooled with other study components	pm	pm
		Focus group (can be pooled with other study components)	On one or two perimeters of the type targeted by the program	3	6
		Field surveys (including the preparation and analysis of questionnaires)	Survey limited to one or two typical perimeters (based on a typology established on the basis of focus group results or available data)	12	30
		Agro-economic analysis (present situation that can be used as baseline situation provided it is formatted appropriately)	Modeling of farm types: technical and economic factsheets, operating accounts	4	8
		Farming scenario and agro-economic analysis (future situation)	Modeling per farm type: evaluation of the production and income (identical agricultural systems + improved irrigation productivity + introduction of new crops based on focus group results)	2	4
		Ability to pay/contribute - Iterative work with pricing	Ability to pay service fees	2	4
		Ability to invest (material): SFC, availability of suitable credit	Integrated in the analysis of producers' operating accounts	pm	pm
			Total days	**25**	**55**

Case 2 - Estimation of the time requirements of the financial analysis of management – Operator

		Activities	Details	Min d	Max d
Operator	**Financial analysis at the operator level** *Iterative work between the economic component and other components to assess management balance conditions: investments, costs, pricing, ability to pay and organizational arrangements*	Financial diagnostic of operator (if already in place)	N/A		
		Organizational component of study - Impact on costs	Appraisal of the major issues of irrigation associations to assess the actions that should be included in the program to support them	2	3
		Identification and costing of operating and maintenance tasks (with technical component)	Per type of perimeter: - scheduling of interventions (periodicity) - costing: estimation of working time requirements (tasks performed by producers) or invoices from specialized companies	3	5
		Identification and costing of administrative tasks (with organizational component)	In particular: collection of fees, accounting management, animation of association and organization of O&M tasks	2	4
		Irrigation fee scenarios/ Pricing	Per type of perimeter	3	6
		Financial analysis	Summary modeling per type of perimeter	2	2
			Total days	**12**	**20**

Case 3 - Estimation of the economic analysis' time requirements - Territory

		Activities	Details	Min d	Max d
Territory	Economic analysis	Data collection	Population, employment, environmental issues, etc.		
		Use of GIS	Processing of GIS data to be pooled with other study components	pm	pm
		Estimation of investments	Technical component	1	1
		Public contributions (investments, subsidies)	Estimation per type of targeted perimeter	1	3
		Project management and reinforcement of public services	Definition and costing: project unit, technical assistance, training, etc.	1	2
		Support measures	Service providers (network of technical advisers, additional studies, etc.)	1	2
		Offset or avoidance measures (negative externalities) - ESMP	Costing of ESMP (exclusive of support measures)	1	3
		Impact on agricultural production	Modeling of project impact on the total production and value added produced	4	8
		Other positive project impacts: social, environmental, etc.	Social: improved income, reduced rural exodus, local job creation Environmental: ?	2	5
		Negative externalities requiring the implementation of offset or avoidance measures	Monitoring of resources harnessed, pollution, etc.	2	5
		Carbon Footprint (formerly ACT)	Based on data from previous steps	5	8
		CBA, including sensitivity analyses	Modeling and calculations	4	8
		MCA	As a tool for consulting and involving stakeholders in the project: definition of the perimeters' selection criteria	3	5
			Total days	**25**	**50**

Case 4: Public Policy Project (subsidy for individual equipment)

Case 4 - Estimation of the agro-economic analysis' time requirements – Producers

		Activities	Details	Min d	Max d
Producers	Agro-economic analysis	Main objectives of the agro-economic analysis	Characterize target producers Define the terms and criteria for awarding subsidies Baseline situation		
		Documentation and data	Data relating to the agricultural systems of program target areas	2	5
		GIS	Limited to the location of areas and representation of agricultural systems	pm	pm
		Focus group (can be pooled with other study components)	3 per targeted area (general, women, youth)	2	6
		Field surveys (including the preparation and analysis of questionnaires)	Limited survey (based on a typology of targeted producers)	10	20
		Agro-economic analysis (present situation that can be used as baseline situation provided it is formatted appropriately)	Modeling of farm types: technical and economic factsheets, operating accounts	3	8
		Farming scenario and agro-economic analysis (future situation)	Modeling per type of targeted farm: evaluation of the production and income (identical agricultural systems + improved irrigation productivity + introduction of new crops)	2	4
		Ability to pay/contribute - Iterative work with pricing	N/A		
		Ability to invest (material): SFC, availability of suitable credit	Costing of the subsidy amounts needed according to producer type	1	3
			Total days	**20**	**45**

Case 4 - Estimation of the economic analysis' time requirements - Territory

		Activities	Details	Min d	Max d
Territory	Economic analysis	Data collection		1	2
		Use of GIS	To assess surface areas concerned	pm	pm
		Estimation of investments	N/A		
		Public contributions (investments, subsidies)	Total amount of subsidies planned for the project	1	2
		Project management and reinforcement of public services	Definition and costing of technical assistance	1	2
		Support measures	Service providers (network of technical advisers, additional studies, etc.)	1	2
		Offset or avoidance measures (negative externalities) - ESMP	Costing of ESMP (exclusive of support measures)	1	3
		Impact on agricultural production	Simple modeling of project impact on the total production and value added produced	3	6
		Other positive project impacts: social, environmental, etc.	Social: improved income, reduced rural exodus, local job creation Environmental: ?	2	3
		Negative externalities requiring the setting up of offset or avoidance measures	Monitoring of samples, pollution, etc.	1	2
		Carbon Footprint (formerly ACT)	Based on data from previous steps	2	4
		CBA including sensitivity analyses	Modeling and calculations	2	4
		MCA	Usefulness to be assessed		
			Total days	**15**	**30**