Annex 3.2

Guidelines for monitoring agricultural water use

Federal Democratic Republic of Ethiopia

Ministry of Water Resources

Food and Agricultural Organization of the United Nations

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GUIDELINES FOR MONITORING AGRICULTURAL WATER USE

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1. Introduction

A lot of efforts are being undertaken in water resources development and improved water management for different purposes and environmental benefits. However, information on water use for different purposes remains unknown. Irrigation policymakers and managers need information on the irrigation performance at various scales to devise appropriate water management strategies, in particular, considering declining water availability, further threats from climate change, and continually rising population and food demand. In practice it is often difficult to access sufficient water supply and use data to determine crop water consumption and irrigation performance. However, area developed under traditional and modern irrigation systems and performance of the different irrigation systems are also unknown. Lack of such information poses difficulties in proper planning and development of water-based programmes and projects. It is therefore imperative to monitor irrigation performance and water use for agriculture and other purposes.

The purpose of this manual is to provide guidelines for collecting and reporting data on agricultural water management (irrigated area, water use and other relevant information) and is prepared primarily for extension agents involved in irrigated and improved rainwater agriculture as well as in natural resources management. It provides guidelines for the completion of the data collection FORMAT and serves especially to:

- initialize the assessment of existing irrigations schemes;
- assist in planning and implementing sound data collection; and
- standardize reporting methods and techniques, enabling later comparison of data and results from different reports, projects, river basins and regions.

2. Purpose of Monitoring Water Use

While the main purpose of monitoring agricultural water management practices is to know the status of irrigated agriculture and agricultural water use to enable informed decision making, data collection and reporting has the following specific objectives:

- To have geo-referenced information of existing irrigation schemes to enable preparation of GIS-based information system.
- To study the existing conditions of irrigation practices, water management, cropping patterns, and cropping intensities in the project area.
- To investigate the physical conditions of irrigation systems and water distribution.
- To study the socio-economic conditions of the current water users of the irrigation schemes.
- To help plan irrigation system improvement interventions.

Information is very important for formulation of policy, development of strategies and undertaking appropriate interventions. Hence, an ultimate effort needs to be made to collect the correct data. One has to avoid guessing or estimating quantitative data unless there is a solid

ground and experience that enable making such estimates. A question for which there is no correct information should be answered by "NA (Not available)".

3. Type of Data and Sources of Information

The information and data to be collected are categorized into three parts:

1. Conventional irrigation schemes including small, medium and large-scale schemes. The information includes irrigated area, crops grown and production, water use and relevant socio-economic, environmental and health information for each irrigation scheme over 2.5 hectares.
2. Improved rainwater agriculture or water harvesting: irrigated area, crops grown and water use (aggregate of all micro-scale irrigated areas).
3. Soil and water conservation: Areas treated with different soil and water conservation measures.

As the types of data vary, so do the data sources. The main information sources are irrigation users, kebeles, woreda agriculture offices, river basin authorities and field observations. Users include irrigation cooperatives, individual users/farmers and investors/managers. The selection depends on the ease and reliability of the information to be collected. Information obtained from documents, users or woredas should be verified by field observation.

4. General Instructions

4.1 Data Collection Procedures

Data can be collected by a team of experts established for the purpose and woreda extension staff or development agents.

a) Data collection to be conducted by external team organized for the purpose

i) First explain the purpose of the survey for the Woreda Agriculture and Rural Development Office.
ii) Give a copy of the FORMAT for the woreda office.
iii) Take a list of traditional and modern irrigation schemes in the woreda including non-functional schemes equipped for irrigation.
iv) Get information on distances of the schemes and their accessibility conditions.
v) Plan the field survey in consultation with the woreda relevant staff.
vi) Ask the woreda office to assign staff to guide and facilitate the survey.
vii) In the field, first meet the kebele administration office or irrigation users' cooperative (if the latter exists) and explain the purpose of your being there and your plan.
viii) Ask for help in arranging a meeting with the beneficiaries of top, middle and tail plots of the irrigation system. Do not insist on the time and place but try to convince them.

ix) Discuss and decide on which one to undertake first: observing the irrigation system or holding of the meeting with the farmers.

x) In the meeting with the beneficiaries:
   - Sit down in a suitable shady place or possibly in the kebele office.
   - Make sure that every one is comforted.
   - Begin with traditional greetings in the local manner and extend your thanks for their coming to the meeting.
   - Introduce yourself and let the farmers introduce themselves.
   - Explain why you are there and explain the purpose of the survey but do not imply promises.
   - State that you are there to know about the irrigation scheme, learn and mean it. Inform them that you can visit the irrigation system.
   - The beneficiaries commonly elaborate on problems seeking any sort of assistance. Hence, advise them to avoid lengthy explanations of the problems and to answer specifically to the questions so that you can release them for their work.

xi) Having completed the questions, observe the irrigation system with the beneficiaries and take necessary measurements/estimates to validate the information from the beneficiaries. If an irrigation system observation is conducted before the meeting, you may raise additional questions based on the field observation.

b) Data to be collected by extension staff/development agent

If data is collected by the extension staff/development agent, there is a possibility that previous knowledge and recorded data about the irrigation scheme can be used in completing the FORMAT. However, some data could still be collected from the beneficiaries. In both cases care should be taken to avoid bias.

The FORMAT will enable the extension staff/development agents to record the type of data for next year reporting while they are doing their regular activities. Therefore, the woredas and the development agents should monitor the irrigation performance based on the parameters listed in the FORMAT.

In completing the FORMAT due consideration should be given to the following:

- All the blank spaces should be completed or all the questions should be answered subject to data availability.
- The information (both text and figures) should be clearly typed.
- Avoid use of abbreviations that are not indicated in the FORMAT.
- Do not use pencils.

4.2 Types of Questions and Responses

There are three types of questions:

- **Blank space and tables**: The tables and the blank spaces should be properly filled with appropriate data.
- **Yes/No-questions**: coded with Yes =1 and No=2
- **Choice-based questions**: These are coded with numbers.

For choice-based questions including Yes/No, tick marks should be put in the boxes corresponding to the number of the answer. As one question may have more than one answer, it is possible to provide appropriate answers by making tick marks on the boxes.

Some of the questions are repeated in different contexts. Therefore, care has to be taken to ensure the correctness and reliability of the data.

5. Technical Aspects of completing the FORMAT

5.1 Definitions of Variables

- **River basin**: This refers to major river basins such as Awash, Abbay, Tekeleze, etc.

- **Sub-basin**: This refers to hydrologic areas drained by tributaries to the river basins.

- **Catchment**: This refers to hydrologic areas drained by small streams.

- **Total estimated potential area**: This is the area than can be developed for irrigation. Water availability and topography as well as suitability for cultivation with good soil are the main criteria for estimating irrigation potential.

- **Total area equipped for irrigation**: This is the area for which irrigation structures are constructed and includes modern and traditional irrigation schemes of all scales (small, medium and large-scale irrigation schemes) as well as equipped spate and wetlands irrigation systems (Figure 1). It may be greater than, equal to or less than the estimated irrigable area.

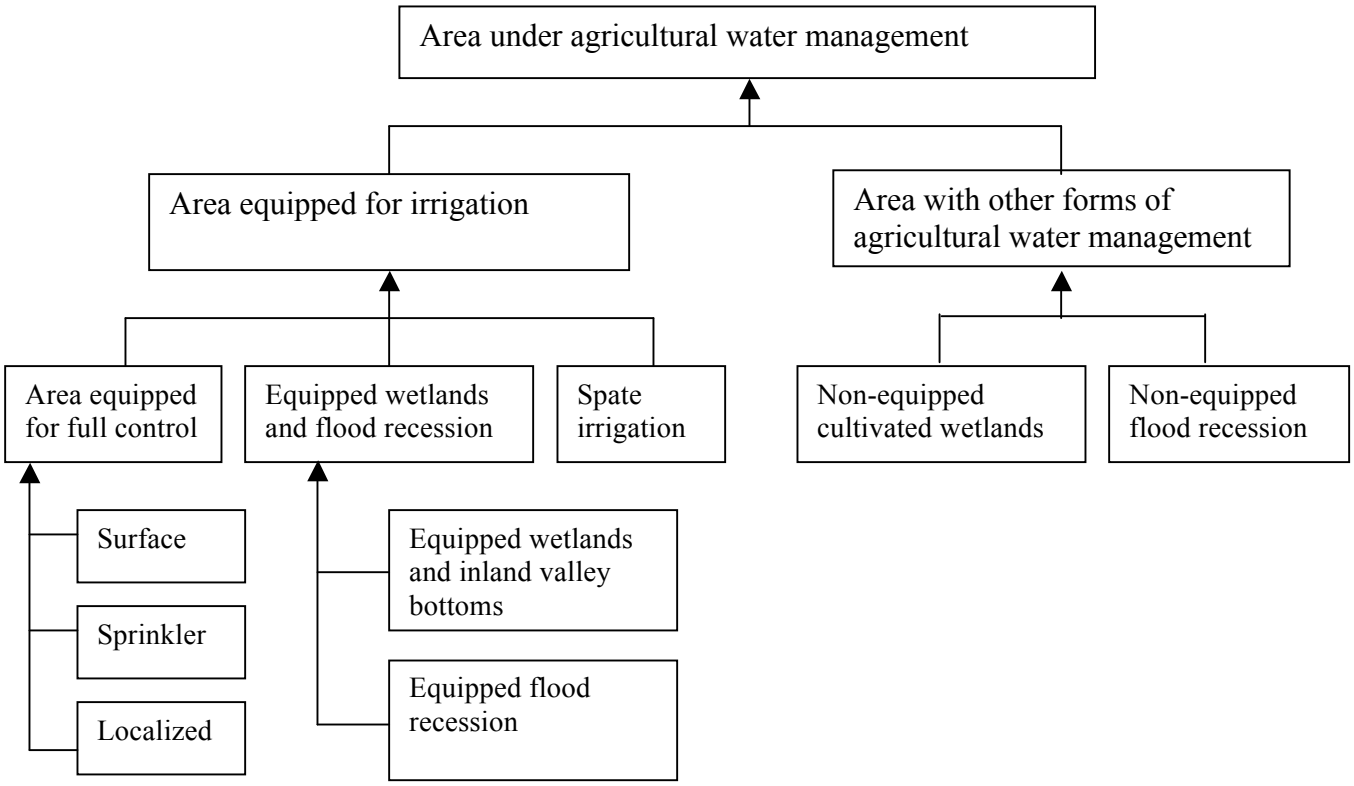
- **Actually irrigated area (physical)**: This is part or whole of the equipped area that is currently irrigated and cropped. It can be equal to the area equipped for irrigation (covered by irrigation structure/system) or less than the area equipped for irrigation.

- **Harvested irrigated area**: This is the irrigated area from which crops are harvested. Some crops on part of the irrigated area may not ripen or may be damaged by different factors including shortage of water, flood damage caused by untimely rainfall, pests, etc. Therefore, the harvested area may be smaller than the area actually irrigated.

- **Equipped wetlands**: This includes cultivated wetland and inland valley bottoms, which have been equipped with water control structures for irrigation and drainage (intake, canals, etc.) and areas along rivers, where cultivation occurs making use of water from receding floods and where structures have been built to retain the receding water

- **Spate irrigation**: This can also be referred to as floodwater harvesting and has two types: (1) floodwater harvesting within streambeds; and (2) floodwater diversion, where the floods - or spates - from the seasonal rivers are diverted into adjacent embanked fields for direct application. Figure 1 shows the category of areas under irrigation.

Figure 1: Categories of Area under Agricultural Water Management



In Ethiopia context, the irrigation schemes are grouped into the following:

- **Traditional irrigation**: These irrigation schemes are constructed by self-help programme of farmers on their own initiatives with the water sources mainly involving springs and river diversions constructed from local materials. The headwork structures are too weak to withstand small floods and hence are washed away frequently. The canal consists of mainly earthen canals without structures for distribution which is made simply from mud and stones.

- **Modern irrigation**: These are irrigation schemes with all types of water sources and irrigation structures involving concrete, masonry and gabion works constructed based on

professional designs and with complete or nearly complete canal networks. These are financed and constructed with external support such as government, NGOs and others.

- **Small scale**: Irrigation schemes with irrigated areas up to 200 hectares.
- **Medium scale**: Irrigation schemes with irrigated areas above 200 hectares and up to 3000 hectares.
- **Large scale**: Irrigation schemes with irrigated areas above 3000 hectares.

Considering ownership, irrigated areas are categorized into three:

- **Public Irrigation Schemes**: These comprise medium and large-scale irrigation schemes with areas owned and run by government enterprises.
- **Community irrigation schemes**: These include all irrigated areas owned and managed by the farmers. They can be traditional or modern irrigation schemes.
- **Commercial farms**: These include all irrigated areas owned and managed by private investors or farm enterprises for commercial purposes.
- **Individual farm**: This includes irrigated farm that is owned by one farmer or household and can be with modern or traditional irrigation structures.

5.2 Cropping Patterns of Irrigated Crops

5.2.1 Cropping Patterns

Data on cropping patterns for irrigated crops should be collected using Tables 1 of the FORMAT in Annex 4. The Table consists of columns for crops, area covered by each crop, planting and harvesting months, production data, actual irrigation water use and estimated irrigation water requirements.

Cropping patterns can be indicated with horizontal bars from the planting date to harvest date. They can also be presented in tables indicating the planting and harvesting dates. Considering the fact that one crop may be planted twice or three times per year, one crop with a suffix of numbers is indicated two or three times in the Table. The cropping pattern with suffix number one should be given for the first production season which is the beginning of European Year. If a crop is planted in the last quarter of the year and is about to be harvested in the first month of the following year, the suffix number should be two or three depending on whether a type of crop is planted twice or three times in that particular year.

Suppose onion is planted three times in an irrigation scheme with planting in October, January and May. The onion that is planted in January should be reported as Onion 1 and those in May and October plantings should be reported as Onion 2 and Onion 3 respectively.

5.2.2 Estimating Areas covered by each crop

While the total area equipped for irrigation is known, actually irrigated area in any cropping season is estimated. Areas of individual holdings are not also accurately known because land allocation or distribution was not made but based on scientific measures. Moreover, a farmer allocates his/her plot to different crops and no measurement is involved. Therefore, it is difficult to estimate areas covered by each crop. The farmers use local estimating measures such as '***timad***', '***kert***' and others and the sizes of these local measures are different depending on the localities. Usually one *timad/kert* is considered to be equivalent to a quarter of one hectare. However, the size of one *timad/kert* differs from one area to another depending on workability of soil and locality. Therefore, one has to measure different fields and calibrate the local measure either in terms of linear measure (m) or equivalent area (ha).

Example

Suppose a plot of land is estimated to be 2 *timad/kert'*and one *timad/kert* is equivalent to 0.25 ha. Then the area is

Area (A) = 0.25 ha x 2 = 0.5 ha

Suppose one 'timad /kert measures 45 m by 45 m.

A = 45 m x 45 m = 2025 m^2

Convert the area estimated into hectare by dividing the estimated area in m^2 by 10,000.

$$A = \frac{2025m^2}{10{,}000m^2} ha = 0.2025ha$$

Therefore, 2 *timad*s = 2 x 0.2025 = 0.405 ha

If the plot measures 55 m by 55 m

A = 55 m x 55 m = 3025 m^2

Then the area of the plot is

$$A = 2x\frac{3025m^2}{10{,}000m^2} ha = 0.605ha$$

Once, the local measure is calibrated in such manner, then collect information from the irrigation users on areas they planted for each crop. It is hoped that the development agents record cropping patterns, areas covered by each crop and time of planting. In such cases, areas occupied by each crop will be entered in Table 1 and the total cropped area will simply be the sum of all the areas allocated for different crops. The summation of the areas covered by each crop in any season should be less than or equal to the area actually irrigated in a specific season. If the sum

of areas under each crop in a particular season is more than the area actually irrigated in the same season the data should be checked.

Example

Consider an irrigation scheme of 45 hectares equipped with an irrigation structure. Assume actually irrigated areas in three planting seasons are 37, 40 and 44 hectares. If four crops are grown in the irrigation scheme the cropping pattern and areas under each crop are shown in Table 1 and Figure 1.

Table 1: Cropping pattern and production of irrigated crops

Crop Type	Area (ha)			Yield (qts/ha)	Planting and Harvesting Months		Water Use (MCM)		Irrigations	
	S1	S2	S3		Planting	Harvesting	IWR	Actual use	Interval	Number
A) Cereals										
1. Maize 1	20		→		January	May				
2. Maize 2		10			June	November				
3. Wheat 1	10				June	October				
4. Wheat 2		15 →			January	May				
B) Vegetables										
5. Onion 1	5				January	April				
6. Onion 2		15			May	August				
7. Onion 3			16		September	December				
8. Tomato 1	2				January	April				
9. Tomato 2			3		September	December				
Total	**37**	**40**	**44**							
Irrigation intensity	**269%**		II=	100 x Total Cropped area in different planting seasons per year (At) / Equipped or Actually Irrigated Area =100 x (37+40+448) / 45						

Note: S1, S2 and S3 are seasons 1, 2 and 3.

Figure 1: Cropping pattern and production of irrigated crops

Crop	J	F	M	A	M	J	J	A	S	O	N	D
Maize 1			**20**									
Maize 2									10			
Wheat 1								15				
Wheat 2			10									
Onion 1		5										
Onion 2						15						
Onion 3											16	
Tomato 1		2										
Tomato 2											3	
Total	**37**				**40**				**44**			

5.2.3 Crop Production

Knowledge on crop yields (production quantity per unit of land) is very important not because it measures productivity of land but also helps to determine the type of interventions to improve land or soil productivity. Farmers do not measure the quantity of harvests from their plots. Hence, crop yields from farmers' plots are in most cases estimate. Therefore, production quantity of each crop should be measured or estimated and the total quantity should be reported in the appropriate column of the FORMAT.

As yield will be affected by type of management and water availability as well as input use, the extension agents can measure crop yields based on two levels of stratification. The first is the location of plots at the top, middle and tail end of the irrigation system while the second is at farmers' level (plots of different farmers within the same location of the irrigation systems). Average yields of the different crops will be estimated and reported in the appropriate column of Table 1 in the reporting FORMAT.

If the FORMAT is to be completed by the external body, measurements will not be carried out. Instead, information will be collected from randomly selected irrigation users whose plots are located at the top, middle and tail end of the irrigation system.

5.3 Agricultural Water Use

5.3.1 Crop Production

5.3.1.1 Irrigation Water Requirement

Agricultural water withdrawal remains unknown in Ethiopia except in some large-scale irrigation schemes due to lack of flow measuring devices with the irrigation system. Crop and irrigation water requirements are estimated from climatic data for modern irrigation schemes. However, actual water withdrawal or water applied to crops often deviates from the estimate due to either

excess or shortage of water. On the other hand, water use should be known in order to determine the level of depletion of renewable freshwater resources and water productivity. But in the absence of water measuring facilities we need to resort to using empirical method to estimate agricultural water use from climatic data and crop properties.

Crop water requirement depends on climatic factors, crop type and growing stages of the crops. Four types of growth stages are generally considered.

If actual water uses or irrigation water requirements are not included in the filled FORMATs these have to be estimated. The estimate can be made for each irrigation scheme which is tedious and time consuming. Alternatively, the irrigation schemes can be categorized based on their agro-ecology setting and cropping patterns as provided in the filled FORMAT. That means, average cropping patterns will be prepared for representative agro-ecology zones based on the MoARD recent classification (Annex 2). These zones will be considered homogeneous in terms of types of irrigated crops grown, crop calendar, cropping intensity and gross irrigation efficiency. The cropping pattern proposed for the agro-ecological zone should be viewed as representative of an 'average' rather than a 'typical' irrigation scheme. To facilitate this categorization, a tool is included in the database which requires entering the cropping pattern data and agroecology. The tool generates cropping patterns with proportions of area under each crop in percentage.

Table 2: Crop growing Stages

Growing Stages	Descriptions
Initial stage	Germination and early growth, little of the soil (less than 10%) is covered with crop.
Crop development	Up to when the crop achieves full ground cover
Mid-season	From full cover is achieved to maturity, when leaves start to discolour or fall off. Flowering and fruit setting occurs during this phase.
Late	From mid-season until harvest.

Therefore, the methodology for estimating irrigation water requirement combines information on irrigated area, cropping patterns, crop coefficients and climate data to produce an estimate of net irrigation water requirement.

Calculation procedure for crop evapotranspiration (ETc) consists of the following steps:

1. Select the type of crops to be grown.
2. Establish planting dates.
3. Identify the crop growth stages and determine their lengths.
4. Select kc values from Table 7 for each growing stage.
5. Adjust the selected k_c values for frequency of wetting or climatic conditions during the stage.
6. Construct the crop coefficient curve (allowing one to determine k_c values for any period during the growing period).
   - Plot kc values at midpoints of growing periods and connect them.

- Construct a curve by connecting straight line segments through each of the four growth stages.
- Read kc values for any period during the growing stage.

7. Calculate ET_c as the product of ET_o and k_c

Crops vary in their nature of growth, that some crops like peas take short time to mature, while others need a long time (cotton). In the same manner, some crops need more water at full maturity than other, for example onions. Hence, the amount of water required by each crop varies daily and seasonally.

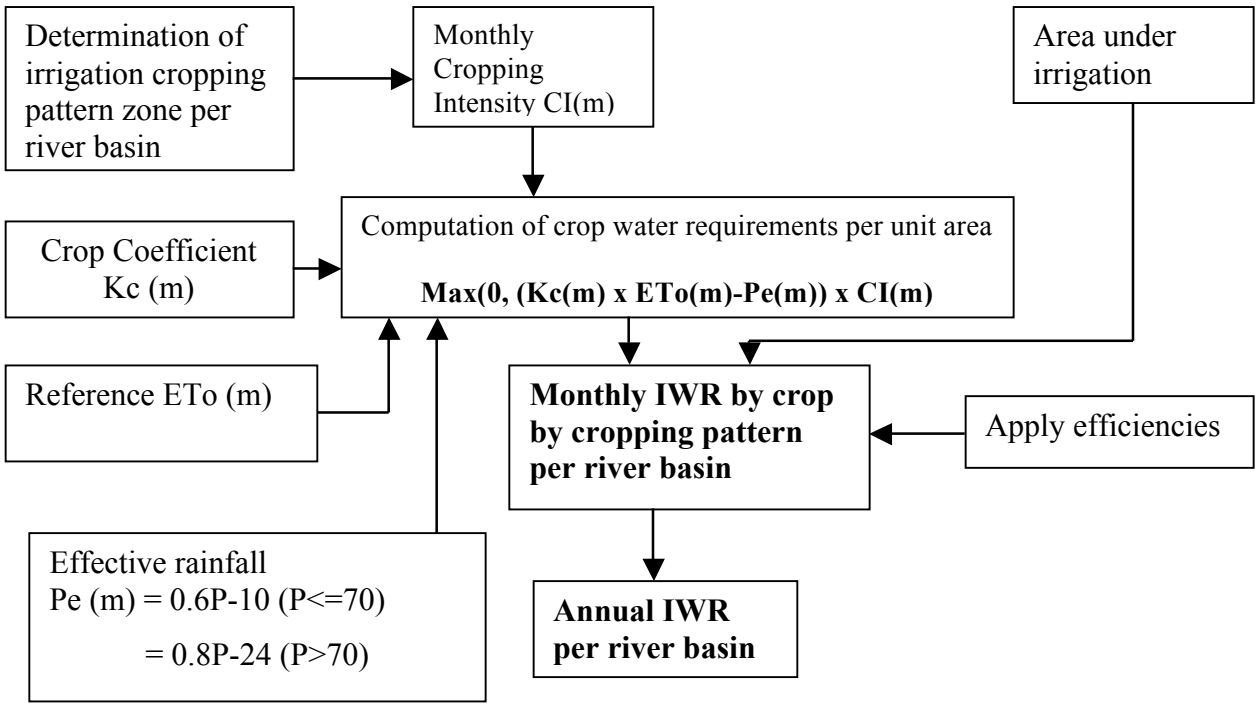


Figure 2 : Schematic Representation of Computing IWR

Irrigation water requirements can be computed based on the following formula:

$$IWRn\ (m) = \max(\ 0\ ,\ (\ (Kc(m) \times ETo(m)) - \mathbf{ETa(m)}\ )\ ) \times A \times CI(m)$$

Where:

IWRn	=	Net Irrigation water requirements to cover crop evapotranspiration
Kc	=	Crop coefficient
ETo	=	Reference evapotranspiration (mm) per month
ETa	=	Actual evapotranspiration (mm)
A	=	Actual irrigated area (without considering double cropping)
CI	=	Cropping intensity
m	=	Monthly time step of the calculation.

Estimation of **ETa** requires conducting water balance study for a river basin using soil-water balance model for which time series hydrological and meteorological data and soil data as well as geo-referenced spatial data are needed.

Because these data are lacking, irrigation water requirements will be estimated using the following formula:

$$IWRn(m) = \max(0 , (Kc(m) \times ETo(m) - Pe(m)) \times A \times CI(m)$$

Where Pe is effective rainfall (mm) estimated from the following

$$Pe = 0.6P-10 \text{ for } P<=70$$

$$= 0.8P-24 \text{ for } P>70$$

Where P = monthly rainfall in mm

Efficiency factor has to be applied to the net irrigation water requirement to take into account the conveyance, distribution and application losses. It will not be wise to apply one efficiency factor at national level because irrigation efficiencies do vary according to socio-economic conditions, type of soils, irrigation system and availability of water. Therefore, different efficiency values have to be applied to each agro-ecology zone.

As shortage of water supply is prevalent in most of the irrigation schemes, crop demands may not be met or there may be excess irrigation. Hence, estimated irrigation water requirements cannot be equated to actual water withdrawal. Therefore, irrigation efficiency (E) in the range of 35-60 must be applied depending on the irrigation system.

Irrigation water requirement is then obtained through the following equation:

$$IWRg = \frac{IWRn}{E}$$

Where IWRg = gross irrigation water requirement
IWRn = irrigation requirement; and
E = irrigation efficiency for a given type of irrigation system

<u>Example: Calculation of ETc for Onion in Sewir Irrigation Scheme- North Shewa, Amhara</u>

Table 3: Crop data

Crop	Onion
Planting date	15 September
Harvesting date	30 December
Soil type	clay

Table 4: ETo for Shewa Robit

Month	S	O	N	D
ETo (mm/day)	4.9	4.7	4.0	4.7
Rainfall (mm)	110	21.3	15.6	0

Step 1: Determine growth stages of the crops (column 2) of Annex 1
Step 2: Indicate ETo Values with Growth Stages (Column 3)

ETo for Onion during initial and development stages:

ETo = 15x 4.9 + 5 x 4.7 = 97 mm and ETo = 25x 4.7 + 25 x 4 = 221.5 mm

Step 3: Select Kc values from Table 4 for each growing stage (column 4)

Step 4: Estimate Net irrigation water requirement (NIWR)

NIWR = ETc – effective Rainfall (Pe)

All the rain that falls is not beneficial to plant growth. Some is lost to evaporation, percolation and runoff. Hence, only effective rainfall is considered in estimating irrigation water requirement. Effective rainfall is estimated as follows:

Pe = 0.8P-24 for P > 75 mm/month

Pe = 0.6P-10 for P <75 mm/month

Pe = dependable effective rainfall
P = monthly mean rainfall

Step 4: Estimate Gross Irrigation Water Requirement (GIWR)

The gross irrigation requirements account for losses of water incurred in canals and application to the field. This is expressed in terms of efficiencies when calculating gross irrigation requirements from net irrigation requirements as shown below:

Gross irrigation water depth (GIR) = $\frac{NIWR}{E}$ Where, E = Irrigation efficiency

The following irrigation efficiencies can be applied depending on the irrigation system (surface, sprinkler and localized/drip) and local irrigation practices for surface irrigation system (furrow, border, basin and wild flooding).

Table 5: Typical Irrigation Efficiencies for Different Irrigation Systems

Description	%
1. Surface irrigation System	30-40
2. Sprinkler efficiency	80-90
3. Drip/localized irrigation efficiency	90-95

Table 6: Kc values for different Growth Stages of Onion

		Growth Stages				
Crop	**Calculation**	**Initial stage**	**Crop development stage**	**Mid-season stage**	**Late season stage**	**Total**
Duration (days)		20	50	20	15	105
Months		15 Sept-5 Oct	6 Oct-25 Nov	26 Nov-15 Dec	16-30 Dec	
Kc values		0.5	0.75	1.05	0.85	0.8
ETo (mm)		97	221.5	91.2	65.8	**475.5**
ETc (mm)	Kc x ETo	48.5	166.1	95.8	55.9	**366.3**
P (mm)		110	21.3	15.6	0	**146.9**
Pe (mm)	0.6P-10 or 0.8P-24	32.5	2.3	0	0	**34.8**
NIWR (mm)	ETC-Pe	16	163.8	95.8	55.9	**331.5**
GIWR (mm)	NIWR/E	32	327.6	191.6	111.8	**663.**

E = efficiency of 50% is considered.

Volume of GIWR for 1 ha for one season = $\frac{\text{Tot x Area (ha) x 10000}}{1000}$ = 10A x Tot m^3.

= 10 x 1 x 663 m^3= 6,630 m^3

This should be multiplied by the total irrigated area planted with onion.

Similarly, GIWR should be calculated for all planted crops for each season. For example, 4 crops are planted in one season and 5 crops in a second season, the total water taken from the water sources or irrigation water withdrawal (IWW) for one year is the sum of GIWRs of all crops:

IWW = GIWR11 + GIWR12 + GIWR13 + GIWR14 + GIWR21 + GIWR22 + GIWR23 + GIWR24 + GIWR25

Where,

GIWR11, GIWR12, GIWR13 and GIWR14 are GIWR for each crop in season one

GIWR21, GIWR22, GIWR23, GIWR24 and GIWR25 are GIWR for each crop in season two

If irrigation is applied before planting, that has to be added to the above gross irrigation water requirement. This can be estimated using one of the following methods if these parameters can be estimated based on canal measurements explained in Section 5.3.1.2 below.

$V_{pr} = 3.6QT$ OR $V_{pr} = 10AD$

Where,
V_{pr}= Volume of water applied before irrigation (m^3)
Q = Canal discharge (l/s)
T = Duration of irrigation (hrs)
A = Irrigated area (ha)
D = Depth of irrigation (mm)

Similar to irrigation water requirements, irrigation scheduling is also determined for modern irrigation schemes during design. However, actual irrigation intervals and durations of irrigation as well as quantity of water applied per irrigation per crop are different from the recommended parameters. Irrigation frequency is set and adopted based on local experience and water availability similar to traditional schemes.

Therefore, irrigation intervals and number of irrigations per crop should be reported for each growing season in order to enable reasonable adjustment of reported irrigation water requirements. For this, the extension agents and the farmers should record irrigation intervals and total number of irrigations for each crop for each growing season.

Pump irrigation

For pump irrigation water use can be estimated as follows:

- Record the pump discharge (Q) is known and duration of pump operation per day (T)
- Record the duration (T) the pump is operated per day and number of days (N) the pump was operated during the cropping season.

$$V_p = 3.6 Q_p T \text{ N}$$

Where,

V_p = Volume of water applied before irrigation (m^3)

Q_p = pump discharge (l/s)

T = duration of irrigation (hrs)

N =Number of days the pump was operated

If discharge and duration per day vary, the volume of water can be estimated by summing daily volume of water pumped.

$$Vp = 3.6 \sum_{i=1}^{N} Q_i T_i$$

Q_i = pump discharge (l/s) in each day

T = duration of irrigation per day (hrs)

5.3.1.2 Estimating Canal Discharge

It is obvious that none of the small-scale irrigation schemes have flow measuring structures incorporated with irrigation structures. Hence, it is difficult to estimate the amount of water abstraction and flows in different canals and into irrigation plots. On the other hand, the amount of water used for irrigation should be estimated. In the absence of any measuring device, we need to resort to a method that does not require structure/device for measurement. The simplest technique is float method which is familiar for most of development agents with agricultural, civil and hydraulic engineering background. While the method is quick and cheap to estimate discharge in a canal, it is not very accurate and errors of at least 10 percent can be expected.

The method consists of estimating the average flow velocity, and measuring the area of the cross-section, called the 'wetted cross-section. The discharge can be calculated by the following formula:

$Q = VA$

Where: Q = discharge in m^3/s;
V = average flow velocity in m/s; and
A = area in m^2 of the wetted cross-section.

If one wants to know the discharge in l/s instead of m^3/s, multiply it by 1 000 as follows

$Q = 1\,000 \times VA$

a) Average Flow Velocity

To estimate the average flow velocity, the flow velocity of the water at the surface, the surface velocity, Vs, is first determined. The surface velocity is determined as follow:

- Select a straight and uniform canal reach, measure it as shown in the Figure below and mark the starting and ending points.
- Place the floating object in the centre of a canal at the upstream mark, and record the time taken by the float to reach the downstream mark. Repeat the measurement at least three times to avoid mistakes.
- Record the lengths and times in the appropriate FORMAT as show in the table (the table enables measurements at three different canal reaches).
- Take Average values of the time records.
- Estimate the surface velocity (Vs) by dividing reach length by average time (Vs= L/T).
- Because surface velocity is faster than flow velocities at depths, average velocity can be estimated by multiplying surface velocity by a factor k. For most earthen irrigation canals this reduction factor, k is about 0.75-0.8 while 0.9 is appropriate for lined canal.

Average velocity,

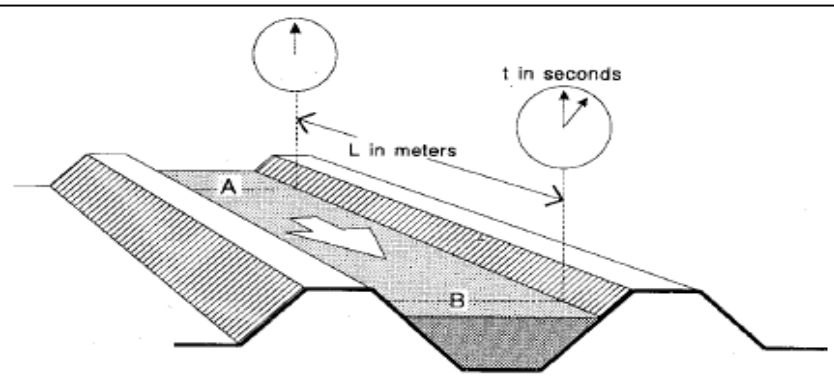


Figure 2: Measuring the surface flow velocity

b) Calculating area of the wetted Cross-section and discharge

Earth canals have trapezoidal cross-sections.

Steps for calculating the wetted cross-section of the trapezoidal section:

- Measure the bottom (B) and top (T) widths of the canal and depth (D) of flow at the selected canal reach as shown in the figure below.
- Take different measurements at different cross sections within the selected canal reach and calculate average figures by dividing the records by the number of measurements in each case.
- Calculate the area of the wetted cross-section (A) by the formula:

$$A = \frac{(B+T)}{2} D$$

B, T and D represent bottom width, top width and depth of the canals as shown in Figure 2.

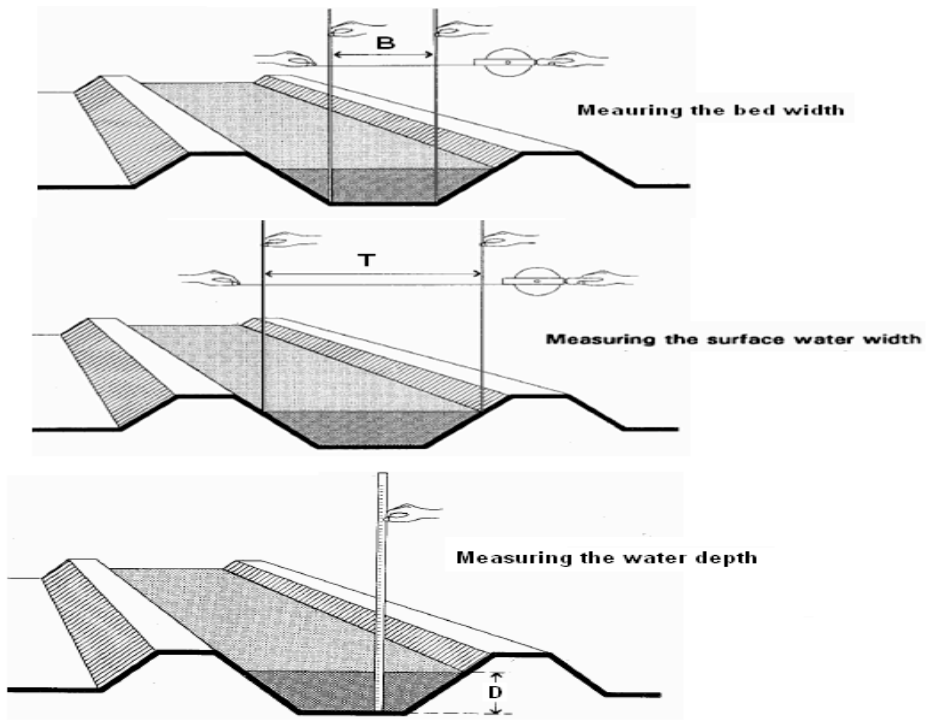


Figure 3: Canal Dimensions

Table 7: FORMAT for recording measurements (three different canal reaches)

Description	**Long.**		**Lat.**	**Long.**		**Lat.**	**Long.**		**Lat.**
Location of reaches									
Lengths of canal reaches (L)	L1			L2			L3		
Time taken for float to travel through the reach length	T1	T2	T3	T1	T2	T3	T1	T2	T3
Average time (T=(T1+T2+T3)/3)									
Surface flow velocity (Vs=L/T)									
Average flow velocity (V=kVs)									
Discharge (Q= VA)									

Record the number of hours per day and the number of days this flow continued and then multiply discharge by total seconds.

<u>Example</u>:

If the measured discharge is 0.50 l/s and it continued flowing for 5 days, the volume of water is calculated as follows:

Number of seconds per day = 24 hours x 60 minutes x 60 seconds = 86400 seconds

Volume = Q T = 0.5 m^3/s x 5 days x 86400 seconds = 216 000 m^3
If the same flow continued for the growing season of about 4 months, the total water taken from the water source will be as follows:

Volume = 0.5 m^3/s x 120 days x 86400 seconds = 518 400 m^3.

5.3.2 Livestock

Livestock water use per head varies with type of animal, differing climates and differing animal-husbandry practices. However, to avoid the complexities, it is proposed to have an average consumption rate irrespective of agro-ecology setting. Therefore, it is best to collect information on types and number of animals from each catchment or sub-basin or kebele/woreda that falls with a catchment, sub-basin or basin. The ranges of daily water requirements of animals are listed in Table 9.

Table 8: Livestock Water Consumption Rates

No	Type of Animal	Water Consumption Rate per head per day (litres)
1.	Cattle	25-35
2.	Sheep and goats	4-5
3.	Equine (horse, mule, donkey)	20-25
4.	Camel	50-70
5.	Poultry	0.15-0.20

Livestock water use can be estimated using the following formula
Annual Livestock Water Demand = 365.25 days x Consumption rate x Number of livestock

5.4 Other Relevant Data

The monitoring of irrigation performance will not be limited to irrigated area and water use but it also needs to cover other relevant information required for complete monitoring of the status of the irrigation schemes aimed at improving the performance. These include the data on:

- **Difference between equipped and irrigated areas:** Actually irrigated areas are often less than the equipped areas due to a number of reasons including unforeseen upstream abstraction, natural reduction of river flow, excessive water losses, damage of irrigation infrastructure and others. Hence, it is very important to know the reason for discrepancy between equipped and actually irrigated areas.

- **Status of irrigation schemes:** An irrigation scheme could be functional, semi-functional or non-functional due to system failure, water shortage or any other reasons or a combination of these. If all the equipped area is irrigated as designed, the irrigation scheme is considered to be fully functional. If part of the irrigation scheme is irrigated due to structural failure or water shortage or any other reason, it can be considered as semi-functional. If irrigation is not practised at all, the irrigation scheme is non-functional. Semi-functionality or non-functionality of an irrigation scheme can be explained by the difference between the equipped and actually irrigated areas. If no area is actually irrigated, the irrigation scheme is non-functional. If actually irrigated area is less than the equipped area, the irrigation system is semi-functional. Hence, possible reasons can be drying of water source, structural damage, siltation of dams or any others.

- **Water management**: This refers to water distribution within the irrigation systems, irrigation scheduling (irrigation interval, how much to apply and duration) and responsible body for water distribution. This is also related to how irrigation users are organized for equitable water distribution and cropping plans (cropping pattern and calendar). Measures taken by the farmers to cope with water shortage are part of the water management.

- **Operation and maintenance**: Operation of an irrigation scheme is simply opening and closing of intake and canal gates for water distribution while maintenance includes planning for maintenance, cost and source of funding. The questions are self-explanatory for answering.

- **Socio-economics**: Information on number of planned/initial and actual beneficiaries by gender, water users' organizations, members of executive committee by gender and basis of water charges. These data can easily be found from the users' organizations (if these exist) or in the discussion from the beneficiaries and woreda agriculture and rural development offices.

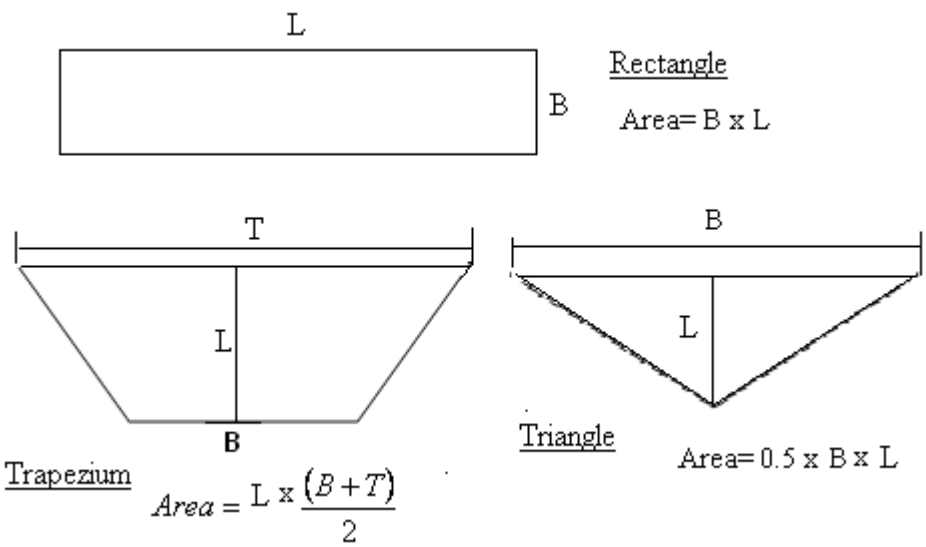
- **Environmental and health problems**: The information on these is very valuable for devising and taking measures to solve the problems. Therefore, one should monitor whether an observed environmental and health problem is related to irrigation.

Ready-made data on area abandoned due to salinity, waterlogged area due to excessive irrigation, eroded area due to improper irrigation and area encroached by flood or riverbank erosion are not available. These have to be estimated based on field observations/measurements:

- Estimate or measure the length and width of the affected area by measuring tape or pacing.
- If the area affected is irregular, divide the area into regular sections (rectangles and triangles).
- If an area under consideration is a long strip with different widths along its length, take some measurements at critical sections and calculate average value of the width. Then multiply the length by the average width.

The calculated area should be converted to hectare by dividing it by 10 000.

Areas of regular sections



5.5 Data on Improved Rainwater Agriculture and Soil and Water Conservation

Improved Rainwater Agriculture includes micro-catchment and macro-catchment water harvesting systems. In this category equipped spate irrigation system, equipped and unequipped wetland irrigation, flood recession, areas using communal and individual ponds, household water harvesting facilities including roof and land catchment sources as well as hand-dug wells are considered.

Household level water harvesting systems use different irrigation application systems such as surface, sprinkler and drip. Therefore, information on area irrigated by each type of

system and water source should be collected. The tables in the data collection FORMAT are simple to be completed provided data are available.

5.6 Data on Soil and Water Conservation

Information on this is not related to agricultural water use. But treatment of degraded lands with different soil and water conservation measures is very important for conservation of water resources. Therefore, data on areas treated with different soil and water conservation measures should be collected. The measures are categorized into four: physical measures (structures such as different types of bunds, checkdams and terraces), biological measures (grass strips, agro-forestry, and plantations for the purpose of conservation of degraded lands), combined measures and area closure. The information needs to be collected according t6o major land use types and catchment level.

If data is not available by category, an aggregate data should be inserted in “Both Measures” column and remarks should be given.

Annex 1

Crop Coefficient (Kc)

Crops	Initial	Crop development	Mid-season	Late & harvest	Depth of Root system (cm)	Depletion level (%)
Seasonal						
• Beans (dry)	0.35 (20)	0.70 (30)	1.00 (40)	0.90 (20)	50-70	0.45
• Cabbage	0.45 (20)	0.75 (25)	1.05 (60)	0.90 (15)	40-50	0.45
• Carrot	0.45 (20)	0.75 (30)	1.05 (30)	0.90 (20)	50-100	0.35
• Cotton	0.45 (30)	0.75 (50)	1.15 (55)	0.75(45)	100-170	0.65
• Cucumber	0.45	0.7	0.90	0.75	70-120	0.50
• Groundnut	0.45 (25)	(35)	1.00 (50)	0.75 (20)	50-100	0.40
• Lettuce	0.45 (20)	0.60 (30)	1.00 (15)	0.90 (10)	30-50	0.30
• Maize	0.40 (20)	0.75 (35)	1.15 (40)	0.75 (30)	100-200	0.60
• Onion	0.50 (20)	0.75 (45)	1.05 (20)	0.85 (10)	30-50	0.25
• Peas	0.45 (20)	0.80 (25)	1.15 (35)	1.05 (15)	60-100	0.35
• Pepper	0.35 (30)	0.75 (35)	1.05 (40)	0.90 (20)	50-100	0.25
• Potato	0.45 (25)	0.75 (30)	1.15 (30)	0.75 (20)	40-60	0.25
• Sorghum	0.35 (20)	0.75 (30)	1.11 (40)	0.65 (30)	100-200	0.55
• Sugar beet	0.45 (25)	0.80 (45)	1.15 (60)	0.80 (45)	70-120	0.50
• Tomato	0.45 (25)	0.75 (40)	1.15 (40)	0.80 (25)	70-150	0.40
• Wheat	0.35 (15)	0.75 (30)	1.15 (65)	0.70 (40)	100-150	0.55
Permanent	Young	Mature				
• Alfalfa	0.35	0.85			100-200	
• Banana	0.50	1.1			50-90	
• Citrus	0.30	0.65			120-150	
• Sugar cane	0.45-0.85	1.15-0.65			120-200	

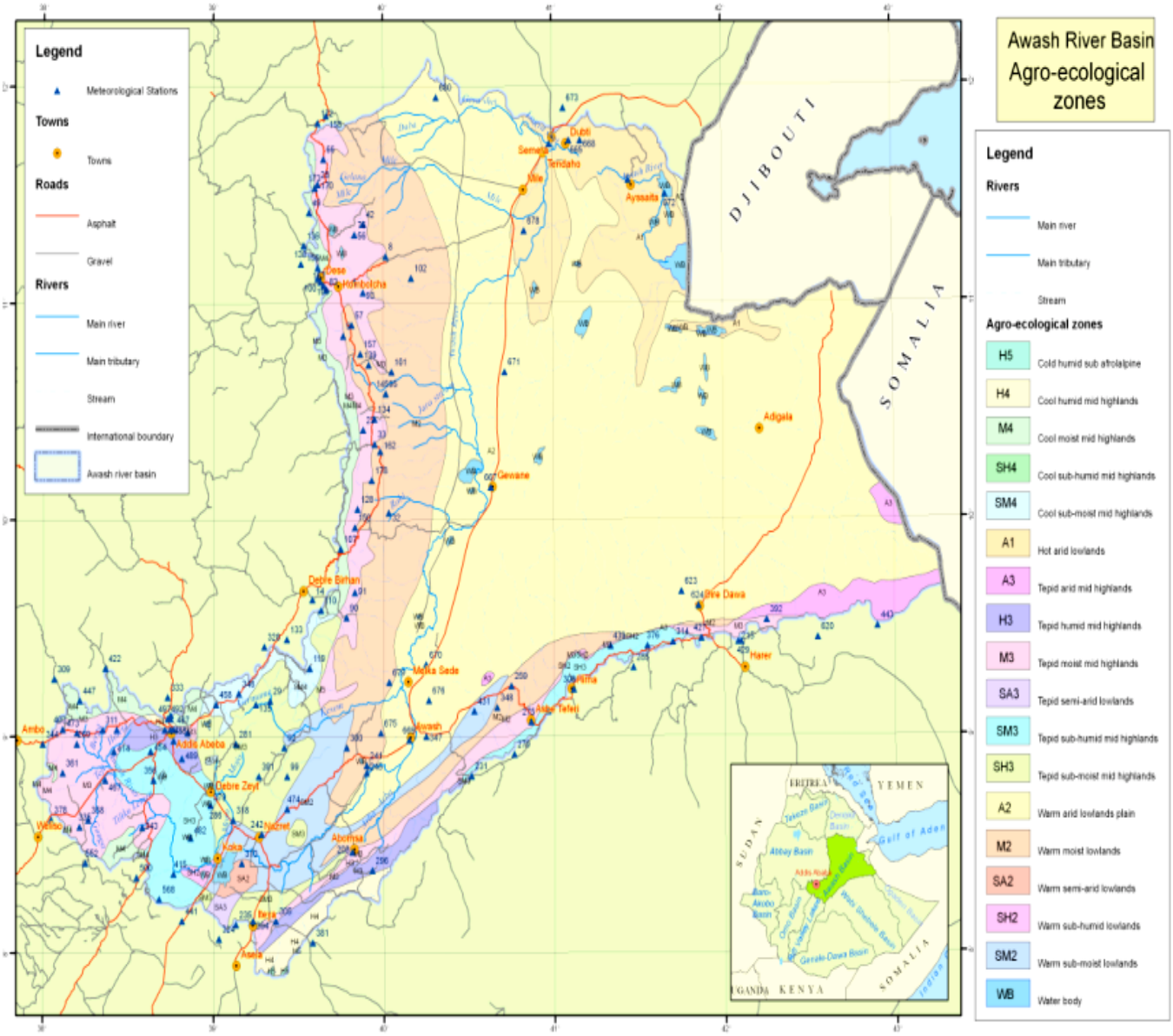
Source: FAO I & D paper 24 (1977) and I & D 33 (1979)

Annex 2

Major Ethiopian Agro-Ecological Zones

Designation	Description
A1	Hot arid lowland plains
A2	Warm arid lowland plains
A3	Tepid arid mid highlands
SA1	Hot semi-arid lowlands
SA2	Warm semi-arid lowlands
SA3	Tepid semi-arid mid highlands
SM1	Hot sub-moist lowlands
SM2	Warm sub-moist lowlands
SM3	Tepid sub-moist mid highlands
SM4	Cool sub-moist mid highlands
SM5	Cold sub-moist mid highlands
SM6	Very cold sub-moist mid highlands
M1	Hot moist lowlands
M2	Warm moist lowlands
M3	Tepid moist mid highlands
M4	Cool moist mid highlands
M5	Cold moist sub-afro-alpine to afro-alpine
M6	Very cold moist sub-afro-alpine to afro-alpine
SH1	Hot sub-humid lowlands
SH2	Warm sub-humid lowlands
SH3	Tepid sub-humid mid highlands
SH4	Cool sub-humid mid highlands
SH5	Cold sub-humid sub-afro-alpine to afro-alpine
SH6	Very cold sub-humid sub-afro alpine to afro-alpine
H2	Warm humid lowlands
H3	Tepid humid mid highlands
H4	Cool humid mid highlands
H5	Cold humid sub-afro-alpine to afro-alpine
H6	Very cold humid sub-afro-alpine
PH1	Hot per-humid lowlands
PH2	Warm Per-humid lowlands
PH3	Tepid Per-humid mid highland

Annex 3: Agro-Ecological Map of Awash River Basin



Annex 4: Data Collection Format for Irrigated Agriculture

Food and agriculture Organization of the United Nations

AGRICULTURAL WATER USE MONITORING MANUAL

A) Irrigation Scheme

B) Improved Rainwater Agriculture

C) Livestock Population by Type and Water use

D) Soil and Water Conservation Measures

Yibeltal Tiruneh
Irrigation Engineer

December 2009
Addis Ababa,
Ethiopia

FORMAT FOR REPORTING AGRICULTURAL WATER USE AT IRRIGATION SCHEME LEVEL (For areas including 2.5 ha and above)

Reporting Year:

Name of Reporter: _____

No	Data Variables	1	2	3	4	5	6	7	8	9	10	11	12
I	**Irrigation scheme, and water sources and outlays**												
1.	Name of irrigation Site:												
2.	**Source of Water** **Surface water**: 1=river 2= dam 3= pond 4= natural lake **Groundwater**: 5= hand dug well 6= Shallow well 7=Deep well 8= Spring **Others**: 9= agricultural drainage water 10= others												
3.	Method of water abstraction: 1=diversion 2= dam 3= motor pump 4= Human powered pump												
II	**Irrigation Distribution System and Command Area**												
4.	Irrigation system: 1=surface 2=sprinkler 3= drip/localized												
5.	Typology of irrigation scheme: 1= Traditional 2 =Modern 3=Equipped spate 4= Equipped wetland 5=Non-equipped wetland 6=Non-equipped flood recession												
6.	Setting of irrigation scheme 1= Rural 2=Urban/Peri-urban												
7.	Area irrigated during the reporting year a) Area equipped for irrigation (ha)												
	b) Actually irrigated area (ha)												
	c) Harvested area (ha)												
8.	If actual irrigated area is less than equipped area, what are the reasons? 1= Damage on headwork 2= Damage on canal 3 = Natural flow reduction 4=Shortage of water due to upstream users 5=headwork damage and water shortage 6=canal damage and water shortage 7= other												
9.	Irrigated area equipped with drainage system (ha)												
10.	Water used for irrigation a) Actual water withdrawal, if measured ('000 m^3)												
	b) Estimated irrigation water requirement ('000 m^3)												
III	**Environment and Health information**												
11.	Environmental Problems:												
	a) Area salinized and abandoned (ha)												
	b) Waterlogged area (ha)												
	c) Eroded area due (ha)												
	d) Eroded area (ha)												
12.	What health problems have been observed since irrigation started? 1=Malaria epidemic 2=Bilharzia 3 =other (specify): _____												
13.	Number of people affected by water-related diseases												

No	Data Variables	1	2	3	4	5	6	7	8	9	10	11	12
IV	**Investment and Maintenance**												
14.	Name of funding agency:												
15.	Name of implementing agency:												
16.	Year construction started:												
17.	Year construction completed:												
18.	Year when first irrigation started:												
19.	Value of Investment or construction cost:	Birr_____ or US$_____											
20.	Average annual maintenance cost:	Birr_____ or US$_____											
21.	Who covers maintenance cost: 1 = Users' annual water charge 2 = Users contribute at system failure 3 = Users' annual water charge and Region/Woreda 4 = Users' contribution and Region/Woreda 5 = others												
V	**Present Status of irrigation scheme**												
22.	What is the current status of irrigation scheme? 1=Functional 2=Semi-functional 3=Non-functional												
23.	If non-functional or semi-functional, what is the reason 1= Water source dried up 2= Infrastructure damaged 3= Dam silted 4= other:_____												
24.	Ownership of the scheme: 1 = public 2= community 3 = Commercial farm 4=Individual												
VI	**Socio-economics**												
25.	Beneficiaries a) Number of planned or Initial beneficiaries												
	b) Number of actual beneficiaries (households)												
	c) Actual number of male beneficiaries (households)												
	d) Actual number of female beneficiaries (households)												
26.	Type of irrigation organization for the management of the irrigation scheme: 1=Irrigation cooperative 2=Water users' association 3=Traditional water committee 4=Not organized												
27.	If organized, name of water user organization												
28.	If organized, number of organization members												
29.	Number of executive members by gender	Male:_____ Female: _____											
30.	If all beneficiaries do not have equal access to water what is the priority of access to irrigation water? 1= male 2=female 3= male youth 4= female youth 5= male old 6 = female old, 7= kebele officials 8= water users executive members 9 = religious leader 10= influential community members 11= clan leader 12 (other specify):_____												
31.	If beneficiaries pay water charges, basis of water charge: 1=Only irrigated area 2= Crop type and area 3=Fixed rate by all users												

No	Data Variables	1	2	3	4	5	6	7	8	9	10	11	12
VII	**Location of Irrigation Scheme**												
32.	Hydrological Location a) River Basin												
	b) Sub-Basin												
	c) Catchment												
33.	Administrative Locations a) Region												
	b) Zone												
	c) Woreda												
	d) Kebele												
34.	Agro-ecology (designation)												
35.	Altitude (metres above sea level)												
36.	Geographic coordinates	Water abstraction point*						Center of command area					
	Latitude/North (deg)	_____						_____					
	Longitude/East (deg):	_____						_____					
	Altitude (masl)	_____						_____					

msal = metres above sea level

37. Cropping patterns and production

Table 1: Irrigated Agriculture: Cropping pattern and production of irrigated crops

Crop Type	Area (ha)	Production (qtl)	Planting and Harvesting Months												Water Use ('000 m^3)	
			J	F	M	A	M	J	J	A	S	O	N	D	Actual use	IWR
A) Cereals																
1. Maize																
2. Maize																
3. Wheat																
4. Wheat																
5. Sorghum																
6. Sorghum																
7. Rice																
8. Rice																
9. Barley																
B) Vegetables																
10. Onion																
11. Onion																
12. Onion																
13. Garlic																
14. Garlic																
15. Tomato																
16. Tomato																
17. Carrot																
18. Carrot																
19. Cabbage																
20. Cabbage																
21. Pepper																
22. Pepper																
23. Lettuce																
24. Swiss chard																
25. Swiss chard																
26. Other vegetables																
27. Other vegetables																
C) Pulses																
28. Beans																
29. Beans																
30. Peas																
31. Peas																
32. Chickpeas																
33. Chickpeas																
34. Groundnuts																
35. Groundnuts																
36. Lentils																
37. Lentils																
D) Root crops																
38. Potato 1																
39. Potato 2																
40. Sweet potato																
41. Sweet potato																
42. Beet roots																
43. Beet roots																

Crop Type	Area (ha)	Production (qtl)	Planting and Harvesting Months												Water Use ('000 m^3)	
			J	F	M	A	M	J	J	A	S	O	N	D	Actual use	IWR
44. Other root crops																
E) Fibre crops																
45. Cotton 1																
46. Cotton 2																
F) Oil crops																
47. Niger seed																
48. Flax seed																
49. Sesame																
50. Sesame																
G) Fruits																
51. Banana																
52. Papaya																
53. Citrus																
54. Mango																
55. Avocado																
H) Sugar cane																
I) Flowers																
J) Grasses																
Total Area																

IWR = Irrigation water requirement '000m^3= in thousands of cubic metres qts= quintals ha=hectare

Part B: Area Developed under Improved Rainwater Agriculture
Woreda Aggregate of Irrigated Areas below 2.5 hectares
Only part of the Woreda falling in a particular Basin

I. Location Data

1. River Basin:_____
2. Sub-Basin:_____
3. Region: _____
4. Zone: _____
5. Woreda: _____

II. Improved Rainwater Agriculture

6. Area irrigated under improved rainwater agriculture

Type of water harvesting system	Irrigated Area (ha)	Agricultural water use ('000 m^3)	
		Actual use (if measured)	Irrigation water requirement (IWR)
a) Water harvested in ponds			
b) Spate irrigation			
c) Wetland irrigation			
d) Flood recession			
e) Water harvested in household water storage systems			
f) Others			
Total area			
Total harvested area			

7. Area irrigated under improved rainwater agriculture by type of system and water abstraction

Description	Ha
a) Area irrigated by type of Irrigation system	
• Surface irrigation	
• Sprinkler irrigation	
• Localized/drip irrigation	
Total area	
b) Area irrigated by water abstraction	
• Surface water	
• Groundwater	
Total area	
c) Area irrigated by water source	
• Surface water	
• Groundwater	
Total area	

Note: The Total area under 6, 7a, 7b and 7c should be equal.

8. Beneficiaries
   a) Total beneficiaries: _____
   b) Male beneficiaries: _____
   c) Female beneficiaries: _____

9. Crops grown under water harvesting systems

Crop	Irrigated Area (ha)	Production (qt)	Cropping calendar												Water use ('000 m^3)	
			J	F	M	A	M	J	J	A	S	O	N	D	Actual	IWR
Vegetables																
1. Onion																
2. Onion																
3. Tomato																
4. Tomato																
5. Cabbage																
6. Cabbage																
7. Kale																
8. Carrot																
9. Carrot																
10. Pepper																
11. Pepper																
12. Other vegetables																
Root crops																
13. Beetroots																
14. Potato																
15. Potato																
16. Sweet potato																
17. Groundnut																
Fruits																
18. Papaya																
19. Banana																
Total																

Part C: Water Consumption by Type of Livestock

1. Region: _____
2. Zone: _____
3. Woreda: _____
4. River Basin: _____
5. Sub-Basin: _____

6. Number and Type of Livestock

Type of Livestock	Livestock population (No)
1. Cattle	
2. Equine	
• Horse	
• Mule	
• Donkey	
3. Camel	
4. Sheep	
5. Goat	
6. Poultry	
Total	

Note: Only livestock that consume water from the above Basin should be included

Part D: Area Treated with Different Soil and Water Conservation Measures (Woreda Aggregate)

1. River Basin:_____
2. Sub-basin:_____
3. Region: _____
4. Zone: _____
5. Woreda: _____
6. Area treated with different soil and water conservation measures by land use type.

(If soil conservation measures are not available by land use, give total area in the last row)

Land Use	Catchment area (ha)		Area treated with different types of conservation measures (ha)				
	Total Catchment Area	Part of catchment that requires treatment	Physical measures	Biological measures	Both measures	Area closure	Total
Cultivated land							
Grazing land							
Hillsides							
Wasteland							
Total							

7 Non-irrigated land that is drained (ha):_____