Irrigation Manual
Module 14

Monitoring the Technical and Financial Performance of an Irrigation Scheme

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List of abbreviations

AEW	Agricultural Extension Worker
Agritex	Department of Agricultural Technical and Extension Services
B/C	Benefit/Cost
BD	Bulk Density
BOND	British Overseas NGOs for Development
CI	Cropping Intensity
CP	Crop Production
DAEO	District Agricultural Extension Officer
DFID	Department For International Development (UK)
DU	Distribution Uniformity
E	Efficiency
EU	Emission Uniformity
FARMESA	Farm level applied research methods for East and Southern Africa
FC	Field Capacity
ICID	International Commission on Irrigation and Drainage
IDS	Institute of Development Studies
IIMI	International Irrigation Management Institute (now renamed IWMI)
IMC	Irrigation Management Committee
IR	Irrigation Requirement
IRR	Internal Rate of Return
IWMI	International Water Management Institute
M&E	Monitoring and Evaluation
MOV	Means Of Verification
NPV	Net Present Value
O&M	Operation and Maintenance
OVI	Objectively Verifiable Indicator
PM&E	Participatory Monitoring and Evaluation
PWP	Permanent Wilting Point
RDC	Rural District Council
SEAGA	Socio-Economic And Gender Analysis
SM	Soil Moisture
SPFS	Special Programme for Food Security
WUA	Water Users Association
Y	Yield

Chapter 1
Introduction to monitoring and evaluation

Monitoring and Evaluation (M&E) of a programme or a project or, in our case, an irrigation scheme is important in order to provide information about how it is performing. There are four distinct reasons for carring out M&E:

- To keep track of the progress of development activities during implementation and to remain alert in case of shortfalls or deviations from projections to enable them to be corrected
- To determine the relevance, efficiency and effectiveness of development activities and the impact on the different stakeholders
- To learn lessons for future development planning, in order to improve the formulation and implementation of projects and increase their performance
- To share progress and results with others

A wealth of literature is available on monitoring, evaluation, indicators and their parameters. This Module briefly touches on a few aspects, without pretending to be exhaustive. Some basic information and definitions related to M&E are given in Chapter 1. Chapters 2, 3 and 4 concentrate on monitoring the technical performance of surface, sprinkler and localized irrigation schemes respectively, while Chapter 5 provides guidance on monitoring the financial performance of an irrigation scheme. The reader is referred to Module 1 for checklists for socio-economic, agro-technical, health and environmental impact assessment (indicators, potential negative impacts and possible mitigation measures).

1.1. Definitions

1.1.1. Monitoring

Monitoring is the collection of information and the use of that information to enable management to assess the progress of implementation and take timely decisions to ensure that progress is maintained according to schedule (Casley and Lury, 1981). Monitoring assesses whether *inputs* are being delivered, are being used as intended and are having the *initial effects* as planned. Monitoring is an internal project or scheme activity, an essential part of good management practice and therefore an integral part of day-to-day management.

The purpose of monitoring is to achieve efficient and effective project or scheme performance by providing feedback to the management at all levels. This enables management to improve operational plans and to take timely corrective action in case of problems. Monitoring is a continuous or regular activity.

1.1.2. Evaluation

Evaluation is a process of determining systematically and objectively the relevance, efficiency, effectiveness and impact of activities in the light of their objectives. It is an organizational process for improving activities still in progress and for aiding management in future planning, programming and decision-making (Casley and Kumar, 1990). Evaluation in the context of rural development programmes is concerned with the assessment of effects, benefits or disbenefits and impacts, on the beneficiaries.

Evaluation concerns are: *who* or *which group* has benefited (or has been adversely affected), by *how much* (compared to the situation before the activity), in *what manner* (directly or indirectly), and *why* (establishing causal relationships between activities and results to the extent possible).

While monitoring is a continuous or regular activity, evaluation is a management task that takes place at critical times of the life of a project or programme (FAO/DFID/ICID, undated). Evaluation can be carried out (FARMESA, 2001):

- during project planning (ex-ante): to assess the potential impact
- during project implementation (ongoing): to evaluate the performance and quality
- at completion (ex-post): to determine the successful completion
- some years after completion (impact): to assess its ultimate impact on development

1.1.3. Indicators

Indicators are a way of measuring progress towards the achievement of the goal, i.e. the targets or standards to be met at each stage. They provide an objective basis for monitoring progress and evaluation of final achievements. A good indicator should define the level of achievement, specifically: *how much?* (quantity), *how well?* (quality), *by when?* (time). This can be demonstrated in the steps below (FAO, 1998):

Step 1 : **Identify indicator**: Small farmers increase rice yields

Step 2 : **Add quantity**: *15 000 men* farmers and *15 000 women* farmers *with land holdings of 2 ha or less* increase their rice yields *by 30%*

Step 3 : **Add quality**: 15 000 men farmers and 15 000 women farmers with land holdings of 2 ha or less increase their rice yields by 30% *while maintaining the same rice quality existing in the 1995 harvest*

Step 4 : **Specify time**: 15 000 men farmers and 15 000 women farmers with land holdings of 2 ha or less increase their rice yields by 30% *between October 1996 and October 1997* while maintaining the same rice quality existing in the 1995 harvest

One set of indicators needs to be formulated to monitor and evaluate the process. These indicators could be, for example, farmers' participation rate, amount of credit repaid, crops grown, training attendance, etc. Another set of indicators needs to be formulated to monitor and evaluate the impact of the programme activities. These indicators could be, for example, yield increase, income gains, environmental effects, changes in workload, relation between investment and benefits, etc. A set of indicators can of course also include both of the above at the same time.

Indicators should disaggregate the information by gender and different socio-economic groups. This means that instead of monitoring the number of farmers, data need to be gathered on the number of male and the number of female farmers from the different socio-economic groups participating. Equally, information on yield increases should be distinguished on the basis of gender of the household head, large versus small farmers, etc. The aim of collecting gender-disaggregated monitoring data is that it may yield valuable information that can lead to measures to improve the programme, especially the performance of specific groups of farmers (FAO, 1998).

Because of the difficulties in collecting information in the field, and because of the related costs, the number of indicators should be kept to the minimum required. A few key indicators should be selected that will adequately fulfill the objective of assessing the conditions of the scheme and identifying causes for failure or success. In this Module some common indicators are given for each type of performance, from which key indicators can be selected.

1.1.4. Parameters

For the calculation of indicators, a certain number of parameters have to be measured in the scheme. The choice of these parameters has to be judicious. They should be easily measurable and re-measurable, at low cost, preferably by the farmers themselves. Some examples of indicators and related parameters are given in Table 1.

1.2. Monitoring and evaluation design and process

The main purpose of M&E is to ensure that the programme or project fulfills the stated goals and objectives within the financial parameters that are set at the beginning.

The objectives of an irrigation scheme can be grouped into six categories (IIMI, 1996; Sally, 1995):

- Production and productivity
- Profitability
- Equity

Table 1
Examples of indicators and related parameters

Indicator	Parameter	Expression
1. Yield Y	– Harvest per season H (kg) – Area cultivated A (ha)	Y = H/A (kg/ha)
2. Gross or net production per quantity of water applied P_gIr or P_nIr	– Harvest H (kg) – Volume of water applied W (m^3)	P_gIr or P_nIr = H/W (kg/m^3)
3. Cropping Intensity CI	– Area harvested per year AH (= sum of the areas harvested per season) (ha) – Area cultivable CA (ha)	CI = AH/CA x 100 (%)
4. Overall project efficiency E_p (see Section 1.7 for more detail)	– Quantity of water entering the conveyance canal V (m^3) – Net irrigation requirements IR_n (m) – Actual irrigated area AIA (ha)	E_p = 100 x (AIA x 10 000 x IR_n)/V (%)

- Rational utilization of the resource
- Sustainability
- 'Non-agricultural' objectives

To these objectives, so-called 'performance indicators' can be attached. For an irrigation scheme, the values of these indicators obtained should be compared with reference values in order to assess the level of performance of the irrigation scheme. For their calculation, performance indicators call upon a certain number of parameters that have to be measured in the scheme (see Section 1.1.4).

In the context of smallholder irrigation schemes, M&E provides data for efficient design, implementation, operation and management of the scheme. It allows for informed decisions to be made by various stakeholders on:

- Operation, maintenance and management of the scheme
- Water management
- Crop production
- Funding and other support services
- Environmental management

From the definitions of monitoring and evaluation given, it is clear that the more clearly the objectives of a programme or project have been stated the more precise the measurement of progress can be. M&E systems must be designed to reflect the achievement of the project objectives as expressed in targets to be met over time. Viewing project objectives as a sequence as shown below will assist in defining the functions of M&E:

a) **Inputs** will be provided or **activities** undertaken that are necessary to achieve agricultural and/or rural development.

   Example: Inputs may be provided in the form of an irrigation system and/or advice, that the beneficiaries are to be encouraged to adopt

b) It is expected that the use of these inputs will result in **outputs** by the project beneficiaries.

   Example: Outputs in the irrigation project may be increased crop production, using recommended agronomic advice

c) These outputs will in turn, generate **effects** amongst the target population, which are the **immediate objectives** or **purpose**

   Example: The effects will be a change in yield levels and/or income

d) Finally, these effects will have an impact on the social and economic life of the community, which is the **long-range objective or goal**.

   Example: As a result of improved incomes, services may develop in the area, providing wider income and employment opportunities.

The process of M&E involves field measurements and analysis of field data from which recommendations for improvements can be made. Basically, the main activities are selection of indicators, data collection and record keeping, data evaluation, identification of problems and development of mitigation measures. For optimal performance, problems should be rectified before negative implications on performance occur.

The responsibilities for irrigation scheme M&E should be clear to all parties from the outset. The responsibility depends on whether an individual farmer, a group of farmers or the government manages the scheme. It is recommended that the responsibility for the monitoring and data collection be designated in by-laws. This is particularly important where several parties jointly manage the scheme. Furthermore, the by-law could state the procedure for the monitoring, such as parameters to be measured, frequency of data collection, measures to be taken to rectify potential problems, etc.

1.3. Use of the logical framework

Project design systems such as the logical framework or log frame allow not only for a viewing of project objectives as a sequence, but also for defining targets to be met over time. A log frame looks like a table (or framework) and aims both to be logical to complete and to present the information on projects in a concise, logical and systematic way (BOND, 2001). A log frame summarizes, for example:

- What the project is trying to achieve
- How it aims to do this
- What is needed to ensure success
- Ways of measuring progress
- Potential problems along the way

The logical framework can be a basis for project M&E. Table 2 gives an example of a model of a log frame.

Table 2
A logical framework (DFID Model) (Source: DFID, 1997)

Objectives	Objectively Verifiable Indicators (OVI)	Means Of Verification (MOV)	Important assumptions
Goal Wider problem the project will help to resolve	Quantitative ways of measuring qualitative ways of judging timed achievement of goal	Cost-effective methods and sources to quantify or assess indicators	**Goal** To supergoal external factors necessary to sustain objectives in the long run
Purpose The immediate impact on the project area or target group, i.e. the change or benefit to be achieved by the project	Quantitative ways of measuring qualitative ways of judging timed achievement of purpose	Cost-effective methods and sources to quantify or assess indicators	**Purpose to goal** External conditions necessary if achieved project purpose is to contribute to reaching project goal
Outputs These are specifically deliverable results expected from the project to attain the purpose	Quantitative ways of measuring qualitative ways of judging timed achievement of outputs	Cost-effective methods and sources to quantify or assess indicators	**Output to purpose** Factors out of project control which, if present, could restrict progress from outputs to achieving project purpose
Activities These are the tasks to be done to produce the outputs	**Inputs** This is a summary of the project budget	Financial report as agreed in grant agreement	**Activity to output** Factors out of project control which, if present, could restrict progress from activities to achieving output

An example of a logical framework for a smallholder irrigation scheme is given in Table 3.

Table 3
A logical framework for a smallholder drag-hose irrigation scheme in Zimbabwe

Narrative summary	Objectively Verifiable Indicators (OVI)	Means Of Verification (MOV)	Important assumptions
Long-range objective – Improved standard of living of the irrigators and the community around the scheme	– 40% of irrigators have brick houses with corrugated iron roofs – 60% of households can afford secondary education for their children	– Yearly household survey – Observation	
Immediate objectives – Increased yields – Increased incomes of smallholder irrigators	– 90% of irrigators increase yields of irrigated crops by 40% compared to dryland yield levels – Mean agricultural income per ha increases by 50%	– AEW records – Farmer records – Yearly household survey – Seasonal survey by project management	– Price of produce remains high
Outputs – Diversification of crop production – Adoption of recommended input levels and other agronomic practices	– 95% of irrigators commit at least 0.4 ha of land to a variety of crops – 60% irrigators adopt the recommended agro-input levels	– Resident AEW records – Farmer records	– No pest outbreak – No electricity cut due to non-payment by some irrigators – No engine breakdown
Inputs/Activities – Selection and training of farmers in irrigated crop production – Scheme equipment installed and tested	– New irrigators trained – Pumping station and pumps installed – Electricity installed – Pipes, valves, fencing installed – Risers, taps, tripods sprinklers supplied – Irrigation system fully operational	– Agritex Irrigation Branch reports – Agritex Crops Branch reports – Baseline survey report	– Inflation rate does not rise beyond 70% making agro-inputs unaffordable

In carrying out M&E, it is important that results are examined sequentially from inputs/activities to outputs to effects/purposes/immediate objectives to impact/goal, as shown in the logical framework (working from the lower end of the table towards the upper end in Tables 2 and 3). There is little point in attempting to do an evaluation of the goal unless we can be sure that the purposes that contribute to it have been achieved. Similarly, at a lower level, there is little point in examining and critically evaluating outputs unless we can be sure that the level of inputs and the mix of activities has been as planned. Each lower-level activity contributes to the achievement of a higher result and the achievement at each level should be examined in turn before moving up to the next highest level. The reason for preferring a bottom-up approach relates to the cost of evaluation. The cost is lowest at the bottom and highest at the top.

Appendix 1 provides an example of indicators to be monitored and evaluated at activity, output, immediate objective and goal level respectively for the smallholder drag-hose sprinkler irrigation scheme in Zimbabwe, for which the logical framework in Table 2 was established.

1.4. Participatory monitoring and evaluation

M&E is vital if governments and aid organizations are to judge whether development efforts have succeeded or failed. Conventionally, this has involved outside experts coming in to measure performance against pre-set indicators, using standardized procedures and tools. Participatory monitoring and evaluation (PM&E) has emerged because of a recognition of the limitations of this conventional approach. This shift in thinking has been prompted by (IDS, 1998):

- ❖ The surge of interest of participatory appraisal and planning a set of new approaches that stress the importance of taking local people's perspectives into account
- ❖ Pressure for greater accountability, especially at a time of scarce resources
- ❖ The shift within organizations, particularly in the private sector, towards reflecting more on their own experiences, and learning from them

PM&E provides an opportunity for development organizations to focus better on their ultimate goal of improving the lives of the poor. By broadening involvement in identifying and analyzing change, a clearer picture can be gained of what is really happening on the ground. It allows people to celebrate successes and learn from failures. For those involved, it can also be a very empowering process, since it puts them in charge, helps develop skills, and shows that their views count.

PM&E differs from conventional monitoring and evaluation approaches in several important ways, as shown in Table 4 (IDS, 1998).

PM&E is based on four broad principles (IDS, 1998):

- ❖ *Participation*, which means opening up the design of the process to include those most directly affected, and agreeing to analyze data together
- ❖ The inclusiveness of PM&E requires *negotiation* to reach agreement about what will be monitored or evaluated, how and when data will be collected and analyzed, what the data actually mean, and how findings will be shared, and action taken
- ❖ This leads to *learning* which becomes the basis for subsequent improvement and corrective action
- ❖ Since the number, role, and skills of stakeholders, the external environment, and other factors change over time, *flexibility* is essential

A wide range of methods and tools have been developed to carry out PM&E. They are not dealt with in this Module, instead the reader is referred to more specialized literature.

Table 4
Conventional versus participatory monitoring and evaluation

Issue	Conventional M&E	Participatory M&E
Who plans and manages the process	Senior managers, outside experts	Local people, project staff, managers and other stakeholders, often helped by a facilitator
Role of 'primary stakeholders' (in our case, the farmers)	Provide information only	Design and adapt the methodology, collect and analyze data, share findings and link them to action
How success is measured	Externally-defined, mainly quantitative indicators	Internally-defined indicators, including more qualitative judgement
Approach	Predetermined	Adaptive

1.5. Why monitor and evaluate smallholder irrigation schemes?

The process of M&E is important to all stakeholders or interested parties in an irrigation scheme. These include the irrigators (plot holders), scheme managers (plot holders, government institutions or both), advisors (extension officers), creditors and financiers of the scheme, be they private (including the plot holders themselves), public or donor agencies. Some of the reasons why M&E is important to the various stakeholders in smallholder irrigation schemes are given below.

❖ Irrigators need M&E information to be able to:
  - Monitor wastage of water and energy and the cost implications
  - Appreciate the need to adopt appropriate agronomic practices and make adjustments in order to improve their performance
  - Compare their yields with those of farmers practicing rainfed cultivation and other irrigators
  - Gauge whether their yield levels are increasing
  - Decide whether to change their cropping programme
  - Compare their incomes with those of farmers practicing rainfed cultivation, other irrigators and their previous incomes under rainfed conditions
  - Gauge whether they are making profit
  - Gauge whether their incomes are increasing in relation to the cost of living
  - Make an assessment as to whether the scheme is sustainable

❖ The scheme management needs M&E information to be able to:
  - Assess the scheme performance
  - Assess whether their services are being accepted and integrated into the farmers' production systems
  - Assess whether the project is reaching its intended clients: do rich community leaders dominate the scheme when, on paper, it was targeted at the poor in the community?
  - Assess whether certain groups, such as female farmers, are accorded the same access as their male counterparts

❖ Advisors (extension officers) need M&E information to be able to:
  - Assess the profitability of the cropping programme they recommended
  - Recommend a more profitable cropping programme
  - Advise on markets for inputs and produce or outputs
  - Advise on possible sources of credit
  - Advise on pricing
  - Devise an effective training programme for irrigators
  - Advise on appropriate agronomic practices to meet certain output targets

❖ Planners and irrigation engineers need M&E information to be able to:
  - Better plan future irrigation development
  - Advise on servicing of equipment, for example if energy consumption suddenly shoots up
  - Advise on energy-saving ways of irrigating
  - Advise on causes of frequent equipment breakdowns
  - Get feedback on the ease, or otherwise, of operation and maintenance of the scheme
  - Get feedback on water management and efficiency of water utilization at the scheme
  - Get feedback on environmental problems affecting the scheme
  - Draw lessons for better scheme planning in the future

❖ Creditors need M&E information to be able to:
  - Assess credit worthiness of irrigators
  - Recover their loans

❖ Government departments need M&E information to be able to decide whether to:
  - Continue funding the scheme
  - Fund similar irrigation schemes in future
  - Supply drought relief to the area
  - Give specific services such as agricultural extension and/or credit, etc.

❖ Donor agencies need M&E information to be able to decide whether to:
  - Continue funding the scheme
  - Fund similar irrigation schemes in future
  - Channel technical support to irrigation institutions or specific schemes

1.6. Development of indicators to monitor and evalute the performance of irrigation schemes

The following six areas of M&E are important for irrigation schemes:

❖ Technical performance

- Agronomic performance
- Financial performance
- Socio-economic performance
- Environmental and health performance
- Managerial performance

To be able to carry out M&E, indicators have to be developed for each of the six areas. As explained in Section 1.1, indicators are variables that help to measure changes in a given situation. They are defined as specific (explicit) and objectively verifiable measures of changes or results brought about by an activity. In other words, indicators are designed to provide a standard against which to measure, assess or show the progress of an activity against stated targets. The performance should be linked to pre-project conditions in order to assess the changes obtained because of the project. Questions to be asked can be, for example: What were the yields of maize before the project and what are they now? What were the living conditions of the farmers before the project and what are they now? What was the incidence of malaria in the past and what is it now? For this, baseline information is required to establish benchmarks with which the changes can be compared. Changes will also be evaluated against what was planned as set out in the project document.

As guidance, some of the indicators related to the six areas of M&E are shown below. Ideally, the indicators are established and selected together with all stakeholders, as explained in Section 1.4.

1.6.1. Technical performance indicators

Technical M&E should be carried out periodically in order to ensure a technically sound and efficient irrigation scheme. The M&E indicators to be measured depend on the irrigation system (surface, sprinkler or localized). Chapters 2, 3 and 4 describe more in detail the monitoring of the technical performance of surface, sprinkler and localized irrigation schemes respectively.

Irrigation systems are designed to provide the water to the crops, that is needed in addition to the effective rainfall and available groundwater. In other words, irrigation provides the remaining part of the crops' water requirements that above-mentioned sources cannot provide. The objective concerning the technical aspects of irrigation is to fulfil the crop's need of water without causing harmful side effects.

Guides for the development of indicators for the technical M&E are:

- Quantity and quality of constructed infrastructure
- Energy consumption rate of equipment
- Pump discharge rate
- Distribution uniformity of irrigation water
- Condition of equipment, canals, reservoirs and other structures
- Condition of land grading
- Frequency of breakdown and repairs of equipment
- Quantity of water used for irrigation
- Irrigation efficiencies

1.6.2. Agronomic performance indicators

Guides for the development of indicators for the agronomic M&E are:

- Type of crops grown and area per crop grown
- Crop quality
- Cropping intensity
- Type, quality and quantity of agricultural inputs used
- Cultural practices used
- Yield levels
- Pests and diseases encountered and control measures
- Timeliness of operations

1.6.3. Financial performance indicators

When assessing financial performance, financial outlays are compared with the original cost tables and budgets to examine whether the financial targets originally agreed upon have been fulfilled and whether in general the financial control is satisfactory. An assessment is made also of how cost over-runs are financed and cost under-runs redeployed. Chapter 5 describes more in detail the monitoring of the financial performance of an irrigation scheme.

Guides for the development of indicators for the financial M&E are:

- Cost of energy
- Cost of water
- Other costs, for example hiring security guard
- Cost of repairs and servicing of equipment, canals and structures (operation & maintenance cost)
- Cost of inputs, for example seed, fertilizer, chemicals, transport
- Prices of produce
- Marketing costs, for example packaging
- Access to credit – source, interest rates, etc.

- Gross margin per crop and per area
- Increase in farmer's income
- Value of Net Present Value (NPV), Benefit/Cost (B/C) ratio, Internal Rate of Return (IRR) compared to the value established during project preparation (see Module 11)

1.6.4. Socio-economic performance indicators

Guides for the development of indicators for the socio-economic M&E are:

- Asset ownership
- Nutritional status of the family
- Change in living conditions
- Ability to pay school fees
- Employment creation
- Advancement of women
- Backward and forward linkages
- Food security status of the area
- Improvement in service provision
- Appropriateness of technology
- Adoption rate of technology

1.6.5. Environmental and health performance indicators

Environmental and health factors have an impact on the short- to long-term performance at field level. Equally important are environmental impacts from irrigation schemes on the external environment and the impact from external factors on the irrigation scheme. Module 1 discusses general environmental and health indicators, potential negative impacts and their mitigation measures.

Guides for the development of indicators for the environmental and health M&E are:

- Changes in water quantity and quality
- Changes in soil salinity, alkalinity, sodicity, acidity and fertility
- Erosion occurrence (soil loss/accumulation)
- Water pollution, for example nitrates in streams
- Presence of water-related diseases, such as malaria and bilharzia, and degree of human infestation, in relation to the status before the introduction of irrigation
- Waterlogging/poor drainage

1.6.6. Managerial performance indicators

Management and entrepreneurial skills are critical for success. A common problem is the lack of long-term thinking. As a result, for example, a frequent mistake is to unconditionally purchase low-priced equipment and spare parts. Unfortunately, poor quality and short durability often characterize such equipment and consequently the repair and maintenance costs increase, and in the end this low-cost purchase might turn out to be the more costly alternative in a long-term perspective. Managerial aspects of smallholder irrigation are discussed in FAO (2000). When assessing the overall managerial performance, questions can be asked such as: Are they able to supervise the scheme activities effectively? Have they established the necessary linkages with governmental agencies and private organizations? Are they task-oriented? Are the human and material resources properly utilized?

Guides for the development of indicators for the managerial M&E are:

- Management structures, roles, responsibilities and skills
- Knowledge management and training at all levels
- Conflict resolution
- Farmer organization and management ability (self-management)

1.7. Examples of indicators to monitor the technical and agronomic performance of smallholder irrigation schemes

Within the framework of FAO's Special Programme for Food Security (SPFS), indicators for monitoring the performance of smallholder irrigation schemes during the demonstration phase have been developed. As an example, the ones for measuring the technical and agronomic performance are copied below (FAO/DFID/ICID, undated).

Objective 1: To intensify and increase agricultural production on irrigated land

1st Indicator: Increase in average production

This indicator will measure the average increase that is being obtained in the demonstration phase as compared to the national averages and/or the production averages in the project area before the demonstration phase. The required data for its application are:

	Project average (kg)	National average (kg)	Increase or decrease (kg)	Percentage increase CP
Crop 1	P(1)	A(1)	P(1) - A(1)	100 x [P(1)-A(1)]/A(1)
Crop 2	P(2)	A(2)	P(2) - A(2)	100 x [P(2)-A(2)]/A(2)
Crop N	P(N)	A(N)	P(N) - A(N)	100 x [P(N)-A(N)]/A(N)

The average percentage of increase or decrease in production (CP) for all the crops is the indicator proposed for agricultural production:

Equation 1

$$CP = 100 \times \sum_{1}^{N} \left[\frac{P(N) - A(N)}{A(N)} \right]^{\frac{1}{N}}$$

Where:

CP = Crop production increase or decrease (percentage)

P = Project crop production average

A = National crop production average

N = Number of crops

2nd Indicator: Cropping intensity

This indicator will provide an evaluation as to what extent second and third crops may take place in a year. The indicator (CI) is defined as follows:

Equation 2

$$CI = \frac{A(C1) + B(C2) + C(C3)}{CA}$$

Where:

A(C1) = Total area harvested in the first season

B(C2) = Total area harvested in the second season

C(C3) = Total area harvested in the third season

CA = Cultivable area

3rd Indicator: Increase in planted area

The intensive use of irrigation water is a good indication that the change towards an intensive agriculture is taking place in an effective manner. Therefore, this indicator aims at evaluating to what extent this change is taking place. For this purpose the increase in planted area from one season to the next (expressed in percentage) is a relevant indicator (IPA):

Equation 3

$$IPA = 100 \times \frac{[AP(S1) - AP(S2)]}{AP(S2)}$$

Where:

IPA = Increase in planted area (percentage)

AP(S1) = Area planted during the current season

AP(S2) = Area planted during the past season

In humid climates, the water flow available is considerably greater during the wet season than during the dry season, therefore the AP(S1) and AP(S2) are considerably greater in the wet season than in the dry season. It is therefore recommended that the IPA be calculated separately for the wet season and the dry season.

Objective 2: To improve performance of existing schemes through on-farm irrigation technology

4th Indicator: Overall irrigation efficiency

Overall irrigation efficiency is a value that varies constantly through the year and is affected by the efficiency of the actual water distribution and farmers' ability to apply water effectively. Still, it is always a good reference for how efficiently irrigation water is utilized.

The following indicator is proposed:

Equation 4

$$OIE = 100 \times \frac{(AIA \times 10\,000 \times CWR)}{(FI \times 3\,600 \times 30 \times N)}$$

Where:

OIE = Overall irrigation efficiency (percentage)

AIA = Actually irrigated area during peak month (ha)

CWR = Crop water or net irrigation requirement for the peak month (mm/month)

FI = Average flow of main intake in the peak month (l/s)

N = Number of hours of irrigation per day

The above indicator will give the efficiency of the water use in the peak month. It is desirable to determine it for every month of the year in order to have an indication of the variations of the OIE along the year. This indicator will be particularly relevant when rehabilitation and improvements works have been undertaken, as the greater physical efficiency of the system must be reflected in higher values of OIE.

5th Indicator: Operation and maintenance costs

Operation and maintenance costs referred to the irrigated hectares are themselves already a good indicator of how efficiently the financial resources are being utilized:

Equation 5

$$OM = \frac{TC}{AIA}$$

Where:

OM = Operation and maintenance costs per ha

TC = Total annual costs incurred in O&M

AIA = Actually irrigated area (ha)

Once O&M costs have been determined, one can get an indication of the farmers' capacity to pay them by referring these costs to the farmers' income through the following equation:

Equation 6

$$IFI = 100 \times \frac{TC}{FI}$$

Where:

IFI = Impact of O&M costs in farmer's income (percentage)

TC = Total annual costs incurred in O&M

FI = Farmers' income (assessed on the bases of a representative sample)

For values of IFI greater than 10%, difficulties can be expected in the collection of fees.

Objective 3: To demonstrate technologies and methods of irrigation expansion

6th Indicator: Percentage of farmers that adopted the irrigation technology

A simple indicator is the percentage of farmers over the total participants in the demonstration area that have adopted the technological package:

Equation 7

$$AT = 100 \times \frac{FAT}{TNF}$$

Where:

AT = Farmers that adopted the technology (percentage)

FAT = Number of farmers that adopted proposed technology

TNF = Total number of farmers of the demonstration area

The apparent simplicity of this indicator is constrained by the fact that is not so simple to clearly determine whether or not a farmer has adopted a technology. As the technological packages will likely be different in each country or demonstration area the criteria for determining the adoption by farmers must be developed locally.

7th Indicator: Water use at farm level

One important aspect of the demonstration phase is the efficient application of water at farm level. By this term we mean that water is applied at suitable intervals (which will depend on the technology used) and the amounts necessary to satisfy the crop water requirements. If irrigation water is not applied with a minimum of technical bases, it is clear that the intended increases in crop production will not be reached. Therefore, it is of great importance to document how irrigation water is applied.

As the number of farmers participating in a scheme can be relatively large, it will be practically impossible to monitor the water use by every farmer as this will be time consuming and costly. The only feasible way will be to do it on sample bases. The sample should be statistically representative, but this is again costly when the number of farmers is large.

For every farmer included in the sample the following records should be kept:

- Number of irrigations, intervals and volumes to be applied to each crop. This should be calculated according to the soil's characteristics and crop water requirements. For this purpose the CROPWAT computer programme is a recommended tool (FAO, 1992) (see also Module 4).
- Actual amounts, intervals (dates) and number of irrigations applied by the farmer concerned should be recorded. Here again the CROPWAT programme will be useful not only to keep these records but also to assess the actual efficiency achieved by the farmer (Module 4).
- Assess how closely the farmers have followed the recommended irrigation schedule. For this purpose three variables must be determined:
  - the relation between the total amount actually applied and the calculated amount
  - the relation between the amount of water applied and calculated for each irrigation
  - the relation between the number of irrigations applied and the calculated number

These three sub-indicators will give a view of how effectively farmers adhered to the recommended schedule. However, this is an expensive indicator to determin.

8th Indicator: Farm irrigation efficiency

The determination of the irrigation schedules mentioned for the 7th indicator implies the application of the farmer's efficiency in applying the irrigation water. The tendency is often to apply this figure based on empirical or personal experience. In the field, it can be carried out following standard procedures (FAO, 1992; other relevant manuals). It will be useful to determine these efficiencies yearly and monitor any progress made by farmers. However, as with the previous indicator it is an expensive indicator to be determined. More information on irrigation efficiencies is given in Module 1.

Objective 4: To improve the capacity of staff and local community for self-management and develop institutional base for irrigation expansion

9th Indicator: Training activities carried out

The number of training activities that have been carried out, the type of activity, its duration and number of participants should be reported here. The number of participants should be related to this potential number to have an indication of what percentage has been covered.

10th Indicator: Self-management

The aim of this indicator will be to assess the degree of self-management that has been achieved. The underlying assumption is that an effort was made to establish a WUA, and through the criteria proposed below the degree of self-management is assessed.

The WUA functions satisfactorily and 80-90% of the water rates are collected	Fully independent
The WUA is established, the water distribution is effected by farmers at tertiary level but secondary canals and upward are operated by government staff, only minor maintenance works are carried out by farmers, 65-80% of water rates are collected	Semi-independent
The WUA has been established but acts mainly as a consultative and information body. Decisions are still made by government officials, 50-65% of water rates are effectively collected	Low degree of independence
The WUA has been established on paper but none of its tasks are carried out in practice	Dependent, it needs explanation
The WUA has not been established	Needs justification

Chapter 2
Monitoring the technical performance of a surface irrigation scheme

This chapter should be read together with Module 1 and Module 7, in which the technical parameters and their range for optimal performance are described. Detailed theory behind the equations included in this chapter is also provided in these modules and in FAO (1989). This chapter will focus on hands-on activities in the M&E process.

According to FAO (1989), the most common field measurements to carry out during monitoring and evaluating surface irrigation systems are:

❖ Field topography

❖ Soil moisture in the field

❖ Water distribution and application

2.1. Field topography

Topographic surveys should be carried out periodically, on an annual or bi-annual basis, since the field levels change because of cultivation practices, especially ploughing. Periodic (annual or bi-annual) land grading is recommended for surface irrigation, in order to maintain the field topography as close as possible to the one in the original design.

If the land slope has changed significantly or is uneven, it may affect the uniformity of water application. This could lead to waterlogging in some areas, for example in depressions, and to water stress in others. Waterlogging causes drowning of crop roots, which results in decrease of crop yields. In cases where the water level reaches the surface it might create puddles of still-standing water, which form favourable breeding sites for waterborne diseases. Additionally, the design irrigation efficiency would be affected negatively and the estimated water requirements at the planning stage may no longer be met by the available water resources. Inappropriate slopes and/or uneven land grades may result in erosion and render the originally selected stream flow inappropriate.

Generally, topographic surveys should be carried out on grid points 20-30 m apart. However, the grid layout depends on the slope and the uniformity of the land. Where the land is steep and irregular, the grid points should be moved closer to each other. Recommended topography and land slopes are discussed in Module 7.

2.2. Soil moisture in the field

The total available water for plant use in the root zone is commonly called soil moisture. The available soil moisture is the difference between field capacity (FC) and permanent wilting point (PWP) (Module 4). FC is the maximum water a soil type can hold. PWP is when all the freely available water is depleted and the soil is 'dry'. When the water content is close to the FC the plant needs to use very little energy for the water uptake. The more water depleted from the soil, the more energy the plant has to waste for the water uptake, thereby creating a water stress situation. Some crops are more sensitive to soil moisture depletion than others or, in other words, they are more susceptible to water stress than others. Therefore, the allowable depletion is different for different crops and different soil types. Allowable soil moisture depletion levels for different crops are given Module 4.

Having more water in the soil than it can hold (i.e. more than FC), means that the soil is waterlogged. In a waterlogged situation the roots are standing in water. This will damage the plant (except rice), given that the roots not only need water but also air.

Soil moisture measurements should be taken periodically during the growing season. The results can be used to determine when the next irrigation should take place and what water depth to apply. After irrigation the results can be used to evaluate whether the correct depth of water was added to the soil or to assess waterlogging or water stress.

Soil moisture content can be optimized through the following actions:

❖ Regulation of water application through good irrigation schedules, in order to avoid either over-watering or under-watering,

❖ Land levelling to prevent poor distribution uniformity resulting in water stress in some areas and waterlogging in others

❖ Installation and maintenance of an adequate drainage system

❖ Use of lined canals or pipes to prevent seepage

Several soil moisture measurement methods can be employed. These include soil feel, gravimetric soil moisture

Table 5
Guidelines for evaluating soil moisture by feel

Available soil moisture	Soil moisture condition	Texture: Coarse fine sand; Loamy fine sand	Texture: Moderate coarse sandy loam; Fine sandy loam	Texture: Medium sandy clay loam; Loam; Silt loam	Texture: Fine clay loam; Silty clay loam
0-25	Dry	Loose. Will hold together if not disturbed. Loose sand grains on fingers	Forms a very weak ball*. Aggregated soil grains break away easily from ball	Soil aggregations break away easily. No moisture staining on fingers. Clods crumble with applied pressure	Soil aggregations easily separate. Clods are hard to crumble with applied pressure
25-50	Slightly moist	Forms a very weak ball with well-defined marks. Light coating of loose and aggregated sand grains remains on fingers	Forms a weak ball with defined finger marks. Darkened . colour. No water staining on fingers	Forms a weak ball with rough surfaces. No water staining on fingers. Few aggregated soil grains break away	Forms a weak ball. Very few soil aggregations break away. No water stains. Clods flatten with applied pressure
50-75	Moist	Forms a weak ball with loose and aggregated sand grains remaining on fingers. Darkened colour. Heavy water staining on fingers. Will not form into a ribbon**	Forms a ball with defined finger marks. Very light soil water staining on fingers. Darkened colour. Will not slick	Forms a ball. Very light water staining. Darkened colour. Pliable. Forms a weak ribbon between thumb and forefinger	Forms a smooth ball with defined finger marks. Light soil water staining on fingers. Ribbons form with thumb and forefinger .
75-100	Wet	Forms a weak ball. Loose and aggregated sand grains remain on fingers. Darkened colour. Heavy water staining on fingers. Will not ribbon	Forms a ball with wet outline left on hand. Light to medium water staining on fingers. Makes a weak ribbon between thumb and forefinger	Forms a ball with well-defined finger marks. Light to heavy soil water coating on fingers. Ribbons form	Forms a ball. Uneven medium to heavy soil water coating on fingers. Ribbon forms easily between thumb and forefinger
Field Capacity (100)	Wet	Forms a weak ball. Light to heavy soil-water coating on fingers. Wet outline of soft ball remains on . hand	Forms a soft ball. Free water appears briefly on surface after squeezing or shaking. Medium to heavy soil water coating on . fingers	Forms a soft ball. Free water appears briefly on soil surface after squeezing or shaking. Medium to heavy soil water coating on fingers	Forms a soft ball. Free water appears on soil surface after squeezing or shaking. Thick soil water coating on fingers. Slick and sticky

** A 'ball' is formed by squeezing a soil sample firmly in one's hand.*

***A 'ribbon' is formed by squeezing soil between one's thumb and forefinger.*

determination and the use of the neutron probe (Module 4). The first method is the cheapest, since it does not require any equipment. It is less accurate than the others, since it is subjective. However, it is very common among surface irrigators in the region. This method involves squeezing a handful of soil and comparing it with general guidelines provided in Table 5.

If the soil water content is more than the FC of the soil, free water can be observed in the soil. In this case, there is risk of waterlogging. Where the soil moisture depletion is more than for example 50 % (depending on the crop), risk prevails for water stress.

2.3. Water distribution and application

2.3.1. Stream size and water intake opportunity time

Inappropriate stream size and water intake opportunity time can result in problems like erosion, water wastage and/or water stress. Advance and recession tests should be carried out periodically in order to ensure the best combinations of stream size and water intake opportunity time for the existing furrows, borders or basins, crops and growing seasons.

Methods for testing infiltration, advance, recession, stream size and water intake opportunity time are discussed in detail in Module 7 and briefly in Section 2.3.3 below.

2.3.2. Water distribution uniformity

The most important technical performance indicators of surface irrigation systems are distribution uniformity and application efficiency (see Section 2.3.3). Field measurements of these parameters for a single irrigation occasion is not sufficient, instead they should be repeated at times when the soil, crop or operational characteristics have sufficiently changed to reveal all facets of the irrigation system.

Poor distribution uniformity of the applied water might lead to waterlogged root zones and increased soil salinity in some areas and insufficient water supply in others. It can be rectified by:

- Adjusting the stream flow in order to ensure the best combinations of stream flow for the existing furrows, borders or basins, crops and growing seasons and different soil types
- Adjusting the land slope through land levelling

Distribution uniformity (DU) indicates the distribution of water over the field being irrigated. This is a parameter similar to the Christiansen coefficient used as a measure of application efficiency. FAO (1989) proposes that the DU for surface irrigation should be defined as:

Equation 8

$$DU = \frac{\text{average depth of water applied in the low quarter end of the field} \times 100}{\text{average depth of water applied}}$$

It also suggests an 'absolute distribution uniformity' as being:

Equation 9

$$DU_a = \frac{\text{minimum depth of water applied}}{\text{average depth of water applied}} \times 100$$

Either of these two equations could be used, depending on the preference of the person carrying out the monitoring. In view of the extensive soil moisture measurements required for the assessment of the DU, these tests are done every few years. An example on assessing distribution uniformity and application efficiency is given in the following section.

2.3.3. Irrigation efficiencies

A detailed description of the different types of irrigation efficiencies (field application, field canal, farm, conveyance, distribution system, overall) is given in Module 1.

Field application efficiency (E_a)

The objective of irrigation is to fulfil the crop's need of water without causing harmful side effects. Poor field application efficiency (E_a) or, in other words, excessive irrigation results in one or several of the following harmful consequences: water wastage, waterlogged root zones, increase in soil salinity and increase in pumping costs.

The major on-field water losses that occur during water application are deep percolation below the root zone and tail-water or runoff. Deep percolation is the water lost through infiltration of water beyond the root zone depth. High deep percolation losses cause waterlogging due to localized rise of the water table. In addition, plant nutrients and other chemicals of benefit to crops can be leached beyond the root zone. Depending on the chemicals leached, groundwater may be contaminated. Runoff is the water loss that occurs when irrigation water flows over the surface beyond the irrigated field. Runoff can cause erosion and increased salinity and siltation in downstream areas, such as rivers and other hydraulic structures. It can also cause waterlogging.

Two parameters are required in order to estimate the field application efficiency E_a:

- Estimates of the net irrigation requirement (IR_n) for the particular site and crop stage
- The amount of water applied to the field (W)

Module 4 provides the means for estimating IR_n. The average volume of water applied to the field can be measured at the head of the furrow, border or basin. This is the amount of water discharged by the siphon, spile or other type of turnout over a given time. When these figures are known, E_a can be determined using the equations below, where either volumes or depths of water can be used:

Equation 10a

$$E_a = \frac{IR_n\ (m^3)}{W\ (m^3)} \times 100$$

Equation 10b

$$E_a = \frac{IR_n\ (mm)}{W\ (mm)} \times 100$$

The estimated IR_n should correspond to the irrigation frequency of the particular location, crop and crop stage. E_a gives an indication of the losses since it shows the fraction of the water that is applied to the soil root zone, which is potentially accessible to evaporation and transpiration. It does not, however, indicate the distribution uniformity or the adequacy of irrigation.

In the example below, borderstrip irrigation will be used to illustrate the process of determining the performance parameters of a surface irrigation system and the causes of water losses in a block. The following data were collected:

- Area of the block under consideration: 1.75 ha
- Net irrigation depth IR_n: 45 mm
- Discharge at the inlet to the field canal from the conveyance canal: 75 l/sec
- Discharge at the head of the borderstrip: 65.3 l/sec
- Actual irrigation time in field canal: 7 hours

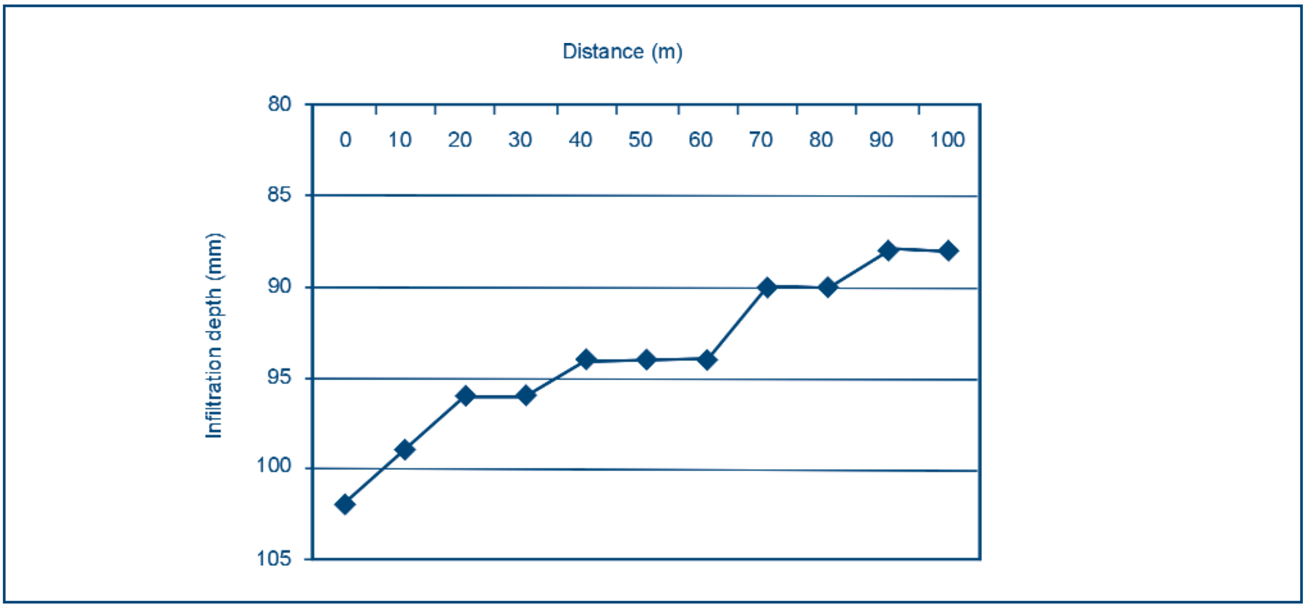
Since the border was dyked at the end, no runoff measurements were needed.

Wooden pegs are set out at 10 m intervals along the length of the borderstrip. Irrigation should be carried out with the same flow as the farmers use. The flow of water at the top of the field should be measured using measuring devices such as flumes and weirs. In the absence of these, buckets can be used. One should ensure that the water enters into the bucket at the same position as it enters the field during normal irrigation. Water should also be applied on the borderstrips at both sides next to the test borderstrip in such way that they will act as buffers. However, if in reality the farmer irrigates only one border at a time, then no water should be applied to the borderstrips at both sides. The flow should be timed, so that the volume can be calculated. The time taken by the water to advance along the borderstrip length should be recorded and so should the recession. The infiltration, i.e. the subsurface profile, should be computed at every peg. This profile is determined by adding the water depth on the surface to the profile developed during the advance phase. Table 6 shows evaluation data of a borderstrip test and the graph shows the data plotted as infiltration (column 7) versus distance along the border (column 1).

Table 6
Borderstrip water advance and recession data

Distance (m) (1)	Advance time (min) clock (2)	Advance time (min) elapsed (3)	Recession time (min) clock (4)	Recession time (min) elapsed (5)	Contact time (min) (6) = (5) - (3)	Water applied (mm) * (7)
0	07.00	0	15.20	500	500	102
10	07.30	30	15.30	510	480	99
20	08.15	75	16.00	540	465	96
30	09.00	120	16.45	585	465	96
40	10.00	180	17.34	634	454	94
50	11.10	250	18.38	698	448	94
60	12.15	315	19.43	763	448	94
70	13.20	380	20.24	804	424	90
80	14.30	450	21.30	870	420	90
90	15.45	525	22.35	935	410	88
100	17.00	600	23.50	1010	410	88

* *Obtained from the graph*



Example 1

What is the distribution uniformity in the field for the borderstrip described above?

Using the depths infiltrated at each peg at the downstream quarter end of the field (between 70-100 m approximately from Table 6), the average depth of water applied at this lower quarter end is:

$$\frac{88 + 88 + 90 + 90}{4} = 89 \text{ mm}$$

Using Equation 8:

$$DU = \frac{89}{94} \times 100 = 94.7\%$$

The absolute distribution uniformity (DU_a) is calculated using Equation 9:

$$DU_a = \frac{88}{94} \times 100 = 93.6\%$$

Example 2

What is the field application efficiency for the borderstrip described above?

Based on Table 6, the average depth of water applied to the field is 94 mm. Therefore the average volume of water applied to the field is:

$$94 \times 1.75 \times 10 = 1\,645 \text{ m}^3$$

The net depth of water IR_n that has to be applied to the root zone is 45 mm, which gives the volume of water required by crops:

$$1.75 \text{ ha} \times 45 \text{ mm} \times 10 = 787.5 \text{ m}^3$$

Either Equation 10a or 10b can be used to calculate the application efficiency as follows:

$$E_a = \frac{787.5}{1\,645} \times 100 = 48\% \quad \text{or} \quad E_a = \frac{45}{94} \times 100 = 48\%$$

Example 1 and 2 show that this irrigation system has a high distribution uniformity and a low field application efficiency. The reason for the high distribution uniformity is that all points along the border have been more than adequately irrigated. However, this causes high deep percolation losses. In order to minimize deep percolation losses, the flow should either be cut off earlier or reduced. The decision on the correct flow can be reached once the same test is done using different stream flows (see Module 7).

Field canal efficiency (E_b)

The field canal efficiency (E_b) is an indication of the losses that occur in these canals, from the outlet of the conveyance canals to the inlet of the field. E_b is defined through the following equation:

Equation 11

$$E_b = \frac{\text{water received at the field}}{\text{water received at the block of fields}} \times 100\%$$

As will be seen in Example 3, losses are fairly low in field canals that are concrete-lined and fairly new with only minor leaks at the joints. However, for unlined canals these losses can be very high, especially when weeds are present in the canals. High losses would also be expected for older lined canals with cracks and weed growth.

Example 3

What is the field canal efficiency in the borderstrip irrigation example?

The measuring device at the intake to the block shows a discharge of 75 l/sec for 7 hours. The measuring device at the field inlet showed a discharge of 65.3 l/sec.

Thus, the water losses in the canal are (75 - 65.3) = 9.7 l/sec.

$$E_b = \frac{65.3}{75} \times 100 = 87\%$$

Conveyance efficiency (E_c)

E_c is defined through the following equation:

Equation 12

$$E_c = \frac{\text{water received at the block}}{\text{water diverted from the headwork}} \times 100\%$$

Example 4

The measuring device at the outlet of the dam of our example provides a discharge of 100 l/sec. What is the conveyance efficiency?

Since the intake of the block was 75 l/sec, this means that:

$$E_c = \frac{75}{100} \times 100 = 75\%$$

Project efficiency (E_p)

This is the overall efficiency of the irrigation scheme:

Equation 13

$$E_p = E_c \times E_b \times E_a$$

Example 5

What is the overall irrigation efficiency of our example?

E_p = 0.75 x 0.87 x 0.48 = 0.31 or 31%

Conclusion

Looking at Example 5, it transpires that over two thirds (69%) of the water is lost in the process of conveyance, distribution and application. Considering that a major cost of a scheme is the construction of a dam and that the greater the area that can be irrigated from the water stored in the dam the more economically viable the scheme, these results give the opportunity to consider various options:

- Improve E_a through the selection of a better stream flow onto the borderstrip
- Improve E_a through periodic land grading
- Improve E_b by sealing the joints of the field canals or by lining the earthen canals
- Improve E_c by lining the conveyance canal

Chapter 3
Monitoring the technical performance of a sprinkler irrigation scheme

This chapter should be read together with Module 1 and Module 8, in which the technical parameters and their range for optimal performance are described.

The most common field measurements to carry out during monitoring and evaluating sprinkler irrigation systems are:

- Soil moisture in the field
- Pressure and discharge in the sprinkler system
- Irrigation efficiencies

3.1. Soil moisture in the field

The importance of soil moisture measurement was explained in Section 2.2. In sprinkler irrigation schemes, the soil moisture content can be optimized through the regulation of water application through appropriate operation pressure and good irrigation schedules.

Several soil moisture measurement methods can be employed, as mentioned in Section 2.2, wherein the soil feel method was described. In this section the gravimetric soil moisture determination is described. Either of the other two methods is also applicable to sprinkler irrigation systems. The objective of this monitoring tool is to establish whether the replenishment of the soil moisture through irrigation is adhering to the designed allowable depletion level.

Through the soils surveys done during the feasibility study the available moisture (by volume) and the bulk density were determined (Module 2). At the monitoring stage the soil moisture content just before irrigation will need to be determined, for example through the gravimetric method. For this purpose, a sample of soil of about 100-200 grams is taken and sealed in an aluminium or stainless steel container. The sample is weighed in the container and put into an oven for 24 hours at 105°C with the cover of the container removed. The dry soil and the container are then weighed again. The difference equals the amount of moisture held in the soil just before irrigation. The following expression provides the moisture content in decimal form:

Equation 14

$$SM_{a(w)} = \frac{\text{wet weight - dry weight}}{\text{dry weight}}$$

Using the same bulk density (BD) as determined during the initial soil surveys, the moisture can be expressed on volumetric basis:

Equation 15

$$SM_{a(v)} = SM_{a(w)} \times BD$$

Where:

$SM_{a(v)}$ = Available soil moisture by volume

$SM_{a(w)}$ = Available soil moisture by weight

BD = Bulk density

For a clearer picture of the concept of volume percent it is noteworthy that 1 mm of water over an area of 1 ha amounts to a volume of water of 10 m^3 (= $10^{-3} \times 10^4$).

3.2. Pressure and discharge in the sprinkler system

One should actually measure the pressure and discharge of the sprinkler. During sprinkler irrigation design, say the allowable pressure variation within one hydraulic unit was established to 20% (see Module 8). Therefore, in the field one can measure the actual sprinkler operating pressures of individual sprinklers within a hydraulic unit in order to determine whether they are conform to this condition. If not, the sprinklers are not applying water as envisaged in the design. This may be due to causes such as wear of different parts of the sprinklers or to the fact that some farmers may be using other sprinklers than those envisaged in the design. Moreover, there may be cases where the sprinklers do not fulfil the manufacturer's specifications. In other cases, the pressure variation may be due to poor design.

Nozzles erode during operation, predominantly because of the abrasive action of sand in the water. After a longer time of operation, nozzles might have been worn to such an extent that the enlarged openings have lead to pressure drops and decreased distribution uniformity. Hence, pressure and discharge tests should be carried out every second year. Any change in the discharge and pressure of sprinklers would shift the operation of the pumping unit to a different point on the performance curve, which may affect the power requirements. In such a case, the existing motor would be overloaded and at times burn out.

Example 6

From initial soil survey:

Available moisture by weight = 0.085 or 8.5% or 85 mm/m
Available moisture by volume = 0.119 or 11.9%
Bulk density (BD) = 1.4 g/cm³
Desirable depletion = 0.5 or 50%

From soil sampling at monitoring just before irrigation:

Wet weight = 215 grams
Dry weight = 210 grams

What is the soil moisture depletion between two irrigations?

Soil moisture on a weight basis is: $SM_{a(w)} = \frac{215 - 210}{210} = 0.0238$

The soil moisture on a volumetric basis is: $SM_{a(v)} = 0.02378 \times 1.4 = 0.0333$

The depletion is: $\frac{0.085 - 0.0238}{0.085} = 0.72$ or $\frac{0.119 - 0.0333}{0.119} = 0.72$, which is 72%

These results show that the crop is allowed by the farmers to deplete the soil moisture to levels well above the desirable depletion of 50%. Hence the crop is stressed. A change in the irrigation schedule is needed.

In order to avoid these problems, nozzles should be replaced from time to time. When surface water is used through the sprinklers, it is recommended that nozzles be replaced every year or every other year depending on the degree of wear. It should also be ensured that the nozzles conform to the design. All farmers should use the sprinklers that were stipulated in the design. In some cases, smallholders are tempted to purchase large size nozzle sprinklers when they replace the old ones, due to the fact that they discharge more water. This, however, leads to pressure drops, in other words this leads to poorer water distribution. In some cases the pressure at which the sprinklers are operating may be either too high or too low. In those cases one has to correct the pressure at the pressure-regulating device for that unit or for the whole irrigation scheme. In addition, one should monitor the quality of water and ensure that efficient O&M is taken place, such as flushing of the sprinkler pipes (see Module 8).

After a number of years, the seals of the sprinklers wear out and substantial losses of water occur before the water reaches the nozzle. Under these circumstances the worn parts should be replaced. This is usually done at the dealer's workshop. This also provides the opportunity to overhaul the sprinkler and also adjust the tension of the spring or replace the spring.

The nozzle pressure is defined as the pitot-static pressure at the vena-contracta of the jet from the main (largest) nozzle. It is measured using a pitot tube attached to the pressure gauge. The sprinkler pressure is tested at the beginning, the middle, and at the end of the hydraulic unit and compliance with the allowable pressure variation checked. Using a bucket, a stop watch, a volumetric cylinder and a short hose (2 m), the flow rate of the sprinkler can also be tested and compared to the original performance data that were obtained during the commissioning of the system. Derivations from the original data would give indications on possible problems to be rectified. It could be that reduced sprinkler pressure and/or discharge is caused by simultanously operating more sprinklers than the number envisaged by the design. Another possibility could be that there are leakages in the system, including the sprinkler itself. Laboratory tests can be very useful in establishing the current performance of an average sprinkler brought from the field and recommending measures to improve it.

3.3. Irrigation efficiences

The justification for irrigation efficiencies as indicators to monitor the technical performance, as given in Section 2.3.3 for surface irrigation, is also valid for sprinkler irrigation.

Using the IR_n estimates for the particular site, crops and stage of growth and the amount of water applied per irrigation, the E_a can be estimated as explained in Section 2.3.3.

In the case of sprinkler irrigation, by measuring the flow as described earlier, the average sprinkler flow is calculated. Using this data, the IR_n estimates and the duration of irrigation, the E_a is estimated.

As far as the E_b, E_c and E_p are concerned, the same principles described in Section 2.3.3 apply here also, as long as water meters are installed at strategic positions in the irrigation scheme. However, in view of the costs, in practice only a main water meter is installed at the pump outlet. Hence, a combined E_c and E_b efficiency, called distribution system efficiency E_d (see Module 1), can be estimated using the reading of the water meter at the beginning and at the end of an irrigation, the number of sprinklers in operation, the average sprinkler flow and the duration of irrigation.

Example 7

The average flow of one sprinkler operating at 35 meters head and spaced at 12 m x 12 m was found to be 0.6 m^3/hrs. Irrigation is practiced for 11 hours every 6 days and the corresponding IR_n at peak demand is 30 mm. What is the field application efficiency?

For the 12 x 12 = 144 m^2 commanded by one sprinkler:

IR_n = 0.030 x 144 = 4.32 m^3

The sprinkler will provide 6.6 m^3 (0.6 x 11) of water to this area.

$$E_a = \frac{4.32}{6.6} = 0.65 \text{ or } 65\%$$

While this is within acceptable limits, after comparing it with the design efficiency of 75% it is low.

The design was based on irrigation for 6 days a week to cover the water requirements of 7 days operating for 11 hours per shift. By adjusting the irrigation depth and frequency, what would be the E_a?

IR_n = 0.035 x 144 = 5.04 m^3

$$Ea = \frac{5.04}{6.6} = 0.76 \text{ or } 76\%$$

This will reduce the energy cost by about 14%.

Alternatively the farmers can be requested to operate the system for 10 hours instead of 11 and maintain the 6-day frequency.

$$Ea = \frac{4.32}{6} = 0.72 \text{ or } 72\%$$

This will result in about a 10% saving on the energy cost.

Example 8

The sprinkler flow was tested and found to be 0.6 m^3/hrs. Over the 10 hour period of irrigation with 100 sprinklers, the water meter at the pump outlet has shown that 65 m^3 of water was pumped. What is the E_d?

$$Ed = \frac{0.06 \times 100}{65} = 0.92 \text{ or } 92\%$$

This indicates that some leaks in the piped network need repairing. Assuming that the E_a estimated earlier was found to be 0.65, the project efficiency would be:

E_p = 0.65 x 0.92 = 0.6 or 60%

This is relatively low for sprinkler systems. Measures to improve the project efficiency were proposed earlier under the discussion of E_a and E_d.

Chapter 4
Monitoring the technical performance of a localized irrigation scheme

This chapter should be read together with Module 1 and Module 9, in which the technical parameters and their range for optimal performance are described.

The most common field measurements to carry out during monitoring and evaluating localized irrigation systems are:

- ❖ Soil moisture in the field
- ❖ Emission uniformity
- ❖ Irrigation efficiencies

4.1. Soil moisture in the field

Localized irrigation systems are known for very frequent applications of small amounts of water. As a rule, irrigation is practiced at almost no moisture depletion. The frequency of irrigation for shallow-rooted crops like vegetables is almost daily and for tree crops it is every 2-3 days.

This very frequent application of small amounts of water, combined with very frequent application of water-soluble fertilizers, is the main reason for the higher yields obtained with these systems. Ideally, farmers should have tensiometers installed in their fields and irrigate when the tension in the soils reaches 15-30 centibars (see Module 4). However for smallholders, where several crops are grown at the same time, irrigation schedules based on CROPWAT are used. In these cases periodic check of the soil moisture by irrigation technicians and/or extension staff is required for refinement and adjustment of the schedules.

Unfortunately, the methods described in Chapters 2 (soil feel method) and 3 (gravimetric method) are not suitable for localized irrigation systems in view of the limited wetted area of the soil and the need to irrigate around field capacity. For localized systems, the quick-probe tensiometers are ideal for measuring the soil moisture (see Module 4). These are portable tensiometers with a steel probe on the end of which a small ceramic cap is attached. They can be inserted at the root zone depth and within 1-2 minutes the soil moisture tension can be read on the vacuum gauge. Periodic checks by the extension staff using this instrument can help adjust and refine the irrigation schedule of smallholders.

4.2. Emission uniformity

One major disadvantage of localized irrigation systems is that they are prone to clogging because of the small size of the aperture of the emitters. While means are provided in the system to remove impurities from the water, not all impurities are removed. Among the recommendations for the operation and maintenance of these schemes is the periodic review of the flow using a flow meter or a water meter, which is usually installed after the filters, and the use of chemigation to clean the system.

A periodic check of the uniformity of water application can also provide the means of checking the effectiveness of cleaning the system, so that the delivery of nutrients and water to the crop is uniformly provided.

A field test of emission uniformity requires a large amount of field data and is a time-consuming process, if the basic equation from Keller and Bliesner (1990) is to be correctly used:

Equation 15

$$EU' = \frac{q_n'}{q_a}$$

Where:

EU'	=	Field test emission uniformity (percentage)
q_n'	=	Average rate of discharge of the lowest one-fourth of the field data emitter discharge reading (lph)
q_a	=	Average discharge rate of all emitters checked in the field (lph)

To simplify matters, it is proposed that indicative values of EU' may be obtained if the test is carried out on the first, middle and last laterals of a plot and include the first, middle and last emitter of each lateral. The greater the number of emitters tested the better the indicative EU' values can be. To run such a test a can, a volumetric cylinder and a stopwatch are required.

Example 9

A test of the discharge of 48 emitters was carried out in plot of vegetables with the following results:

No. of emitters	q lph	No. of emitters	q lph	No. of emitters	q lph	No. of emitters	q lph
1	2.11	13	2.10	25	2.00	37	2.00
2	2.01	14	2.14	26	2.10	38	1.98
3	2.00	15	1.94	27	2.09	39	2.05
4	2.03	16	1.95	28	1.99	40	2.06
5	2.12	17	2.00	29	1.95	41	2.00
6	2.07	18	2.01	30	2.11	42	2.08
7	2.00	19	1.98	31	2.10	43	2.10
8	2.15	20	2.01	32	2.08	44	1.98
9	1.95	21	2.00	33	2.10	45	2.07
10	2.02	22	1.96	34	1.99	46	2.08
11	2.05	23	2.10	35	1.96	47	1.99
12	2.12	24	2.00	36	2.10	48	2.00

$$q_n' = \frac{1.95 + 1.94 + 1.95 + 1.98 + 1.96 + 1.99 + 1.95 + 1.99 + 1.96 + 1.98 + 1.98 + 1.99}{12} = 1.968 \text{ lph}$$

$$q_a = \frac{\sum(q_1 \ldots q_t)}{48} = 2.037 \text{ lph}$$

$$EU' = 100 \times \frac{1.968}{2.037} = 96.6\%$$

4.3. Irrigation efficiences

The procedure explained in Section 3.3, for a sprinkler irrigation scheme, should be followed for a localized irrigation scheme.

Chapter 5
Monitoring the financial performance of an irrigation scheme

Financial and economic viability are central to the planning, design, implementation, operation, maintenance and management of an irrigation scheme, as any investor would expect an acceptable return to their investment, regardless of whether it is a large or a small scheme or whether it is a private or public investment. Financial and economic viability are thus widely used as criteria for project selection and also as measures of project sustainability. The key guiding principle is always that of minimizing costs whilst at the same time maximizing the benefits from the project. Therefore, the need to continuously assess and compare the benefits accruing from the running and operation of an irrigation scheme to costs incurred is inevitable, in order to justify (or not) the continued operation of the scheme and the initial investment.

Module 11 describes the financial and economic appraisal of irrigation projects. This Chapter focuses on monitoring the financial performance at plot and scheme level.

Apart from simple, good financial management and accounting systems, the cost incurred and benefits accruing from the operation of an irrigation scheme are also largely dependant on the technical aspects. For example, frequent breakdowns of machinery and equipment inevitably result in increased maintenance costs. It is important, therefore, that financial monitoring is applied in conjunction with technical monitoring, as described in the previous chapters, for the different types of irrigation systems.

For financial monitoring it is important that the indicators are not only quantified in terms of timing but also that projections on the anticipated costs of implementing each of the activities be made. Each activity, therefore, has to be costed.

5.1. Monitoring the financial performance at plot level

For irrigators to keep records of their plots, it is important that they are trained not only on how to keep records, but also on how to analyze and use the records for their own benefit. Only if irrigators benefit from keeping records, will they keep useful records. Some areas to emphasize during training include the following:

- Irrigators should record activities as soon as they happen instead of waiting until the end of the season. This is meant to help them not to forget what took place
- Records should be kept in a logical manner, following the sequence in which the farming operations or activities being recorded take place
- The irrigators should keep records in a format that they themselves understand best, since they are going to be the prime users of the records
- Recording is a continuous process from the start of the enterprise to the end

Enterprise records, which a farmer ought to keep, include the records shown on page 26 to be collected for each crop. These data relate to agricultural and financial performance and will be used to calculate the farm's gross margins, which is the difference between the total gross income and the total variable costs for a crop (see Module 11).

It is not necessary for the farmer to record all these items. A farmer will record only those activities, that they have done on a particular crop. For example, a farmer may not record anything about fertilizers if none were used.

Training of irrigators in record-keeping should also emphasize the importance of valuing the issues mentioned below, since failure to capture such data will make it difficult for the irrigators to assess their production levels accurately:

- Payments in kind
- Produce consumed
- Gifts or donations to relatives, friends and others
- Barter exchanges (trading commodities without the use of money)

Agricultural records	Financial records
– Name of the crop planted	
– Variety of the crop	
– Dates of land preparation	– Cost of land preparation
– Dates of planting	– Cost of planting
– Area planted	
– Amount of seed used	– Cost of seed used
– Type and quantity of fertilizer used	– Cost of fertilizer used
– Pests and diseases encountered	
– Type and quantity of chemicals used	– Cost of chemicals used
	– Cost of transport for farmer to buy inputs
	– Cost of transport of inputs to the farm
– Quantity of hired labour (labour days)	– Cost of hired labour
	– Payments made in kind
– Dates of harvesting	
– Amount of crop harvested	
– Amount of produce consumed	– Estimate of price of produce consumed
– Amount of produce given to others	– Estimate of price of produce given to others
– Amount of produce retained	– Estimate of price of produce retained
– Dates of marketing	
	– Cost of transport to ferry produce to market
	– Cost of transport for farmer to sell produce
	– Cost for food, accommodation while marketing
	– Costof packaging crop for marketing
	– Cost of hiring stands, entry fees into market, etc.
– Amount of produce sold	– Price of produce sold

Following are two examples of enterprise records kept and presented by two farmers from Murara irrigation scheme in Zimbabwe. The records were captured in June 2001.

Example 10

Farmer's name: Farai

Block 6: **Tomatoes**

Nursery planting: 16-01-2001
Size of land: 0.04 ha
Land preparation date: 30-01-2001
Transplanting date: 06-02-2001
Variety: Rodade
Quantity of seed: 25g, total US$1.82
Initial fertilizer: Compound D: 10 kg, total US$3.18
Date of top dressing application 10 kg: 16-02-2001
Weeding – casual labour: US$0.90
Chemicals: Rogor: 50 ml, total US$1.45

Date start of marketing: 25-04-2001

Transport to the market:	US$14.09
Transport to the market:	US$20.09
Transport to the market:	US$9.89

Marketing:	25-04-2001	2 boxes	US$9.09	Farm gate
	09-05-2001	101 boxes	US$122.73	Mbare Market
	16-05-2001	42 boxes	US$157.18	Mbare Market
	22-05-2001	3 boxes	US$13.64	Farm gate
	24-05-2001	22 boxes	US$87.73	Mbare Market
	30-05-2001	1 box	US$3.64	Farm gate

Quantity consumed: 8 boxes

still selling

Example 11

Farmer's name: Betty
Block 2: **Sweet Potatoes**
Land size: 0.04 ha
Land preparation date: 27-11-2000
Quantity of runners: 7 x '50 kg' bags
Cost of runners: free
Planting date: 05-12-2000
Fertilizer: Gypsum: 10 kg
Cost of Fertilizer: US$1.82
Date of fertilizer application: 15-12-2000
Weeding date: 07-01-2001

Harvesting date:	28-04-2001:	5 x '90 kg' bags
	09-05-2001:	6 x '50 kg' bags
	11-05-2001:	3 x 20 litre tins
	15-05-2001:	3 x '50 kg' bags
Selling dates:	30-04-2001:	US$40.00
	10-05-2001:	US$49.78
	11-05-2001:	US$7.09
	17-05-2001:	US$24.00
Transport:	US$9.09	
	US$10.73	
	US$5.45	
Mbare Musika: cost of stand plus lunch:		US$2.62
		US$2.98
		US$2.22
Quantity consumed:	4 x 20 litre tins	
	6 x 20 litre tins	
	2 x 20 litre tins	
Value of produce consumed:		US$21.82

The above two examples are taken from true farmer records. They bring out the importance of standardizing units of measurement. For example, looking at Example 11, it would be difficult to get an estimate of the total production of sweet potato tubers without knowing the weight of a 20 litre tin of sweet potato tubers. From the same example:

❖ A '50 kg' bag of sweet potato runners means that the runners are in a bag that normally weighs 50 kg when full of maize.

❖ A '90 kg' bag of sweet potato tubers means that the tubers are in a bag that normally weighs 90 kg when full of maize.

It is important for the irrigators to assess, with the assistance of the AEW, the weights of the different units of measurement for the various products used in the scheme. Use of standardized measures will make data comparable between farmers as well as usable by outsiders.

For example, the following weights were agreed upon in Murara irrigation scheme in 2000-2001:

❖ A '50 kg' bag sweet potato runners: 5-7 kg

❖ A '90 kg' bag sweet potato tubers: 100-110 kg

❖ A '50 kg' bag sweet potato tubers: 55-60kg

❖ A 20 litre tin of sweet potato tubers: 22kg

Based on the enterprise records given in Example 10, the gross margin budget for the tomato crop of farmer Farai has been established and is shown in Table 7. The same has been done for the sweet potato crop of farmer Betty, based on the enterprise records given in Example 11, as shown in Table 8. The figures have also been converted on a hectare basis in order to allow for comparison between different crops, between different farmers and between different production methods (for example with irrigation and without irrigation).

Table 7

Gross margin analysis for the tomatoes of farmer Farai

Description	Unit	Per plot	Per ha
Area planted	ha	0.04	1
Amount of seed	kg	0.025	0.625
Amount of basal (initial) fertilizer	kg	10	250
Amount of top dressing fertilizer	kg	10	250
Total output	boxes	179	4 475
Gross income * (1)	**US$**	**423.13**	**10 578.25**
Variable Costs:			
Land preparation	US$	0	0
Cost of seed	US$	1.82	45.50
Cost of initial fertilizer	US$	3.18	79.50
Cost of top dressing	US$	3.18	79.50
Cost of chemicals	US$	1.45	36.25
Trellising	US$	0	0
String	US$	0	0
Hired labour	US$	0.90	22.50
Transport cost (inputs)	US$	0	0
Seasonal loan	US$	0	0
Transport cost (of produce to market)	US$	44.07	1 101.75
Packing materials (used old boxes)	US$	0	0
Total variable costs (2)	**US$**	**54.60**	**1 365.00**
Gross Margin (3) = (1) - (2)	**US$**	**368.53**	**9 213.25**

* *The value per box of the 8 boxes consumed is considered to be equal to the farm gate price per box on 30-05-2001 and has to be added to the value of produce sold.*

Based on the above, the average price received per 10 kg box of tomatoes is equal to US$2.36 (= 423.13/179). According to the enterprise records in Example 10, the price that farmer Farai got during the selling period varied between US$1.22 and US$3.99 at Mbara market per 10 kg box and between US$3.64 and US$4.55 when selling very small quantities at the farm gate. The fluctuation in prices is due to the general availability of tomatoes on the market: the higher the supply the lower the price.

Table 8

Gross margin analysis for the sweet potatoes of farmer Betty

Description	Unit	Per plot	Per ha
Area planted	ha	0.04	1
Amount of runners	kg	42	1 050
Amount of basal (initial) fertilizer	kg	0	0
Amount of top dressing fertilizer	kg	10	250
Total output	kg	1 377	34 425
Gross income * (1)	**US$**	**142.69**	**3 567.25**
Variable Costs:			
Land preparation cost	US$	0	0
Cost of runners	US$	0	0
Cost of initial fertilizer	US$	0	0
Cost of top dressing	US$	1.82	45.50
Hired labour	US$	0	0
Transport cost (inputs)	US$	0	0
Seasonal loan	US$	0	0
Transport cost (of produce to market)	US$	25.27	631.75
Packing materials	US$	0	0
Cost of stand plus lunch	US$	7.82	195.50
Total variable costs (2)	**US$**	**34.91**	**872.75**
Gross margin (3) = (1) - (2)	**US$**	**107.78**	**2 694.50**

* *Gross income includes the value of the produce sold (US$120.87) plus the value of the produce consumed (US$21.82).*

Based on the above, the average price received per kg of sweet potatoes is equal to US$0.10 (= 142.69/1377). According to the enterprise records in Example 11, the price that farmer Betty got during the selling period varied between US$0.09 and US$0.14 per kg. For the calculation of these prices the bags and tins had to be converted into kg, using the conversion factors given on the previous page.

Besides enterprise data, individual irrigators should also keep details of their contribution towards:

- Energy costs
- Water bills
- Repairs to scheme infrastructure
- Servicing of equipment
- Security guard, etc.

These data, combined with the gross margin analysis, will allow individual plot holders to calculate their irrigation plot net farm income. The incentive for smallholder irrigators to keep good records is for them to be able to get an idea of the profitability of their various enterprises (crops) as well as of the profitability of the whole irrigation plot. It also will help them to get an idea of the profitability of irrigated crop production compared to rainfed crop production (see below).

These records, which irrigators are keeping primarily for their own use, will be useful to other stakeholders in the irrigation scheme as well as to those who may want to know about the agricultural and financial performance of the scheme. Averaging records of a representative sample of irrigators (or a census of irrigators if the population is small) will answer questions on agricultural and financial performance (gross margin per plot or per ha) of the scheme.

Table 9 presents the sort of analysis a farmer could carry out using their enterprise records, including costs of energy and repair and maintenance, for their whole irrigated plot where several crops at the same time are growing. One farmer has an irrigated plot of 0.5 ha and the cropping intensity is 200%, which gives a total cropped area of 1.0 ha per year. In the summer grain maize (0.2 ha), sugar beans (0.2 ha) and groundnuts (0.1 ha) are cultivated, while in the winter wheat (0.2 ha), green maize (0.2 ha) and cabbages (0.1 ha) are cultivated.

The farmer is able to compare the income they receive from their 0.5 ha irrigated plot with the income from their 3.0 ha of rainfed land, which is shown in Table 10. Under rainfed conditions, there are no costs for energy and repair and maintenance.

Table 9

Gross margin for an irrigated plot of 0.5 ha (200% cropping intensity) at Mutange irrigation scheme

Crop	Area		Gross margin (US$) per area
	(%)	(ha)	
Grain maize	40	0.2	193
Sugar beans	40	0.2	255
Groundnuts	20	0.1	149
Wheat	40	0.2	331
Green maize	40	0.2	1 355
Cabbages	20	0.1	705
Gross margin (1)	**200**	**1.0**	**2 988**
Less:			
Energy costs for drag-hose sprinkler (2)			105
Repair and maintenance costs (3)			156
Net income per plot of 0.5 ha with 200% cropping intensity (4) = (1) - (2) - (3)			**2 727**

Table 10

Gross margin for a rainfed area of 3 ha close to Mutange irrigation scheme

Crop	Area		Gross margin (US$) per area
	(%)	(ha)	
Grain maize	36.7	1.10	278
Sorghum	5.0	0.15	30
Pearl millet	1.7	0.05	12
Groundnuts	23.3	0.70	379
Cotton	33.3	1.00	-74
Total gross margin for 3 ha	**100.0**	**3.00**	**625**

It can be concluded from Tables 9 and 10 that the net income of the 0.5 ha irrigated area (US$2 727) is over 4 times that of the 3.0 ha rainfed area (US$625). Using enterprise records, farmers can also compare their output and income per ha with other irrigators.

To assess whether irrigators' yields and/or incomes have increased, the same analyses will have to be repeated yearly and a comparison made of income per plot and income per ha for the different years.

5.2. Monitoring the financial performance at scheme level

Sources of data for monitoring the financial performance at scheme level include the following:

- Enterprise records kept by individual irrigators (the same records as used in Section 5.1)
- Scheme records kept by the Irrigation Management Committee (IMC)
- Scheme records kept by the Agricultural Extension Worker (AEW)
- Data collected by experts at specific intervals
- Data collected by an evaluation team assigned the task of evaluating the scheme

A questionnaire for smallholder irrigation scheme evaluation and non-exhaustive checklists for IMC, AEW and experts data, which can be used as guidance for collecting data, are attached in Appendix 2.

5.2.1. Irrigators' data and records

Taking a sample of irrigators' agricultural and financial records (or a census if the population is small), as presented in Section 5.1, will allow for conclusions about scheme-level performance. Table 11 presents the result of the analysis that can be done at scheme level. The figures for the areas per cultivated per crop have been calculated by adding up the figures of the individual farmers. When comparing the enterprise records kept by the individual irrigators, conclusions about seed rates, fertilizer levels per ha for various crops (i.e. adoption rates) can be made about irrigators and so can conclusions be made about yields and incomes. Scheme level analysis can be carried out by the AEW for the scheme and/or by an external evaluation team.

5.2.2. Irrigation Management Committee (IMC) data and records

In a scheme where irrigators have the responsibility of managing scheme affairs, the IMC will keep records of scheme level costs and responsibilities. Scheme level costs kept by the IMC include:

- Water bills
- Energy bills
- Repair and servicing costs
- Security guard cost
- Replacement costs
- Levies (for example subscription fees to irrigation associations, etc.)

These scheme records (fixed costs) will allow for the calculation of scheme costs per hectare. Individual farmers may keep a record of their individual contributions to these costs as well as repairs and other costs relating to their plots. This will allow for calculation of irrigation profit per plot (see Section 5.1).

Table 11
Gross margin for Mutange irrigation scheme, total area 105 ha (200% cropping intensity)

Crop	Area		Gross margin (US$)
	(%)	(ha)	per area
Grain maize	40	42	40 487
Sugar beans	40	42	53 552
Groundnuts	20	21	31 254
Wheat	40	42	69 567
Green maize	40	42	284 633
Cabbages	20	21	147 953
Gross margin (1)	**200**	**210**	**627 446**
Less:			
Energy costs for drag-hose sprinkler (2)			22 126
Repair and maintenance costs (3)			32 727
Net income whole scheme of 105 ha with 200% cropping intensity (4) = (1) - (2) - (3)			**572 592**

The IMC should also keep other records, like frequency of breakdown of equipment. Monitoring the breakdown frequency, for example engine breakdown, will allow for decisions to be made on whether, for example, a new engine should be bought.

The IMC also needs to keep records on the energy consumption rate. Monitoring the energy consumption rate will allow for early detection of problems. A sudden rise in the rate of energy consumption may indicate that the equipment needs servicing. Servicing equipment in time may prevent costly repairs following equipment breakdown. Records of power failure, where national electricity supply is available, should also be kept.

The IMC may also keep other non-financial records such as, for example:

- ❖ List of plot holders
- ❖ Gender disaggregation of plot holders
- ❖ List of IMC post bearers
- ❖ Gender disaggregation of IMC post bearers

These data can be updated as and when the need arises. They will be useful in monitoring issues such as advancement of women, for example whether, over time, women access irrigation plots in their own right or hold leadership positions.

5.2.3. Agricultural Extension Worker (AEW) data and records

The AEW assigned to the scheme may keep the same data as the IMC. This is because the AEW is well placed to communicate the data (should the need arise) to various stakeholders such as the scheme engineer, planners and other researchers in the scheme.

Over and above these data, the AEW will keep records of:

- ❖ Crops grown in the scheme
- ❖ Total area per crop
- ❖ Cropping programme
- ❖ Recommended agronomic practices
- ❖ Condition of the irrigation infrastructure
- ❖ Irrigation scheduling
- ❖ Details of courses run for committees and farmers and attendance
- ❖ Courses attended by the AEW
- ❖ Problems encountered, such as disease outbreaks, conflicts, etc.

5.2.4. Experts data and records

Some data, which may have financial implications, will have to be collected by experts, since they are difficult or impossible for farmers to collect. Such data include technical performance data such as discharge rate, the assessment of condition of equipment, and irrigation infrastructure.

The discharge rate can be taken at the commissioning of the scheme. Monitoring the discharge rate on a regular basis, for example yearly, will allow for decisions to be made on whether equipment should be kept as it is, or whether it should be serviced or replaced altogether. Estimating the volumes of water used can be the means for estimating the efficiency of the scheme. Checking the condition of the equipment regularly will allow for early detection of worn parts.

Some of the environmental performance data, such as soil pH and water pollution, will also need to be measured regularly, for example yearly, throughout the life of the scheme in order to detect whether there are any changes in soil and water quality as a result of the scheme.

5.2.5. External evaluators data and records

A team of outsiders working closely with the stakeholders in the scheme can carry out a survey among irrigators just before they start irrigating their new plots (baseline study). Thereafter, mid-term evaluation, ex-post evaluation (at completion of the project) and impact evaluation (some years after completion) missions should be undertaken. The missions do not need to be carried out by the same team. For example, a mid-term and ex-post evaluation may be commissioned by a donor agency using its own staff.

Issues to be covered in a formal survey include:

- ❖ Asset ownership by irrigators
- ❖ Nutritional status of the family
- ❖ Ability to pay school fees
- ❖ Employment creation
- ❖ Food security status
- ❖ Disease incidence among irrigating households and the surrounding community
- ❖ Farmer organization and management ability

The external evaluating team may also have informal discussions with various stakeholders and make observations to cover issues such as:

- ❖ Advancement of women
- ❖ Backward and forward linkages with the scheme

- ❖ Food security status of the area
- ❖ Appropriateness of the technology, for example treadle pumps to women
- ❖ Erosion
- ❖ Waterlogging/drainage problems

The external evaluating team may also use agricultural and financial data from a sample of farmers and scheme-level data from IMC to cover issues such as:

- ❖ Financial viability of scheme
- ❖ Change in irrigators' yields and/or incomes

5.2.6. Monitoring the financial performance of Mutange irrigation scheme

Table 12 shows the financial analysis of Mutange irrigation scheme seven years into operation. These figures then can be compared with the figures in Table 13, which show the financial analysis prepared during the financial and economic appraisal of the project (Module 11). The actual data on costs and benefits collected over a period of six years are used to re-appraise the scheme. This is done in order to determine whether the scheme is still financially viable or deserves support only on social, political or food security grounds. In order to be able to compare Tables 12 and 13, and to be able to re-assess the NPV, B/C ratio and the IRR (see below), it was assumed that after the 7th year of operation (= 8th year after construction) until the end of the 20th year of operation, the costs would be the same as those of the 7th year. The discount rate has been estimated at 13% instead of the 12% that was used during the appraisal of the project.

Indicators to measure the viability of a project are the Net Present Value (NPV), the Benefit/Cost (B/C) ratio and the Internal Rate of Return (IRR). For a detailed description of these indicators and their calculation the reader is referred to Module 11. Suffice it to say here, that the higher the values of these parameters the more viable the project is. In any case the NPV should be greater than 0, the B/C ratio greater than 1 and the IRR should be greater than the discount rate. Table 12 shows that this is the case for the project 7 years into operation; so it continues to be viable. However, when comparing these figures with the ones calculated during appraisal (Table 13), they all have gone down:

- ❖ The NPV has gone down from US$2 608 425 to US$2 112 273, which is a decrease of 19%
- ❖ The B/C ratio has gone down from 2.48 to 2.09, which is a decrease of 16%
- ❖ The IRR has gone down from 42% to 30%, which is a decrease of 29%

When, however, comparing Table 12 with Table 14, which during the financial and economic appraisal had already taken into consideration price increases due to inflation, the difference is much less. In this case:

- ❖ The NPV has gone down from US$2 236 154 to US$2 112 273, which is a decrease of 6%
- ❖ The B/C ratio has gone up from 2.05 to 2.09, which is a increase of 2%
- ❖ The IRR has gone down from 33% to 30%, which is a decrease of 9%

Table 12

Financial analysis of Mutange irrigation scheme, 7 years into operation (US$)

Year	Investment	Replacement costs	Energy costs	Repairs and maintenance	Technical support	Without-project benefits	Total project cost[a]	With-project benefits	Net benefits[b]	Discount factor (13%)	Present value of costs[c]	Present value of benefits[d]	Present value of net benefits[e]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1	1 200 000					36 878	1 236 878	0	-1 236 878	0.8850	1 094 582	0	-1 094 582
2			25 000	30 000	14 545	36 878	106 423	451 663	345 240	0.7831	83 344	4 353 718	270 374
3			27 100	33 000	16 000	36 878	112 978	548 352	435 375	0.6931	78 299	380 036	301 736
4			28 782	35 672	17 599	36 878	118 931	627 446	508 516	0.6133	72 942	384 824	311 882
5			34 100	40 250	19 359	36 878	130 587	712 469	581 882	0.5428	70 877	386 699	315 822
6		27 000	35 490	41 500	21 295	36 878	162 163	712 469	550 306	0.4803	77 890	342 212	264 322
7			36 600	42 210	23 425	36 878	139 113	712 469	573 356	0.4251	59 131	302 842	243 711
8			37 000	42 500	24 000	36 878	140 378	712 469	572 091	0.3762	52 804	268 002	215 198
9			37 000	42 500	24 000	36 878	140 378	712 469	572 091	0.3329	46 730	237 170	190 440
10			37 000	42 500	24 000	36 878	140 378	712 469	572 091	0.2946	41 354	209 885	168 531
11		80 000	37 000	42 500	24 000	36 878	220 378	712 469	492 091	0.2607	57 452	185 739	128 287
12			37 000	42 500	24 000	36 878	140 378	712 469	572 091	0.2307	32 386	164 371	131 985
13			37 000	42 500	24 000	36 878	140 378	712 469	572 091	0.2042	28 660	145 461	116 801
14			37 000	42 500	24 000	36 878	140 378	712 469	572 091	0.1807	25 363	128 726	103 363
15			37 000	42 500	24 000	36 878	140 378	712 469	572 091	0.1599	22 445	113 917	91 472
16		90 000	37 000	42 500	24 000	36 878	230 378	712 469	482 091	0.1415	32 598	100 812	68 214
17			37 000	42 500	24 000	36 878	140 378	712 469	572 091	0.1252	17 578	89 214	71 636
18			37 000	42 500	24 000	36 878	140 378	712 469	572 091	0.1108	15 556	78 950	63 395
19			37 000	42 500	24 000	36 878	140 378	712 469	572 091	0.0981	13 766	69 868	56 102
20			37 000	42 500	24 000	36 878	140 378	712 469	572 091	0.0868	12 182	61 830	49 647
21			37 000	42 500	24 000	36 878	140 378	712 469	572 091	0.0768	10 781	54 717	43 936
	1 200 000	**197 000**	**705 072**	**817 632**	**448 223**	**774 428**	**4 142 355**	**13 739 429**	**9 597 074**	**7**	**1 946 719**	**4 058 993**	**2 112 273**

a *Total project costs (8) = (7) + (6) + (5) + (4) + (3) + (2)*

b *Net benefits (10) = (9) - (8)*

c *Present value of costs (12) = (8) x (11)*

d *Present value of benefits (13) = (9) x (11)*

e *Present value of net benefits (14) = (10) x (11)*

Net Present Value (NPV) at 13%:	**2 112 273**
Present value of benefits:	**4 058 993**
Present value of costs:	**1 946 719**
Benefit/Cost (B/C) ratio:	**2.09**
Internal Rate of Return (IRR):	**30%**
Payback period:	**4 years**

Table 13

Financial analysis of Mutange irrigation scheme, as established during the financial and economic appraisal of the project (US$)

Year	Investment	Replacement costs	Energy costs	Repairs and maintenance	Technical support	Without-project benefits	Total project cost[a]	With-project benefits	Net benefits[b]	Discount factor (13%)	Present value of costs[c]	Present value of benefits[d]	Present value of net benefits[e]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1	1 090 909					36 878	1 127 787	0	-1 127 787	0.8929	1 007 001	0	-1 007 001
2			22 126	32 727	14 545	36 878	106 276	451 663	345 387	0.7972	84 723	360 066	275 343
3			22 126	32 727	14 545	36 878	106 276	548 352	442 077	0.7118	75 647	390 317	314 670
4			22 126	32 727	14 545	36 878	106 276	627 446	521 171	0.6355	67 538	398 742	331 204
5			22 126	32 727	14 545	36 878	106 276	712 469	606 193	0.5674	60 301	404 255	343 954
6		24 936	22 126	32 727	14 545	36 878	131 212	712 469	581 257	0.5066	66 472	360 937	294 465
7			22 126	32 727	14 545	36 878	106 276	712 469	606 193	0.4523	48 068	322 250	274 181
8			22 126	32 727	14 545	36 878	106 276	712 469	606 193	0.4039	42 925	287 766	244 841
9			22 126	32 727	14 545	36 878	106 276	712 469	606 193	0.3606	38 323	256 916	218 593
10			22 126	32 727	14 545	36 878	106 276	712 469	606 193	0.3220	34 221	229 415	195 194
11		77 097	22 126	32 727	14 545	36 878	183 373	712 469	529 096	0.2875	52 720	204 835	152 115
12			22 126	32 727	14 545	36 878	106 276	712 469	606 193	0.2567	27 281	182 891	155 610
13			22 126	32 727	14 545	36 878	106 276	712 469	606 193	0.2292	24 358	163 298	138 939
14			22 126	32 727	14 545	36 878	106 276	712 469	606 193	0.2046	21 744	145 771	124 027
15			22 126	32 727	14 545	36 878	106 276	712 469	606 193	0.1827	19 417	130 168	110 751
16		84 456	22 126	32 727	14 545	36 878	190 732	712 469	521 737	0.1631	31 108	116 204	85 095
17			22 126	32 727	14 545	36 878	106 276	712 469	606 193	0.1456	15 474	103 735	88 262
18			22 126	32 727	14 545	36 878	106 276	712 469	606 193	0.1300	13 816	92 621	78 805
19			22 126	32 727	14 545	36 878	106 276	712 469	606 193	0.1161	12 339	82 718	70 379
20			22 126	32 727	14 545	36 878	106 276	712 469	606 193	0.1037	11 021	73 883	62 862
21			22 126	32 727	14 545	36 878	106 276	712 469	606 193	0.0926	9 841	65 975	56 133
	1 090 909	**186 489**	**442 520**	**654 540**	**290 900**	**774 428**	**3 439 786**	**13 739 429**	**10 299 643**		**1 764 335**	**4 372 760**	**2 608 425**

a Total project costs (8) = (7) + (6) + (5) + (4) + (3) + (2)

b Net benefits (10) = (9) - (8)

c Present value of costs (12) = (8) x (11)

d Present value of benefits (13) = (9) x (11)

e Present value of net benefits (14) = (10) x (11)

Net Present Value (NPV) at 13%:	**2 608 425**
Present value of benefits:	**4 372 760**
Present value of costs:	**1 764 335**
Benefit/Cost (B/C) ratio:	**2.48**
Internal Rate of Return (IRR):	**42%**
Payback period:	**4 years**

Table 14

Financial analysis of Mutange irrigation scheme, as established during the financial and economic appraisal of the project, taking into consideration a 30% increase in investment, replacement, repairs and maintenance costs (US$)

Year	Investment	Replacement costs	Energy costs	Repairs and maintenance	Technical support	Without-project benefits	Total project cost[a]	With-project benefits	Net benefits[b]	Discount factor (13%)	Present value of costs[c]	Present value of benefits[d]	Present value of net benefits[e]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1	1 418 182		0	0	0	36 878	1 455 059	0	-1 455 059	0.8929	1 299 222	0	-1 299 222
2			22 126	42 545	14 545	36 878	116 094	451 663	335 569	0.7972	92 550	360 066	267 516
3			22 126	42 545	14 545	36 878	116 094	548 352	432 259	0.7118	82 635	390 317	307 682
4			22 126	42 545	14 545	36 878	116 094	627 446	511 352	0.6355	73 777	398 742	324 965
5			22 126	42 545	14 545	36 878	116 094	712 469	596 375	0.5674	65 872	404 255	338 383
6		32 417	22 126	42 545	14 545	36 878	148 510	712 469	563 958	0.5066	75 235	360 937	285 701
7			22 126	42 545	14 545	36 878	116 094	712 469	596 375	0.4523	52 509	322 250	269 740
8			22 126	42 545	14 545	36 878	116 094	712 469	596 375	0.4039	46 890	287 766	240 876
9			22 126	42 545	14 545	36 878	116 094	712 469	596 375	0.3606	41 863	256 916	215 053
10			22 126	42 545	14 545	36 878	116 094	712 469	596 375	0.3220	37 382	229 415	192 033
11		100 226	22 126	42 545	14 545	36 878	216 320	712 469	496 149	0.2875	62 192	204 835	142 643
12			22 126	42 545	14 545	36 878	116 094	712 469	596 375	0.2567	29 801	182 891	153 089
13			22 126	42 545	14 545	36 878	116 094	712 469	596 375	0.2292	26 609	163 298	136 689
14			22 126	42 545	14 545	36 878	116 094	712 469	596 375	0.2046	23 753	145 771	122 018
15			22 126	42 545	14 545	36 878	116 094	712 469	596 375	0.1827	21 210	130 168	108 958
16		109 793	22 126	42 545	14 545	36 878	225 886	712 469	486 582	0.1631	36 842	116 204	79 362
17			22 126	42 545	14 545	36 878	116 094	712 469	596 375	0.1456	16 903	103 735	86 832
18			22 126	42 545	14 545	36 878	116 094	712 469	596 375	0.1300	15 092	92 621	77 529
19			22 126	42 545	14 545	36 878	116 094	712 469	596 375	0.1161	13 478	82 718	69 239
20			22 126	42 545	14 545	36 878	116 094	712 469	596 375	0.1037	12 039	73 883	61 844
21			22 126	42 545	14 545	36 878	116 094	712 469	596 375	0.0926	10 750	65 975	55 224
Total	**1 418 182**	**242 436**	**442 520**	**850 902**	**290 900**	**774 428**	**4 019 367**	**13 739 429**	**9 720 061**		**2 136 607**	**4 372 760**	**2 236 154**

a *Total project costs (8) = (7) + (6) + (5) + (4) + (3) + (2)*

b *Net benefits (10) = (9) - (8)*

c *Present value of costs (12) = (8) x (11)*

d *Present value of benefits (13) = (9) x (11)*

e *Present value of net benefits (14) = (10) x (11)*

Net Present Value (NPV) at 13%:	**2 236 154**
Present value of benefits:	**4 372 760**
Present value of costs:	**2 136 607**
Benefit/Cost (B/C) ratio:	**2.05**
Internal Rate of Return (IRR):	**33%**
Payback period:	**5 years**

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Appendix 1
Examples of indicators used for monitoring and evaluation of activities, outputs, immediate objectives and goals

Example of a drag-hose sprinkler irrigation scheme in Zimbabwe, following the logical framework of Table 2

INPUTS/ACTIVITIES: Selection and training of new irrigators and installation of equipment

Area of indicators	Specific data or information (indicators)	Source of information	Method of collection and frequency	Who uses this information	Use of information	Comments
Selection	Number of farmers selected – Females, males – Agricultural training, for example Master farmer – Farming experience – Average age – Asset ownership, for example equipment and draft power – Crops grown currently under dryland	AEW RDC Baseline survey	Part of selection Committee Survey of new irrigators once at start of the scheme	Agritex, RDC Funding Agency	Agritex & RDC want to know what sort of training is required by new irrigators so as to organize the courses. Funding Agency wants to know whether project beneficiaries fall within its priority area eg. women farmers, the poor, etc.	Agritex can carry out the baseline survey through one of its units to provide the data Funding Agency can engage a researcher to do the survey and analysis to provide the data
Training	Courses run for irrigators – Types of courses – Dates – Attendance – men, women	AEW	Contained in monthly report to DAEO	Agritex Funding Agency	– Keep track of courses run for irrigators – Keep track of output related to funds disbursed	AEW's report to DAEO could be copied to Funding Agency
Irrigation equipment installed, tested and performing as expected	– Energy consumption rate of system – Discharge rate – Condition of equipment – Uniformity of irrigation – Frequency of breakdown	IMC Experts Experts Farmers & AEW IMC & AEW	Take meter reading weekly Tests and physical check on equipment at inauguration of scheme and then every 6 months Observation weekly IMC & AEW records of all breakdowns and repairs when they occur	Irrigators, Funding Agency, Agritex	– Energy consumption rate determines size of the scheme energy bill – Any change in discharge rate gives advance warning about problems either at the water source or with the equipment – Frequent breakdown affects the repair bill, also results in periods of non- irrigation – Any deterioration in the condition of equipment may mean • imminent breakdown • need for rehabilitation, etc.	Regular monitoring of these indicators is required

OUTPUTS: Increased diversity into high-income crops and adoption of appropriate agronomic practices

Area of indicators	Specific data or information (indicators)	Source of information	Method of collection and frequency	Who uses this information	Use of information	Comments
Diversify crop production	Number of irrigators growing and area under: – Green maize – Groundnuts – Irish potatoes – Sugar beans – Leaf vegetables – Green peppers – Peas – Etc.	Individual farmer records	Farmer keeps record of each crop after every operation	Farmer	To be able to estimate total production and organize for packaging, transport and selling	Also compare farmer records with what farmers used to grow under dryland as detailed in the baseline study
		AEW records	AEW may record as they visit and observe each plot at least once a month	Agritex	To be able to help farmers look for markets, negotiate prices, etc.	Training of irrigators on record keeping is important before they can be expected to keep records
				Funding Agency	To make a preliminary assessment of whether the project objective is likely to be achieved	
Adoption of appropriate agronomic practices	Crop varieties grown – Average seed rate per ha per crop	Farmer records	– Farmer records as soon as they are through with a particular operation	Farmer	This data will help him / her to budget for the same crop next season	Compare data from farmer records with information on what the AEW recommends
	Type and average quantity of top dressing fertilizer used per crop Cultural practices used to control pests and diseases per crop Type and average quantity of pesticide used per crop	Agritex AEW	– AEW summarizes a sample of irrigators' records for one of their monthly reports to DAEO	Agritex	To assess whether farmers need further training on agronomy	The project monitoring system could be designed in such a way that the AEW's report to DAEO is copied to Funding Agency An evaluation of adoption rate by an external team will give an objective assessment of adoption rate
	Timeliness of operations	External evaluation team	– Adoption survey once every year or just midway into the implementation	Funding Agency	To make a preliminary assessment of whether the project objectives are likely to be achieved	

IMMEDIATE OBJECTIVE: Increased yields and incomes in an environmentally sustainable way

Area of indicators	Specific data or information (indicators)	Source of information	Method of collection and frequency	Who uses this information	Use of information	Comments
Increased yields	Average yields per ha for each of the crops in the scheme for successive seasons	Individual farmer records of area and output of each crop Agritex AEW	– AEW summarizes a sample of irrigators' records for one of his monthly reports to DAEO – External evaluation team may also summarize a sample of irrigators' records to make its own independent assessment once every year or just midway into the implementation	Farmer Agritex Funding Agency	Wants to compare with past performance. Wants to find a market. Wants to organize transport. Wants to estimate income To help farmers find a market. To help farmers improve on past performance To assess to what extent project objectives are being met	Agritex can carry out an end-of-term evaluation of the scheme through one of its units to provide the data Funding Agency may engage a researcher to do the analysis to provide the data
Increased incomes of irrigators	Gross margin per crop Average net irrigation profit per irrigator	Individual farmer enterprise records Scheme level costs of electricity, water, repairs, etc.	– AEW analyses a sample of irrigators' records to get average gross margins less fixed costs (Net irrigation income) for one of their monthly reports to DAEO – External evaluation team may also analyze a sample of irrigators' records to make its own independent assessment once every year or just midway into the implementation	Farmer Agritex Funding Agency Creditor	To compare with past performanceTo decide whether to remain in the scheme or seek alternative employment To assist farmers make decisions on favourable markets for inputs and produce. To assess to what extent project objectives are being met To assess irrigators' ability service loans	Agritex can carry out an end-of-term evaluation of the scheme through one of its units to provide the data Funding Agency may engage a researcher to do the analysis to provide the data
Viability	NPV IRR Pay back period	Farmer records, scheme level records, investment cost records	Calculated using farmer records, scheme level records and investment cost records Calculated every 5 years or so to see whether the scheme is still viable	Donor agency Creditor Agritex	– To gauge whether the scheme is still viable – To decided whether the scheme is sustainable – To decide whether to rehabilitate the scheme – To decide whether to fund a similar scheme or a different project altogether in future To gauge whether the scheme will manage to service its loans To decide whether the scheme is worth the investment in man-power, training of irrigators, etc.	Agritex can carry out an end-of-term evaluation of the scheme through one of its units to provide the data Funding Agency may engage a researcher to do the analysis to provide the data

Technical and environ-mental sustainability	Soil moisture in field	Experts	– Field measurement	Farmer, Agritex, Funding agency	To gauge technical performance and improve
	Pressure and discharge in sprinkler system	Experts	– Field measurement		
	Irrigation efficiencies	Experts	– Field measurement		
	Soil pH / salinity	Soil samples	– Laboratory soil tests by experts every 3 years	– Agritex and Donor Agency	– To gauge sustainability of the scheme
	Erosion	Irrigators, AEW and outsiders	– Observation yearly	– Donor Agency	– To fund corrective measures
	Water pollution	Water sample from stream	– Laboratory test for nitrate every 3 years	Agritex	To spearhead rehabilitation of affected areas
	Waterlogging / poor drainage	Irrigators, AEW	– Observation yearly		
	Human disease incidence: – Malaria – Bilharzia	Local clinic records	Access to clinic records once a year	Local health worker	Local health center may want to put together a training programme to curb spread of disease
		Survey of irrigators	Survey once every year or just midway into the implementation	Funding Agency irrigators	Funding Agency may only want to be associated with 'environ-ment friendly' scheme Irrigators may want to take precautions to prevent the spread of diseases

GOAL: To improve the standard of living of the irrigators and the community around the scheme

Area of indicators	Specific data or information (indicators)	Source of information	Method of collection and frequency	Who uses this information	Use of information	Comments
Improved standard of living of irrigators	– Change in quantity and quality of assets – Change in quality of housing – Change in clothing quality – Improved access to education – Improvement in diet – Change in role of women in the scheme	Observation Survey of irrigators by external evaluation team	Observation Survey 4-5 years after implementation when the scheme is supposed to be operating at full potential	Agritex and Funding Agency Political leaders	Decide whether to invest in a similar scheme or a different project altogether in future To highlight the achievements of the government of the day	Funding Agency can engage a researcher to do the survey, midway into the implementation as well as just before the end of the funding Agritex can carry out a mid term and end-of-term evaluation of the scheme through one of its units
Improved standard of living of the community around the scheme	– Change in quantity and quality of access roads – Better access to services such as shops, credit facilities, markets etc.	Observation by external evaluation team	Observation 4-5 years after implementation when the scheme is supposed to be operating at full potential	Funding Agency and political leaders	Decide whether to invest in a similar scheme or a different project altogether in future To highlight the achievements of the government of the day	

Appendix 2
Examples of questionnaires and checklists

1. QUESTIONNAIRE FOR PLOT HOLDERS TO BE USED FOR SMALLHOLDER IRRIGATION SCHEME EVALUATION

Identification details

Name of interviewer:

Date of interview:

Name of irrigation scheme:

District:

Province:

Name of registered plot holder:

Sex: Male: ☐ Female: ☐

Marital status:
- Married ☐
- Single ☐
- Widowed ☐
- Divorced ☐
- Separated ☐

Age of registered plot holder:

Level of education of registered plot holder (years):

Agronomic and financial performance

1. When did you join the irrigation scheme?
2. Plot size (state units):
3. Total area under irrigation (state units):

4. Please give details relating to crops you grew in your irrigation plot in 2001 in the table below[a]

Crop name:				
Variety				
Area planted (ha)				
Cost of land preparation				
Manure:				
– Amount of manure				
– Cost of manure				
Basal or initial fertilizer:				
– Type				
– Quantity (kg)				
– Cost				
Seed:				
– Quantity (kg)				
– Cost				
Fertilizer for top dressing:				
– Type				
– Quantity (kg)				
– Cost				
Pesticides:				
– Type 1				
– Type 2				
– Type 3				
– Total cost of pesticides				
Cost of transport of inputs to farm				
Casual labour cost:				
– Land preparation				
– Weeding				
– Harvesting				
– Other casual labour cost				
Total output produced				
Total quantity consumed				
Total quantity given away				
Markets:				
– Market 1				
– Market 2				
– Market 3				
Total quantity sold				
Average price				
Cost of transport of produce to market				
Cost of transport of farmer (fares)				
Other marketing costs				

a *This table will be completed using farmer records.*

5. Crop pests and diseases encountered:

6. What items did you repair/replace in your own plot in year 2001?

Item repaired/ replaced	Date	Cost
1.		
2.		
3.		

7. What were your contributions towards electricity, water and other bills (for example security) in year 2001?

Type of bill	Amount paid	Period covered
Electricity bill		
Water bill		
Other (specify)		

8. What items were replaced at scheme level in 2001?

Item repaired/ replaced	Your (individual farmer) contribution to cost
1.	
2.	
3.	

9a. Did you borrow any money for crop production on your plot in the scheme in year 2001?

Yes ☐ No ☐

9b. If yes, please give details of the loan below

Amount	Source of funds	Terms of loan	Amount repaid

Social performance

10. Indicate who in your household makes decisions and/or does the following activities related to your plot in the scheme.

Activity	Who makes decisions on activity?	Who performs the activity?
Ploughing		
Planting		
Buying of inputs		
Weeding		
Fertilizer application		
Chemical application		
Harvesting		
Marketing		
Irrigating crops		

11. Who decides on how irrigation money is spent? Explain.

12. Asset ownership

Assets	Number
Ox-drawn plough	
Cultivator	
Planter	
Scotch cart	
Wheel barrow	
Harrow	
Hoe	
Knapsack sprayer	
Irrigation pump	
Tractor	
Other (specify)	

13. Livestock ownership

Livestock	Who owns them?	Number
Cattle		
Draft cattle		
Donkey		
Goats		
Sheep		
Poultry		
Rabbits		
Pigs		
Bee hives		
Fish ponds		
Other (specify)		

14. Household items owned

Item	Number
Radio	
Solar panel	
Television	
Phone	
Fridge	
Sewing machine	
Knitting machine	
Car	
Bicycle	
Motor bike	
Stove	
Sofa	
Chairs	
Table	
Bed	
Wardrobe	
Headboard	
Dressing table	
Kitchen unit	

15. Quality of main house (circle the number)

1) Brick under tile
2) Brick under thatch
3) Brick under asbestos
4) Brick under corrugated iron
5) Pole and dagga under thatch

16. How many times a week does your household consume the following?

Food Items	Times per week
Beans	
Meat	
Fresh vegetables	
Chicken	
Milk	
Eggs	
Potatoes	
Mufushwa	
Others (specify)	

17a. Are all your school going age children at school? Yes ☐ No ☐

17b. If some are not at school state the reasons:

17c. If yes, is it boarding or day?

18a. Number of people in respondent's household:

18b. Household members breakdown by age

	Number		Number of permanent residents	
Age	Female	Male	Female	Male
0 - 5 years				
6 - 10 years				
11 - 18 years				
19 and above				

19. How many people did you employ in 2001 as:

a) Casual labour number of men: number of women:

b) Permanent labour number of men: number of women:

20a. What are the advantages of the irrigation technology that you are using?

20b. What are the disadvantages of the irrigation technology that you are using?

Technical performance

21a. Is the equipment easy to operate? Elaborate.

21b. Is the equipment easy to maintain? Elaborate.

22a. What is the condition of the canals (any leakage)?

22b. What is the condition of the reservoir (any leakage)?

22c. What is the condition of the sprinklers (do they give all the same jet)?

23. Is water ponding on your plot?

24. Do all farmers receive the same amount of water?

25. Do you have an irrigation schedule?

Environmental performance

26. Do you have any erosion problems? Elaborate.

27a. Do you have problems with nutrient mining or are there any visible soil changes since you started using the scheme?

Yes ☐ No ☐

27b. If yes, explain.

28a. Do you have problems with waterlogging/drainage? Yes ☐ No ☐

28b. If yes, explain how big is the area affected?

29. How many members of your family suffered from the following diseases in year 2001:

Disease	Number
Malaria	
Bilharzia	
Diarrhoea	
Kwashiokor	

2. CHECKLIST FOR SCHEME-LEVEL RECORDS OF THE IRRIGATION MANAGEMENT COMMITTEE (IMC) AND THE AGRICULTURAL EXTENSION WORKER (AEW)

2.1. Checklist for the IMC

- Size of scheme
- Total area under irrigation
- List of irrigators (gender disaggregated)
- List of IMC members (name, post, sex)
- Details of other scheme committees
- Minutes/records of IMC meetings
- Details of scheme savings account(s)
- Details of scheme levies
- Schedule of maintenance fee payment
- Energy consumption/meter reading
- Energy (i.e. electricity or fuel) bills and payment schedule
- Water consumption/meter reading

- Water bills and payment schedule
- Details of breakdowns, repair and maintenance work undertaken in the scheme and costs associated with this
- Weights of different units of measurement for each crop used in the scheme
- Number of toilets in the scheme
- Copy of constitution and scheme by-laws
- Record of IMC courses attended
- Records of field days organized
- Irrigation schedule
- Record of health checks by Department of Health for bilharzia snails

2.2. Checklist for the AEW

Over and above the IMC records the AEW must also keep the following records:

- Crops grown in the scheme
- Total area per crop
- Cropping programme
- Recommended agronomic practices
- Details of courses run for committees and farmers and attendance
- Courses attended by the AEW
- Problems encountered-disease outbreaks, conflicts, etc.

3. CHECKLIST FOR EXPERTS DATA

3.1. Environmental expert

Environmental experts should assess/measure on a yearly basis the following:

- Soil pH
- Soil salinity, area affected, damage to crops, estimate of yield reduction
- Stream nitrate/chemical content
- Salinity in wells
- Erosion problems
- Drainage problems
- Condition of slope of all the plots
- Whether scheme causes water to pond (in fields, drains, main canal, field canals, structures, tanks may cause extra hazards for malaria and/or bilharzia

3.2. Irrigation engineer

The irrigation engineer should assess and advise on a regular basis on the following:

- Condition of irrigation equipment and irrigation infrastructure
- Uniformity of irrigation
- Amount of water used
- Irrigation efficiency
- Energy consumption
- Discharge rate