Manual for Water Distribution in Irrigation Schemes

(Version-1)




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National Irrigation Commission, Ministry of Water and Irrigation

(MoWI)

Terminology

Irrigator's Organization (IO)	Irrigators' Organisations: means the organisation to accommodate the joint interests and activities of all the farmers on an irrigation scheme primarily for ensuring increased crop productivity through optimal management of irrigation water and the operation and maintenance of their scheme.
Out-grower	Out-grower: means the famers who cultivate (irrigate) outside the irrigation scheme and using same water source.
Irrigation scheme	Irrigation Scheme: means the area where crops are grown under irrigation through any method including flood recession; gravity or pump fed canal systems supplying either surface or groundwater; water harvesting and pressurised systems such as drip and sprinkler.
Irrigation efficiency	Irrigation Efficiency: means a ratio between the amounts of water effectively used for crop growth to the amount diverted from the source.
Net water requirement	Net water requirement: means how much water is needed at each plot directly for crop growth.
Gross water requirement	Gross water requirement: means how much water is needed to be taken at intake point for irrigation which includes loss of water
Infiltration	Infiltration :means the movement of water in the soil
Evapo-transpiration	Evapo-transpiration :means Sum of transpiration and evaporation from crops
Effective rainfall	Effective rainfall: means rainfall which is directly utilized for crop growth.

Table of Contents

1 Introduction

1.1 Background

Irrigation can realize stable production and high productivity in agriculture if proper amount of water is estimated and distributed in the irrigation schemes. Actually, in most irrigation schemes of Tanzania, irrigation water is not fairly distributed because of absence of rationally prepared water distribution plan and proper operation manner of irrigation facilities. In addition, the increment of out-growers around irrigation scheme causes the conflict of water distribution between farmers within the scheme and out-growers. Moreover, it is said that unfair water distribution of limited water source causes the conflict between upstream and downstream water users.

Fact-finding revealed that irrigation water is distributed based on conservative water distribution manner in some irrigation schemes, but it is not quantitatively distributed in most cases. It is because of lack of proper knowledge on the formulation of water distribution plan based on actual cultivation state and facility operation. In this context, proper water distribution plan and its implementation should be taken into consideration in order to promote efficient water use and improve irrigation scheme management.

Meanwhile, even the irrigation schemes which seem to be realized adequate water use at present might be affected by global climate change. Hence, it is essential for all irrigation schemes to be operated in efficient water use status through preparation of water distribution plans.

1.2 Objectives of the manual

The objectives of this manual are to guide Irrigators Organization (IO) supported by district irrigation staff mainly engineers and technicians in the schemes to prepare water distribution plan which ensures a fair water distribution, proper operation of irrigation structures and sustainable water management.

1.3 Scope of the manual

This manual is prepared for water distribution planning and operation of the facilities in small scale irrigation schemes. It is assumed that the manual is used by Water Master, O&M or Water sub-committee of IOs and the farmers to be engaged in water distribution through assistance from Zonal Irrigation Offices and District offices. The water distribution plan to be discussed in this manual mainly focuses on water distribution to irrigation blocks. Water distribution within the blocks is operated by block leaders and farmers.

There are following pre-conditions for the utilization of this manual.

- Presence of an IO
- Availability of water use permit
- Presence of irrigation infrastructure such as intake, canal and diversion structures to distribute irrigation water to the irrigation scheme.

2 Preparation of Water Distribution Plan

Item 1 Roles and duties of water management organization

Who are the main actors of water management of the irrigation scheme and their roles and duties.

If farmers abstract water from canal without any consensus or consultation, water shortage at some parts of the irrigation scheme might occur. So unity of farmers under water management organization or group is important to avoid such a result.

In Tanzania, typical IO's organization chart is shown in Figure 2-1. IO management committee is organized as overall management body, which consists of chairperson, secretary and accountant (treasurer) to make IO's policy and coordinate the sub-committee.

Sub-committees are working groups to implement IO's activities' plan in several fields. For example, O&M or Water sub-committee, Agricultural and Environmental sub-committee and Planning and Financial sub-committee are organized. In terms of fair water distribution, O&M or Water sub-committee is needed to operate the irrigation structures and manage water distribution. The roles and duties of the members of this sub-committee are explained in Table 2-1.

There are some irrigation schemes surrounded by out-growers upstream or downstream of the scheme. Out-growers means the famers who cultivate (irrigate) outside the irrigation scheme and using same water source. It is also critical issue how to involve out-growers in the water management of irrigation scheme.

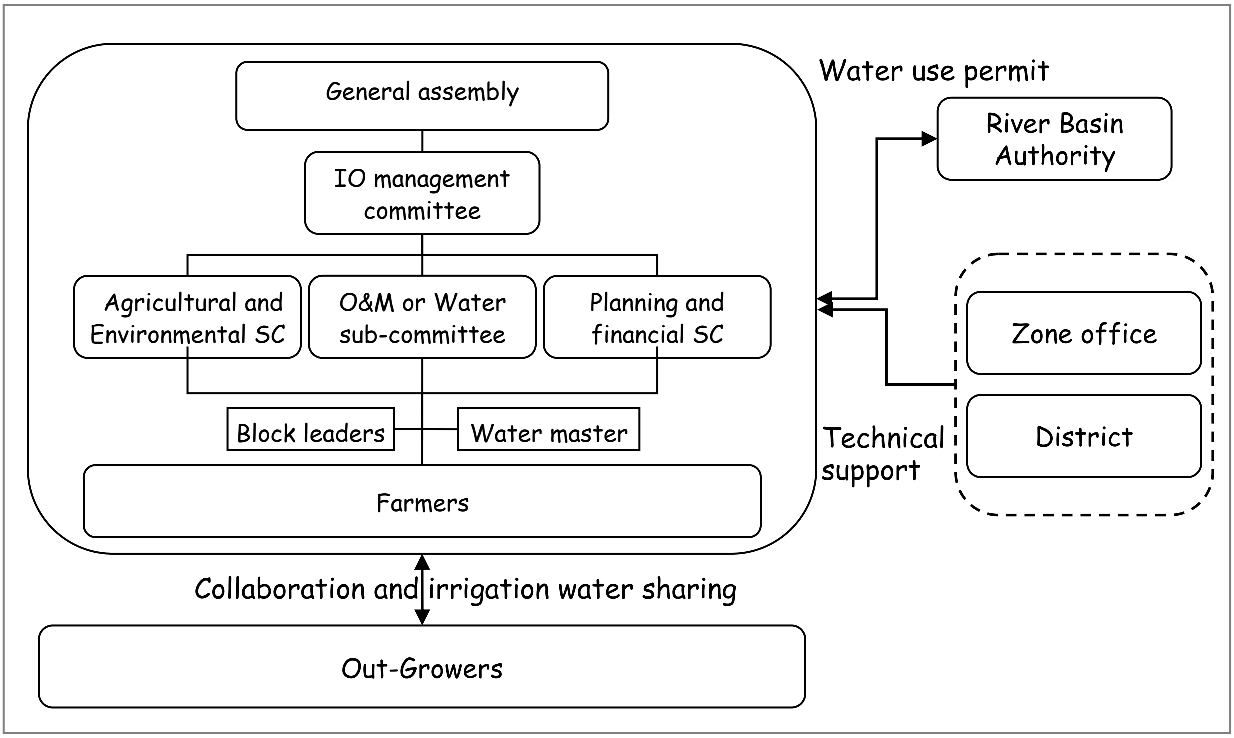


Figure 2-1: Typical Organization and relationship between each organization

Table 2-1: Example of roles and duties of sub-committee for water distribution

Responsible	Duty
Member of sub-committee:	· Supervision of the block leaders and water master. · Record keeping of implementation of the water distribution plan prepared at the scheme. · Coordination with other water users outside the scheme such as out-growers and upstream and downstream water users
Water master (Gate keeper of intake): one or two person	· Keep the key of gates and operate the intake gate and gates along the main canal. · Ensuring proper water distribution along the plan. · Maintenance of the intake facility and gates on the main canal such as greasing · Reporting the status of facility to O&M sub-committee · Note: If possible it is advisable to employ the water master or use someone outside the scheme in order to avoid biasness during water distribution.
Block leader: assigned for each block	· Distribution of water within each block in cooperation with farmers. · Lead farmers to maintain field canal · Confirmation of canal condition and reporting to O&M sub-committee in case of any damage. · Communicate with other block leader to adjust amount of water distribution within the scheme whenever water shortage occurs in some blocks. · Water fee collection · Submission of the farmers list and activity record
Secretary of Irrigation Block	· Support block leader to record their activity · Prepare the list of farmers within the block
Canal leader	· Support block leaders to distribute irrigation water · Ensuring the canal clearness within the block · Confirm the condition of canal within the block

Supporting Organization

Regional Secretariat	· Technical support for formulating water distribution plan · Guidance and Supervision for facility operation
District office	· Technical support for formulating water distribution plan · Guidance and Supervision for facility operation
Zone Irrigation office	· Technical support for formulating water distribution plan · Guidance and Supervision for facility operation
River Basin Authority (RBA)	· Issue of water use permit and claiming water fee to IO · Solving water conflict between upstream and downstream water users of river

Item 2 Confirming present water use status in irrigation scheme

Before making Water Distribution Plan, it is very important to know current situation. Water is enough or not, how to distribution water in the scheme etc.

In order to grasp the outline of the irrigation scheme where the water distribution plan would be formulated, it is proposed to find the existing documents such as feasibility study report (F/S report). In the case that the documents are not available but water distribution has already been carried out, it is necessary to confirm the current water use status such as water use permit, water distribution rule, water committee etc.

It is recommended to review Comprehensive Guideline (CGL) "Form 1 Basic Operation Plan" which shows current irrigation blocks, sketch of irrigation area, basic water distribution method and the persons in charge of water distribution as shown in **Appendix-1**. If such form is not available, necessary information is referred in Feasibility Study report from District office. In addition to this, the allowed amount for abstraction should be observed if the IO already has the water use permit.

Basic information to be confirmed is;

- Number of farmers and IO members
- Total irrigation area, number of irrigation blocks with respective areas
- Water use permit
- Current water distribution practice and rules (Type of water distribution and irrigation schedule)
- Current water committee (Number of block leaders and water masters)
- Type of crops

The sample form "Basic Information Sheet for Water Distribution" for collection of above information is attached in **Appendix-2**.

Item 3 Establishment and Observance of Rules for Water Distribution

Rules are indispensable to establish properly water distribution plan, and to enhance observance of the established rules.

In order to make effective and fair utilization of limited water resources, the rules are indispensable to be established. Failing to follow the established rules leads to unfair water use and conflicts among water users. For efficient and fair water distribution, cooperation among farmers is important, and it is necessary to enhance awareness of observance of the rules as well.

For example, the following behaviour has to be avoided or prevented by the rules of the IO.

- Unauthorized intake of water from canal
- Arbitrary construction of canal and gate
- Water distribution deviating from the plan
- Structure operation by the person who is not authorized
- Cultivation not following the proposed cropping calendar

Payment of water fee is duty of the farmers who use water. Unless each farmer pays water fee, the IO is not able to pay the water use permit fee to the RBA, and there is a possibility that the water use permit will be withdrawn. On the other hand, the farmers who properly pay water fees have right to use water and receive appropriate amount of water (see Figure 2-2).

Generally, there is no problem in case of taking water amount within the range of water permit to the irrigation scheme. If water amount more than permitted is taken, available water amount for downstream water users will decrease. It will affect their activities related to water use, and conflicts may occur in some cases. Therefore, attention must be paid by the water master and members of sub-committee so that the scheme does not face serious problems over water.

In order to distribute water according to the plan, cooperation among water users are very important, and individuality should be avoided in the irrigation scheme.

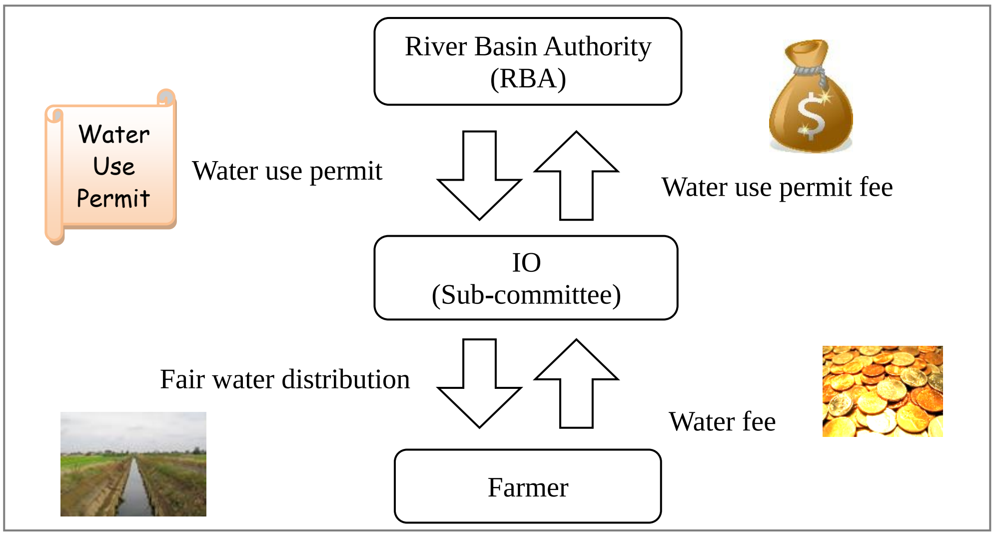
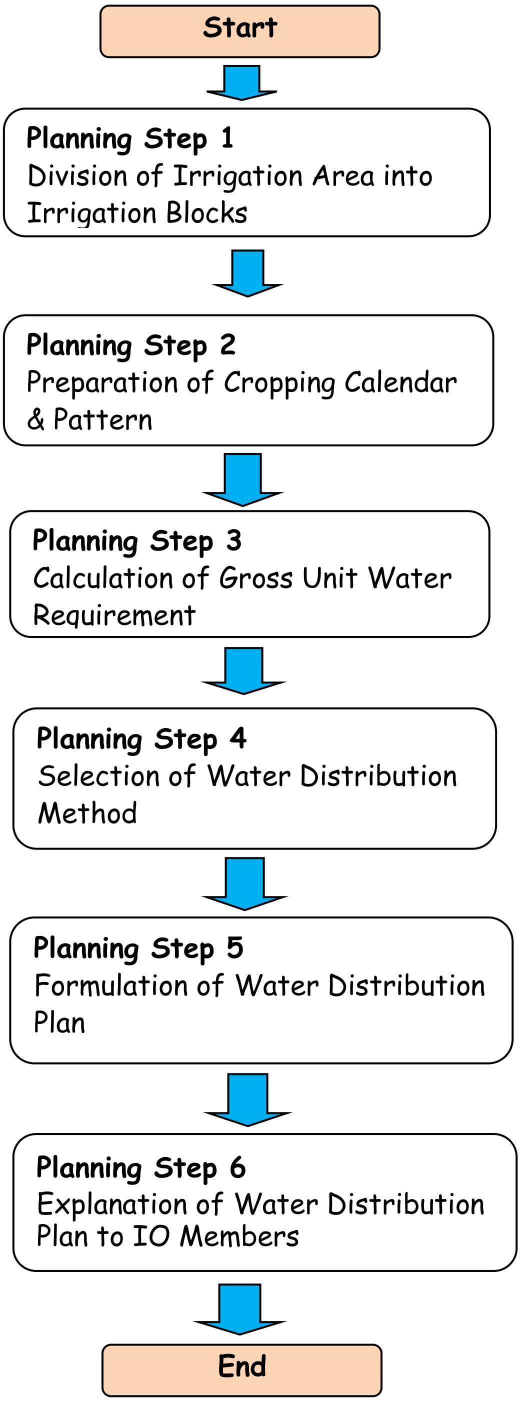


Figure 2-2: Relationship between farmers and RBA

3 Formulation of Water Distribution Plan

Water distribution plan is the guidance which shows when and how much water is distributed to each irrigation block. Procedure of the formulation of water distribution plan is explained in this section.

Figure 3-1 shows the process from Step 1 to 6 in formulating water distribution plan.



At first, the scheme is divided into several irrigation blocks, which is a basic water distribution unit.

Then, cropping calendar and pattern should be made in consideration of actual farming practice to know different water demand by crops in line with calendar and pattern.

After establishing the cropping calendar and pattern, it should be clear how much water is needed along the crop growth stages. Gross water requirement is amount of water needed in the scheme.

In order to distribute water to the irrigation block, two type of water distribution method is selected such as Flow sharing and Time sharing based on water availability.

After determining the water distribution methods, water distribution schedule is made in consideration of water balance between supply and demand and frequency of irrigation of each irrigation block.

Once water distribution plan is formulated, the plan should be open to all water users to follow it. IO management committee or sub-committee concerned should be in charge of this matter.

Figure 3-1: Flow of formulation of water distribution plan

Planning Step 1 Division of Irrigation Area into Irrigation Blocks

How to distribute water fairly to all famers? Dividing the scheme area into some blocks makes easer to distribute water.

A Scheme can be divided into several blocks by irrigation and drainage canal, access road, and administration boundary. It is also advisable to consider crop variety for dividing blocks since different crops have different water requirement. Example of division of irrigation area is shown in Figure 3-2. Size of blocks should be carefully decided because when they are too big it is difficult to manage, and too small blocks need many block leaders. Recommended size of the blocks should be from 20 to 30 ha depending on farmers' capability. A sketch map of the scheme is helpful to clarify the proposed irrigation blocks.

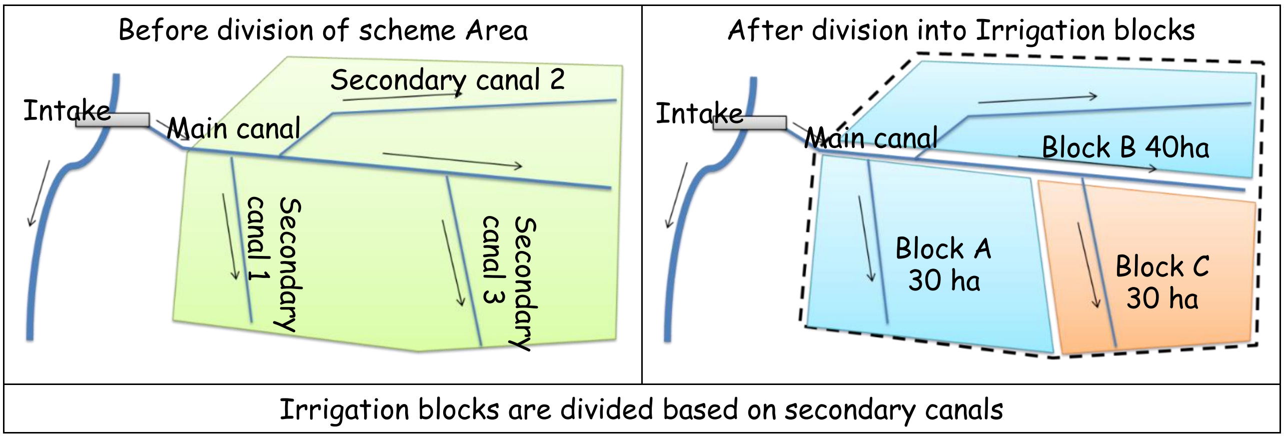


Figure 3-2: Division of an Irrigation Scheme into blocks

In order to simplify the further calculation, unit of area is converted from acres to hectare. To convert the unit of area from acre to ha, multiply the area (acre) by 0.4.

$$\textbf{Area (ha)} = \textbf{Area (acre)} \times \textbf{0.4}$$

Formula-1

Table 3-1: Conversion of unit of area (Example)

Crops in dry season	Area (acre)	Area (ha)
Paddy	74	74 × 0.4 = 29.6 ≒ 30
Maize	100	100× 0.4 = 40.0 ≒ 40
Vegetable	74	74× 0.4 = 29.6 ≒ 30
Total	248	100

Planning Step 2 Preparation of Cropping Calendar and Cropping Pattern

Without cropping calendar and pattern, how can we know when, where and how much farmer need water. Those are essential information to prepare water distribution plan.

Cropping calendar is an indication for the farming practices along the timeline (monthly basis), and it provides information on the sequence of crop growth and on the timing of farming activities such as transplanting, sowing and harvesting. In this respect, it is very important to establish the cropping calendar. More detailed cropping calendar showing such as when farmer apply fertilizer is developed in some irrigation schemes. Example of detailed cropping calendar is shown in Table 3-2.

Table 3-2: Example of cropping calendar

Month	Jan				Feb				Mar				Apr				May				Jun				Jul				Aug				Sep				Oct				Nov				Dec			
Week	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Period	Rain season																				Dry season																				Rain season							
Activity																																																
Plough and Cultivation																					■	■	■	■																		■	■					
Preparation of nursery and Irrigating nursery bed																						■	■	■																	■	■	■					
Transplanting																									■																			■				
Irrigate the field	■	■	■	■	■	■	■	■																	■	■	■	■	■	■	■	■	■	■	■	■								■	■	■	■	■
Application of fertilizer			■																						■		■					■												■		■		
Weeding			■																								■					■														■		
Harvesting										■	■																													■	■							

Cropping pattern is a diagram which shows when the crop will be planted, and when the crop will be harvested in a particular irrigation area as shown in the Figure 3-3. The cropping pattern can be defined as the sequence in which crops in the given area are grown.

The horizontal axis represents the time in accordance with the growth stage of the crop, the farming activities and irrigation activities. The vertical axis represents the irrigation area in ha or acre. Since cultivation gradually starts from some part of scheme and there is some time lag among plots. Generally the cropping pattern is drawn in parallelogram shape. If all farmers start cultivation at once, the cropping pattern shows square like Maize in the Figure 3-3.

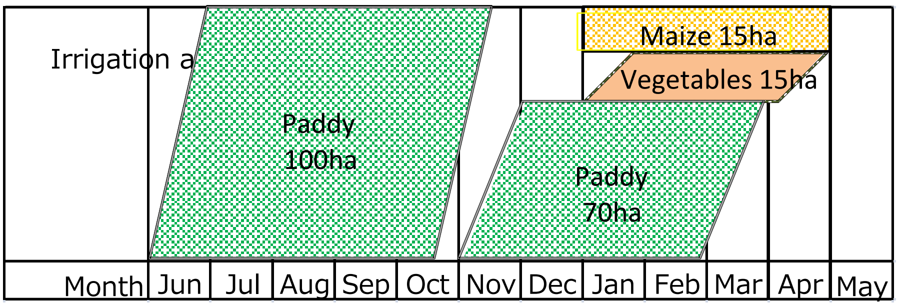


Figure 3-3: Explanation of cropping pattern

Why cropping pattern is needed?

Amount of water requirement for crops varies depending on the crop type, season and growth stage. If the farmers follow the proposed cropping pattern, it is easy to calculate water requirement at each stage, otherwise it is difficult to find out how much water is needed in the scheme (see Figure 3-4).

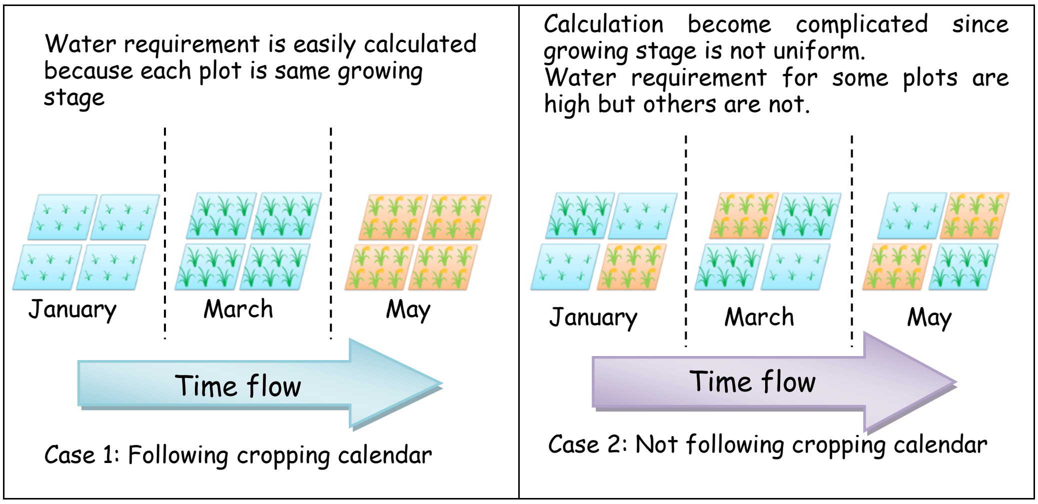


Figure 3-4: The use of a Cropping Calendar

To start cultivation within the scheme in accordance with a scheduled cropping pattern is basic rule for fair and efficient water distribution. If cultivation schedule is uniformly coordinated, it is also possible to harvest at the same time with farm machines as shown in Figure 3-5.

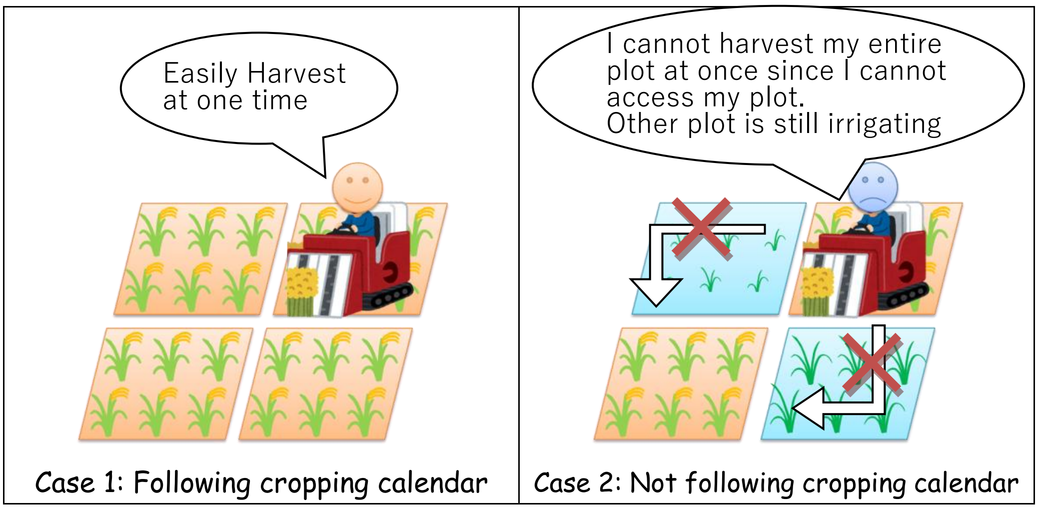


Figure 3-5: Advantage to follow cropping calendar

Preparation of prepare the cropping pattern

In Figure 3-6, initial water distribution starts at point A, and has started in the whole area at point B. In a similar way, harvesting starts at point E, and has finished in the whole area at point F.

The irrigation area gradually increases in the period from A to B, is at a peak in the period from B to C, and gradually decreases in the period from C to D. Also, the period from B to C shows full utilization of planned irrigation area with maximum water demand and maximum water utilization.

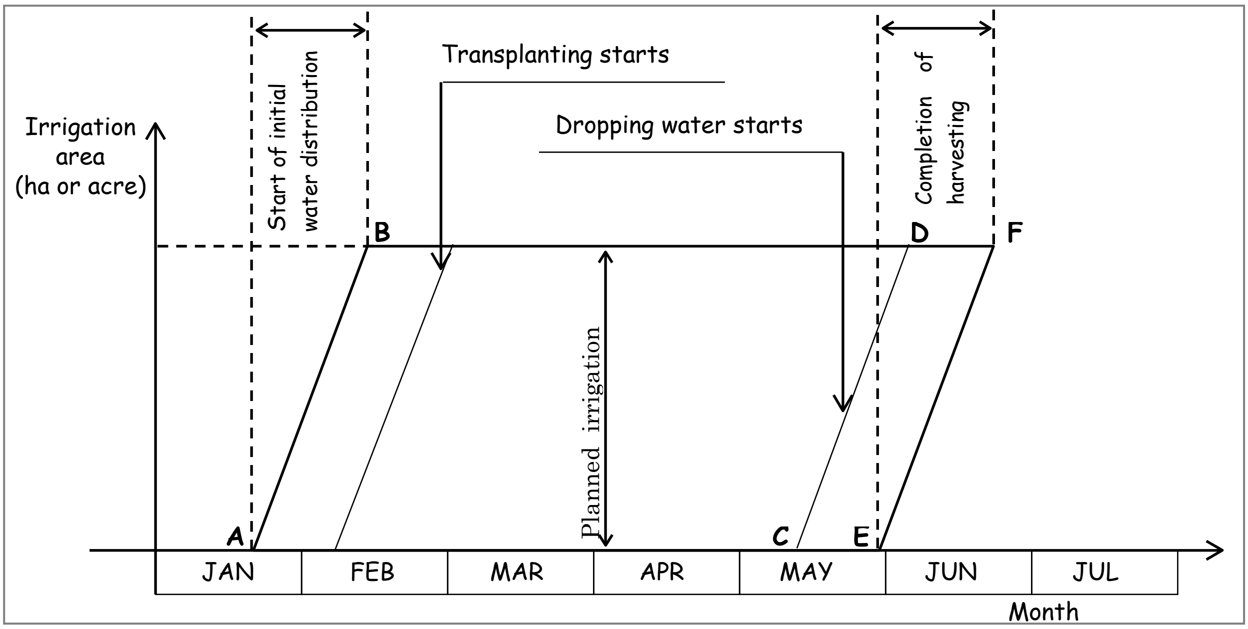


Figure 3-6: Explanation of cropping pattern for paddy

If farming practice based on farmers' experience is available, it will be a good reference in formulating cropping pattern. Market price of the product is also one of the important factors to consider in the preparation of cropping pattern. Meanwhile, water source availability (discharge in the river, dam) and amount of rainfall during cropping season are the most critical factors.

In CGL (Volume 1, Page 3-12), typical cropping season in Tanzania under irrigation condition is divided into dry season and rainy season as shown in Table 3-3.

The advantages of this cropping season are as follows,

- The cropping season is based on the Tanzanian climate condition.
- Data for calculating net water requirement for all regions based on this season are provided in CGL.

But if the cropping season in your scheme has been well practiced for long time, you have to adopt actual cropping season in your scheme.

Table 3-3: Typical cropping season

Seasons	**Dry season cropping**						**Rainy Season Cropping**					
Month	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun

Planning Step 3 Calculation of Gross Unit Water Requirement

How much water to deliver to the farm can be estimated using CGL technical information. It is not so difficult but needs technical support from irrigation engineers or technicians.

(CGL volume 1, page 2-15)

What is Gross and Net water requirement?

The Figure 3-7 shows the example of gross and net weight of banana. Gross weight of banana means whole weight including inedible part of the banana, and Net weight means weight of edible part of the banana.

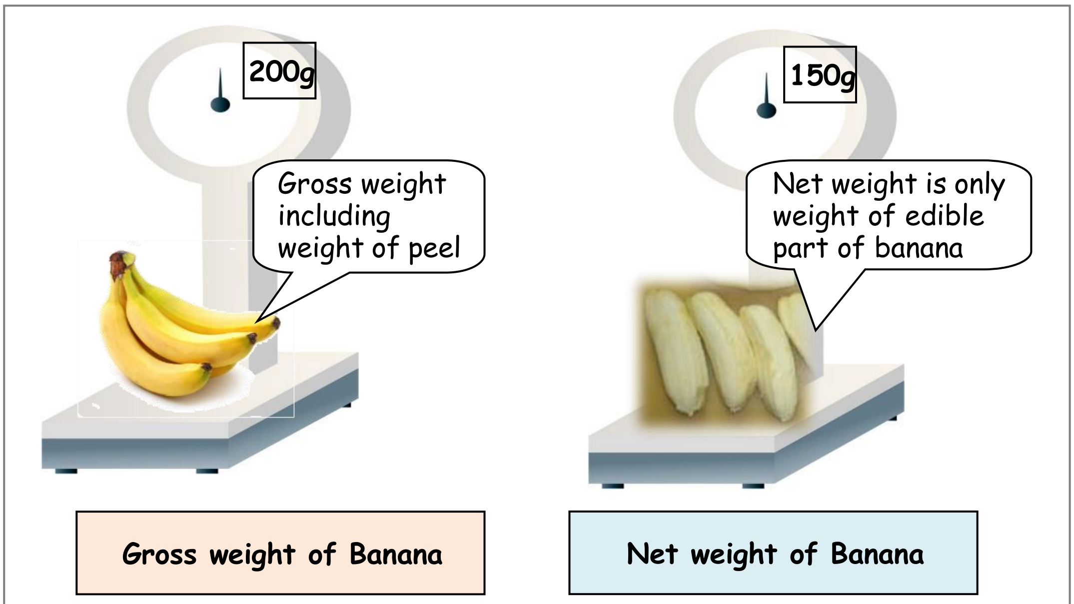


Figure 3-7: Example of Gross and Net weight

Same as Figure 3-7, Gross water requirement means how much water is needed to be taken at intake point for irrigation, which includes losses during water conveyance such as leakage through canals and breakage of division boxes, and water losses such as seepage through bunds and over irrigation at the field. Whole water amount taken from intake point cannot reach to the field due to water losses described above. These losses that crop cannot use are same as peel of banana which is not edible. Since Gross water requirement includes these losses, it is needed to consider those in the calculation of water requirement.

Net water requirement means how much water is needed directly for crop growth at the field. Water is consumed as **Evapo-transpiration** from crops and **Infiltration** through ground. Evapo-transpiration is the sum of evaporation from the ground and water surface and transpiration from crops.

Transpiration means the release of water from crop leaves. Just as you release water vapour when you breathe, plants do, too. Infiltration means the movement of water in the soil. The irrigated water moves from the ground surface to the root zone where crop can use and is abstracted from roots of the crop. Irrigation water further moves to the underground if crops cannot use it.

Rainfall is also important component to determine the net water requirement since rainfall supplies water to the fields. The rainfall utilized by crop is called **Effective Rainfall**. As observed in the field, some amount of rainfall evaporates from ground surface and/or water surface before being utilized by crop. Especially, in case of small amount of rainfall, effective rainfall is almost zero. In case of high intensity rainfall, some amount of rainfall directly flow away over the soil surface and drained; therefore, it is not used by crop.

Figure 3-8 shows the relationship between Gross water requirement and Net water requirement in the irrigation scheme. As indicated here, Gross water requirement can be obtained by Net water requirement by dividing irrigation efficiency. A term of Irrigation Efficiency is explained later (page 14).

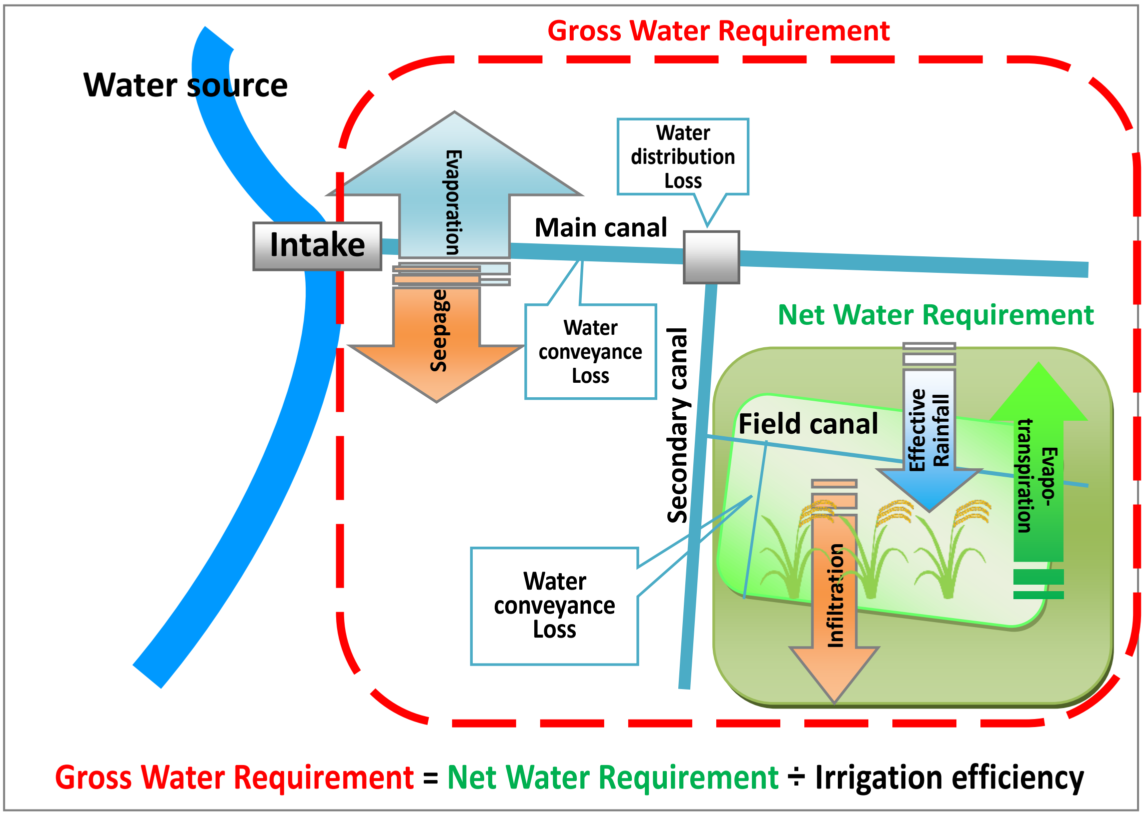


Figure 3-8: Coverage of Gross water requirement and Net water requirement

Figure 3-9 shows components of Net water requirement. Those are rainfall, evapo-transpiration and infiltration. Net water requirement can be obtained with following equation.

Net irrigation water requirement = Evapo-transpiration + Infiltration – Effective rainfall

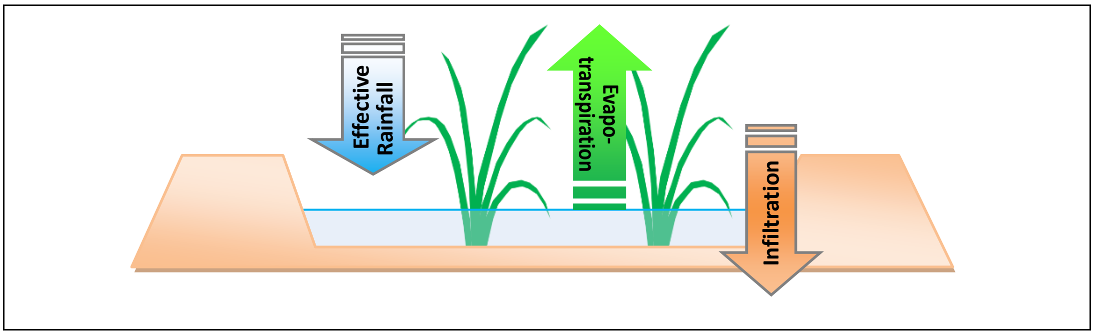


Figure 3-9: Component of Net irrigation water requirement

Net water requirement is determined by season and growth stage of crop in consideration of effective rainfall. Net water requirement of paddy, maize, beans and vegetables are listed by the region and soil type in CGL Volume 1, page 3-13, 3-14.

Table 3-4 shows Net Water Requirement stated in CGL as an example of Kilimanjaro region. Unit is mm/month means net amount of water needed to the scheme in mm per month. In irrigation, the unit of mm is very convenient to calculate water demand, and the unit of rainfall is also expressed in mm. You can refer to CGL to know data of Net Water Requirement in your region in accordance with crops and soil type.

Table 3-4: Net Water Requirement (NWR) in Kilimanjaro region (example)

Unit: mm/month

Region	**Crop**	**Soil type**	**Dry Season**						**Rainy Season**					
			Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Kilimanjaro	Paddy	Sandy Loam	633	461	507	512	-	-	736	506	540	403	406	-
		Clay Loam	428	311	357	357	-	-	531	366	385	253	251	-
		Clay	285	221	267	264	-	-	388	282	292	163	158	-
	Maize		89	112	198	202	187	-	72	157	220	103	90	-
	Bean & Veg		89	112	172	182	-	-	72	138	193	102	85	-

As for the soil type, CGL explains how to know the soil type practically. Figure A- 1 in **Appendix-3** shows a simple method how to know the soil type by you. You just follow the instruction to find the soil type.

How to calculate Gross Unit Water Requirement?

Next is how to calculate Gross unit water requirement from Net water requirement.

In order to calculate Gross unit water requirement, **Irrigation efficiency** is very important to understand calculation process of Gross unit water requirement.

Irrigation efficiency is a ratio between water amount abstracted from water source (e.g. intake or gate) and water amount consumed effectively by crop at the field. Without considering irrigation efficiency, what will be happen? You may not irrigate proper amount of water to your field. Dominating factor of irrigation efficiency is water losses. Figure 3-10 explains importance of irrigation efficiency in the irrigation scheme.

Example: irrigation water without consideration of irrigation efficiency

You asked a water master to supply 1,000 lit of water to your plot. Based on farmers' order, the water master took 1,000 lit of water from the river. But 1,000 lit cannot reach to your plot actually (see Figure 3-10).

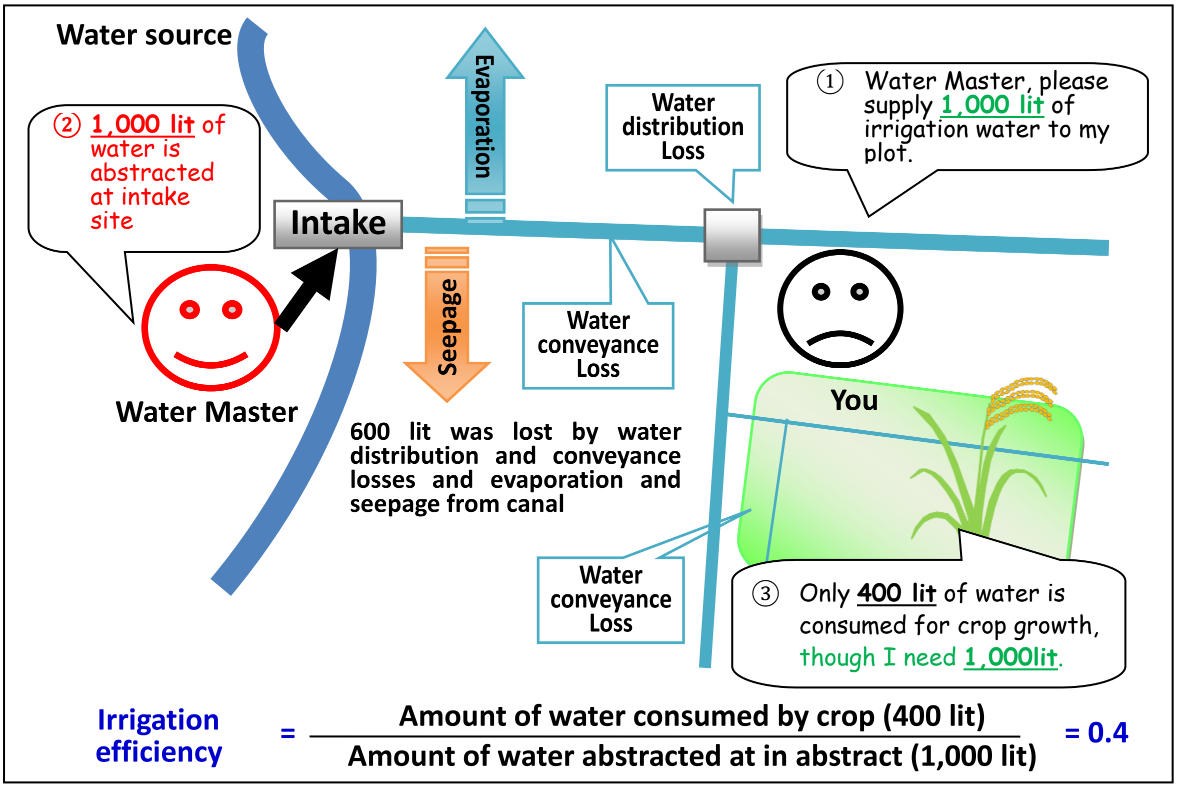


Figure 3-10: Irrigation water without consideration of irrigation efficiency

As shown in Figure 3-10, you failed to get required water for your plot because irrigation efficiency is not 100% but 40%.

So, how much water should be taken at intake point by taking into consideration irrigation efficiency of 0.4? Figure 3-11 shows the answer. If you know the irrigation efficiency, you have to ask water master to take more water amount at the intake point. Otherwise, you will be suffering from water shortage.

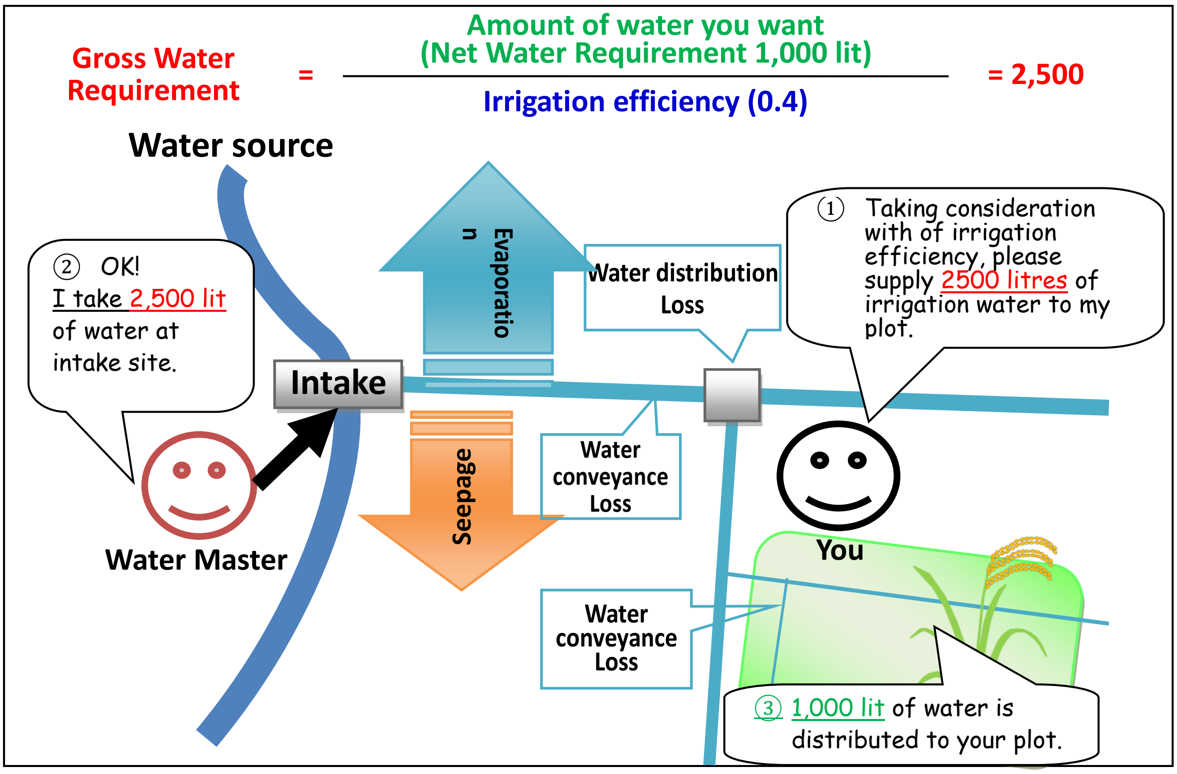


Figure 3-11: Irrigation planning with consideration of irrigation efficiency

Typical irrigation losses depending on the canal condition and farmers' experience of water distribution are mentioned in CGL Volume 1, page 3-14. Table 3-5 shows the typical value of irrigation efficiency.

Table 3-5: Irrigation efficiency in the irrigation scheme

Proposed canal condition	Lined	Unlined	
Farmers' experience	-	Sufficient	Poor
Irrigation efficiency	0.4 (40%)	0.3 (30%)	0.25 (25%)

Figure 3-12 shows how to find irrigation efficiency in your scheme. You start from the top to find appropriate value of irrigation efficiency. Technically speaking, irrigation efficiency shall be determined by a lot of determinant factors such as canal seepage, evaporation, condition of division boxes and water management skills of farmers. Practically, you can refer to the value of CGL, and adjust it in consideration of the site condition of your irrigation scheme.

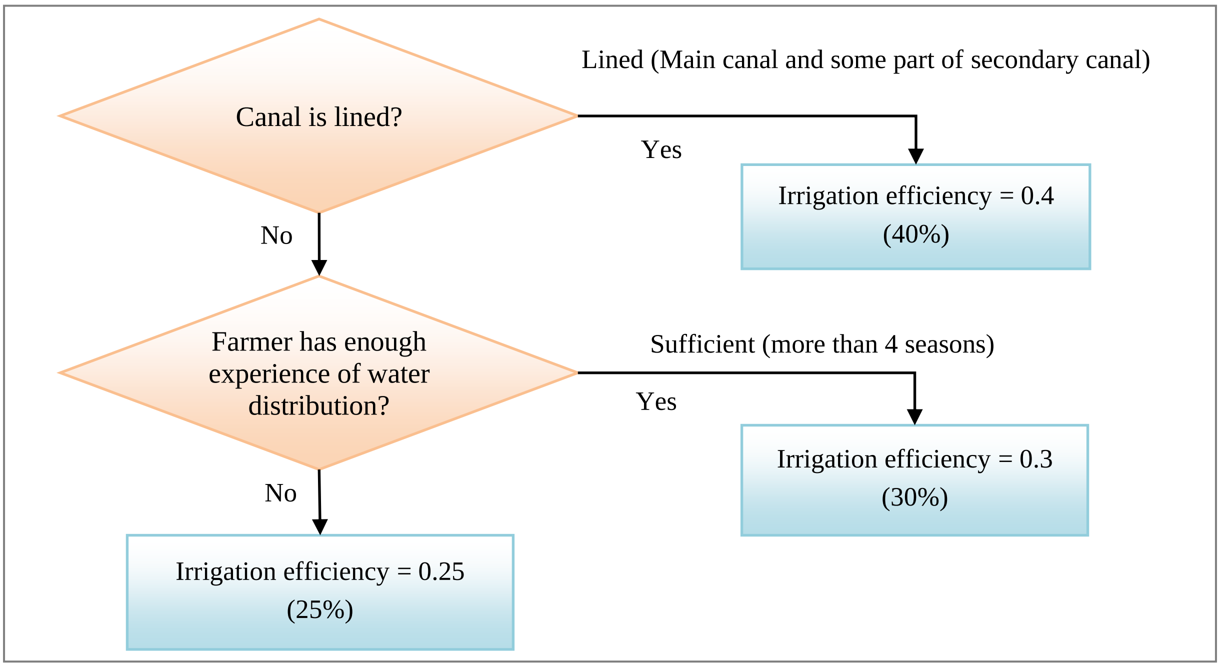


Figure 3-12: Flow of Selection of Irrigation efficiency

Now you got Net water requirement, irrigation efficiency. Let us go to calculate Gross unit water requirement. Following example is given to help your understanding.

Assumption

- Region: Kilimanjaro
- Crop: Rice
- Soil type: Sandy loam
- Cropping period: from January to June.
- Irrigation efficiency: 0.4 (40%)

Now let us see data of Net water requirement in Kilimanjaro region in page 14 or Appdendix-4.

According to the conditions above, necessary data in Net water requirement for the calculation of Gross unit water requirement (736, 506, 540, 403 and 406) are highlighted with gray colour in the Table 3-6 from January to May respectively.

Table 3-6: Net Water Requirement (NWR) in Kilimanjaro region

Unit: mm/month

Region	Crop	Soil type	Dry Season						Rainy Season					
			Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Kilimanjaro	Paddy	Sandy Loam	633	461	507	512	-	-	736	506	540	403	406	-
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		Clay	285	221	267	264	-	-	388	282	292	163	158	-
	Maize		89	112	198	202	187	-	72	157	220	103	90	-
	Bean & Veg		89	112	172	182	-	-	72	138	193	102	85	-

Calculation formula of Gross unit water requirement (lit/sec/ha) stated in CGL is as follow.

$$Gross\ unit\ water\ requirement = \frac{Net\ water\ requirement}{irrigation\ efficiency \times 8.64 \times number\ of\ days\ in\ the\ month}$$

Formula-2

The figure of 8.64 in the formula is a conversion coefficient from unit of (mm/month) to (lit/sec/ha).

For example, in January, Net water requirement is 736 (mm/month) and number of days in January is 31. Taking value of irrigation efficiency 0.4, you can get 6.9 (lit/sec/ha) which means 6.9 lit per second of discharge for 24 hours is needed to deliver for 1 hectare of paddy field.

You should remember, Net water requirement varies depending on the soil type and cropping season when you start cultivation. So it is necessary to know the type of soil and cropping season in your scheme.

The Gross unit water requirement usually comes up with unit of 'lit /second /ha'. This is very convenient to calculate discharge because water demand is equal to Gross unit water requirement (lit/sec/ha) multiplied by area (ha). Let us see an example of the calculation showing unit conversion.

$$Water\ Demand\ \left(\frac{litter}{sec}\right) = Gross\ unit\ water\ requirement\ \left(\frac{\frac{litter}{sec}}{ha}\right) \times area(ha)$$

Formula-3

Since water demand for each block is obtained as a product of Gross unit water requirement and area of each block. As you can see the example below, by using Gross unit water requirement and area of target irrigation block, water demand is easily obtained as follows:

Water demand for Block A (30ha) = 6.9 (lit/sec/ha) × 30 (ha) = 207 (lit/sec)

Table 3-7 shows Gross unit water requirement in Kilimanjaro region with various values of irrigation efficiency. Once you make this kind of table, you do not need to calculate again and again under various conditions.

The table for Gross unit water requirement expressed by the unit (lit/sec/ha) in each region with various values of irrigation efficiency is prepared and attached in **Appendix-5**.

Some of irrigation scheme, intercropping or mixed cropping are conducted to increase land productivity. In the point of view of calculation of water requirement, it makes complicated to obtain the water demand. In general, the evaporation from crops will be increased since the density of the vegetation increase. On the other hand, evaporation from ground will be decrease since the ground surface will be covered by the vegetation and vegetation prevent sun light to reach ground surface. Those effects of intercropping or mixing cropping on evapo-transpiration vary based on the combination of the crops, growth stage of each crop and density of the crops. Therefore, water requirement vary complicatedly and it is difficult to estimate actual water requirement.

Table 3-7: Gross Unit Water Requirement in Kilimanjaro Region

Irrigation hour :24hours/day

Unit: lit/sec/ha

	Region	Crop	Soil type	Dry Season						Rainy Season					
				Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Irrigation efficiency **E=0.4**	Kilimanjaro	Paddy	Sandy Loam	5.9	4.3	4.9	4.8	-	-	6.9	5.2	5.0	3.9	3.8	-
			Clay Loam	4.0	2.9	3.4	3.3	-	-	4.9	3.8	3.6	2.4	2.3	-
			Clay	2.7	2.1	2.6	2.5	-	-	3.6	2.9	2.7	1.6	1.5	-
		Maize		0.8	1.0	1.9	1.9	1.8	-	0.7	1.6	2.1	1.0	0.8	-
		Bean & Veg		0.8	1.0	1.6	1.7	-	-	0.7	1.4	1.8	1.0	0.8	-
Irrigation efficiency **E=0.3**	Kilimanjaro	Paddy	Sandy Loam	7.9	5.7	6.5	6.4	-	-	9.1	7.0	6.7	5.2	5.1	-
			Clay Loam	5.3	3.9	4.6	4.4	-	-	6.6	5.1	4.8	3.2	3.1	-
			Clay	3.5	2.7	3.4	3.3	-	-	4.8	3.9	3.6	2.1	2.0	-
		Maize		1.1	1.4	2.5	2.5	2.4	-	0.9	2.2	2.7	1.3	1.1	-
		Bean & Veg		1.1	1.4	2.2	2.3	-	-	0.9	1.9	2.4	1.3	1.0	-
Irrigation efficiency **E=0.25**	Kilimanjaro	Paddy	Sandy Loam	9.4	6.9	7.8	7.6	-	-	11.0	8.4	8.1	6.2	6.1	-
			Clay Loam	6.4	4.6	5.5	5.3	-	-	7.9	6.1	5.7	3.9	3.8	-
			Clay	4.3	3.3	4.1	3.9	-	-	5.8	4.7	4.4	2.5	2.4	-
		Maize		1.3	1.7	3.1	3.0	2.9	-	1.1	2.6	3.3	1.6	1.3	-
		Bean & Veg		1.3	1.7	2.6	2.7	-	-	1.1	2.3	2.9	1.6	1.3	-

Although the formulation of the water distribution plan is explained in the steps ahead, it is also convenient to prepare water distribution diagram as a method of grasping the spatial distribution of water demand within the scheme. The detailed preparation method of the diagram is explained in the **Appendix-6**.

Planning Step 4 Selection of Water Distribution Method

Two (2) major water distribution methods are introduced, Flow sharing and Time sharing. Selection is depending on water availability and water management skills.

(CGL Volume 3, page 4-2)

Two types of water distribution method such as **Flow sharing** and **Time sharing** are introduced in CGL.

Flow sharing: distributing water continuously to each irrigation block

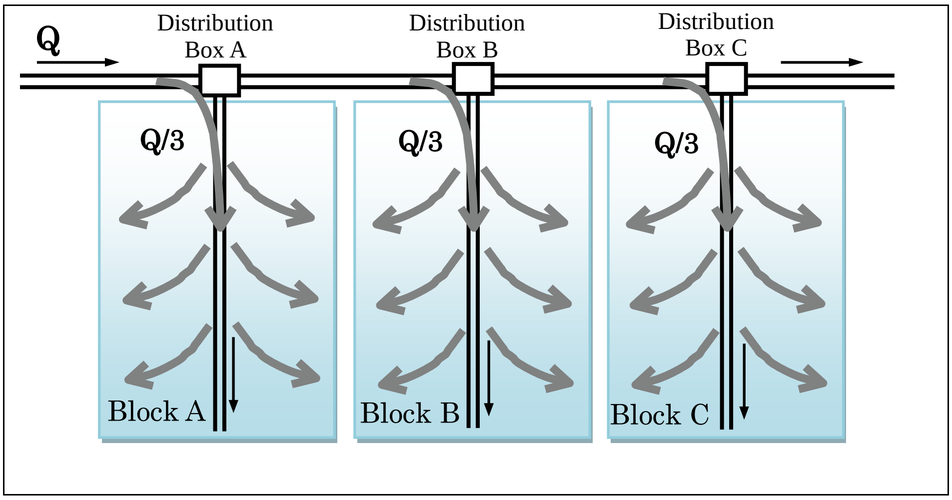


Figure 3-13: Flow sharing method

Time sharing: distributing water by rotation to each irrigation block

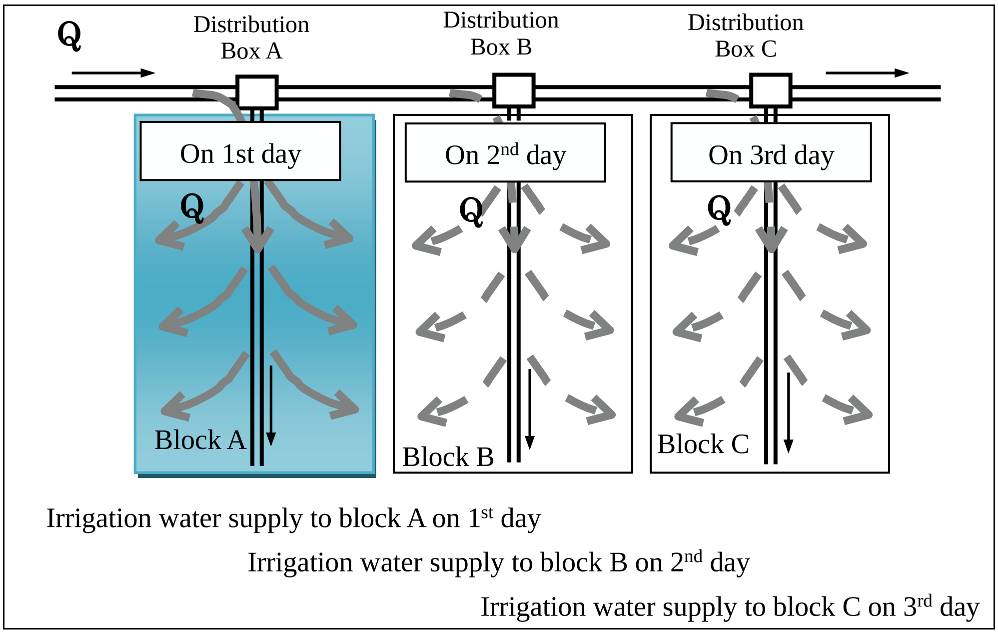


Figure 3-14: Time sharing method

Advantage of the flow sharing method is that you can irrigate any time, while in time sharing method you have to wait for your turn. In case of abundant water, the flow sharing method is applicable whereas the time sharing method is preferred in limited water supply.

In cases of rotation irrigation (time sharing), it should to be considered carefully about irrigation interval which means how often you irrigate such as every 2 days and every 3 days. For example, if irrigation interval is 3 days that means you have to irrigate 3 times of water amount per day you calculated because next irrigation to your block is after 3 days.

Moreover, soil type should be considered to determine the irrigation interval because the water holding capacity is different by the soil type. In the case of sandy soil, the water holding capacity is small and high percolation rate, so irrigation interval should be shortened and small amount and frequent irrigation is desirable. In the case of clay soil, it is possible to hold more soil water amount at one time compared to sandy soil.

It is impossible to deliver water beyond the capacity of the canal. Attention should be paid not to overflow water from the canal top in order to avoid destruction of the banks in tertiary and field canals when large amount of irrigation water is distributed at once.

Even if irrigation water is distributed by Flow sharing method in entire irrigation scheme, it is possible to distribute irrigation water by time sharing method within each block. On the other hand, although irrigation water is distributed by Time sharing method in entire irrigation scheme, it is possible to distribute the water based on the flow sharing method within each block. It is not necessary to apply same water distribution method for either entire scheme or each irrigation block. The type of water distribution within the irrigation block is decided by discussion among farmers with the initiative of block leaders.

Planning Step 5 Formulation of Water Distribution Plan

Water demand of each block is calculated by knowing irrigation blocks, water distribution method, Gross water requirement of each block, and finally water distribution plan is established.

(CGL Volume 3, page 3-18)

As a result of the previous steps, the water demand for each block can be calculated using the following formula.

$$Water\ Demand\ \left(\frac{liter}{sec}\right) = Gross\ unit\ water\ requirement\ \left(\frac{\frac{liter}{sec}}{ha}\right) \times area(ha)$$

Formula-3

Area of the above formula is area of irrigation block. For example, Gross unit water requirement is 6.9 (lit/sec/ha) and area of irrigation block is 40 ha then water demand becomes 276 (lit/sec).

Accordingly you can calculate the water demands in different months by gross unit water requirement which is very important for water distribution plan.

How to calculate water demand (discharge in canal)?

As explained above, Gross unit water requirement and area of block irrigated is needed to calculate the water demand. Gross unit water requirement is calculated by Formula-2 in page 18. Net water requirement and irrigation efficiency are shown in CGL Volume 1 page 3-13, 14. All necessary data is available.

But, area irrigated is a bit complicated in applying Formula-2 because area irrigated at beginning of season and at ending of season is not same as total area of irrigation block. There is some time lag of farming activity among the farmers in the same block. This is explained in Figure 3-6 in page 10.

Figure 3-15 shows an example of area irrigated at the beginning and ending of the season. Area irrigated in Block C is a half in January as well as in June. So a half area of Block C, 15 ha, is substituted in Formla-2. In February, March, April and May, full area of Block C is irrigated therefore full area 30 ha are substituted in Formula-2. If time lag is 2 months, area irrigated in January is 1/4 of total area and area irrigated in February is 3/4 of total area of Block C.

In order to estimate adequate water demand, cropping pattern indicating area irrigated along the farming practice is very important.

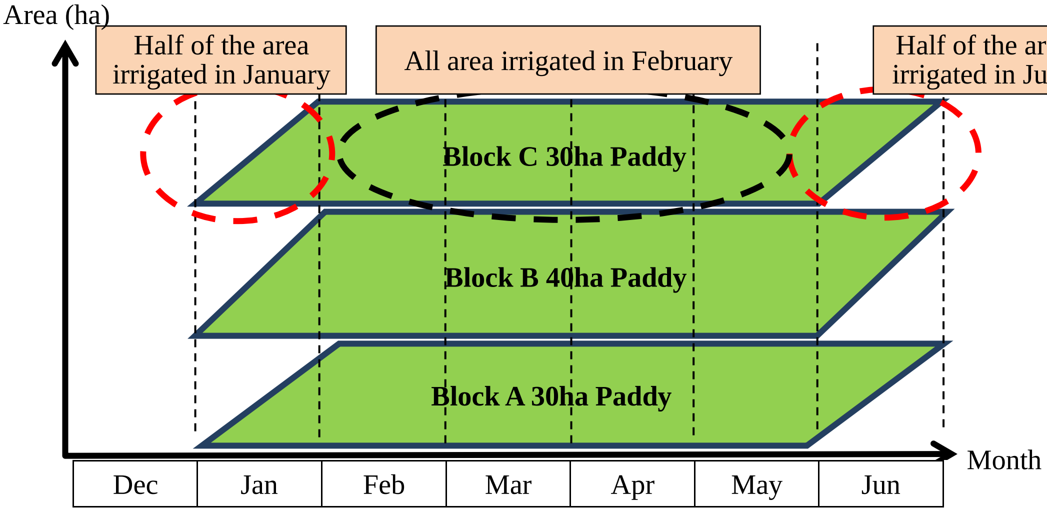


Figure 3-15: Cropping pattern

Meaning of “Water demand” and “Discharge” are almost same, and both of them are expressed by same units. In this manual, “Discharge” means an amount of water to be irrigated during certain irrigation hours in irrigation block, not just the volume rate of water flow in the river or canal.

Gross unit water requirement is calculated based on 24-hour irrigation. If the irrigation time is not 24 hours, discharge to each irrigation block must be adjusted using following formula.

$$\text{Discharge to irrigation block} = \text{Gross unit water requirement} \times \text{area} \times \frac{\text{24 hours}}{\text{irrigation hour}}$$

Formula-4

In some schemes, irrigation hour is not 24 hours, for example 12 hours. In this case, supply discharge is doubled of 24 hours. When the irrigation hour becomes shorter, it is necessary to increase the supply discharge in order to meet water demand for one day. Further explanation how to adjust the supply discharge with given irrigation hour is shown in **Appendix-7**.

In case of the time sharing method, the irrigation interval must be considered when you calculate water demand. Table 3-8 is showing the Water demand calculated by daily irrigation and 3 days’ irrigation interval to 30ha of irrigation block. Water demand for 3 days’ interval will be 621 lit/sec which is calculated by daily water demand of 207 lit/sec × 3days irrigation interval.

In principle, after your irrigation turn, you have to wait until the next your irrigation turn according to the water distribution plan, but it can be negotiable with other farmers to change the irrigation order.

Table 3-8: Change of amount of water irrigated under 3 days' interval

Date	Everyday	Once a 3 days
1st day	**207** lit/sec	**621** lit/sec
2nd day	**207** lit/sec	No irrigation to your block
3rd day	**207** lit/sec	No irrigation to your block
4th day	**207** lit/sec	**621** lit/sec
5th day	**207** lit/sec	No irrigation to your block
6th day	**207** lit/sec	No irrigation to your block

Table 3-9 is cropping period based on the cropping pattern. Generally cropping period of rice is about 5 months, but due to time lag total cropping period is 6 months. This means that data of Net Water Requirement should cover 6 months although the cropping period of rice is actually 5 months.

Table 3-9: Cropping period of each block

Block name	Area (ha)	Crop	Period
Block A	30	Paddy	January to June (6 months)
Block B	40	Paddy	January to June (6 months)
Block C	30	Paddy	January to June (6 months)

Table 3-10 is a part of Table 3-7 in page 19. Let us take data in rainy season, Sandy Loam and Irrigation Efficiency =0.3 (30%). But data of Gross water requirement in June is missing because Net water requirement in June is also missing in CGL. In order to estimate data of June, just use data of May of Net water requirement then calculate Gross water requirement. It is very rough method but very easy for farmers.

Net water requirement in May is 406 (mm/month) (see data of May in Table 3-6 in page 17); therefore, Gross unit water requirement is calculated as follows by Formula-2.

$$\frac{406}{0.3 \times 8.64 \times 30} = 5.2$$

Gross unit water requirement in June is 5.2 (lit/sec/ha)

Table 3-10 shows the result of the Gross unit water requirement in Kilimanjaro region with paddy, sandy loam and irrigation efficiency 0.3.

Table 3-10: Gross Unit Water Requirement in Kilimanjaro Region

Irrigation hour :24hours/day

Unit: lit/sec/ha

	Region	Crop	Soil type	Dry Season						Rainy Season					
				Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Irrigation efficiency E=0.3	Kilimanjaro	Paddy	Sandy Loam	7.9	5.7	6.5	6.4	-	-	9.1	7.0	6.7	5.2	5.1	5.2
			Clay Loam	5.3	3.9	4.6	4.4	-	-	6.6	5.1	4.8	3.2	3.1	-
			Clay	3.5	2.7	3.4	3.3	-	-	4.8	3.9	3.6	2.1	2.0	-
		Maize		1.1	1.4	2.5	2.5	2.4	-	0.9	2.2	2.7	1.3	1.1	-
		Bean & Veg		1.1	1.4	2.2	2.3	-	-	0.9	1.9	2.4	1.3	1.0	-

Table 3-11 is the result of water demand in each block of paddy with Sandy Loam. The Gross unit water requirement is extracted from Table 3-10.

Table 3-11: Example of calculation for plan of water distribution

Block	Name of block	Jan.	Feb.	Mar.	Apr.	May	Jun
Block A	Gross unit water requirement (lit/sec/ha)	9.1	7.0	6.7	5.2	5.1	5.2
	Area (ha)	15	30	30	30	30	15
	Water demand (lit/sec)	137	210	201	156	153	78
Block B	Gross unit water requirement (lit/sec/ha)	9.1	7.0	6.7	5.2	5.1	5.2
	Area (ha)	20	40	40	40	40	20
	Water demand (lit/sec)	182	280	268	208	204	104
Block C	Gross unit water requirement (lit/sec/ha)	9.1	7.0	6.7	5.2	5.1	5.2
	Area (ha)	15	30	30	30	30	15
	Water demand (lit/sec)	137	210	201	156	153	78
Total water demand (Expected water demand) (lit/sec)		456	700	670	520	510	260
Expected water supply (lit/sec)							
Plan of water distribution (lit/sec)							

Identification of plan of water distribution

Plan of water distribution means capacity of the irrigation scheme to irrigate based on balance between supply (how much water to be taken from water source) and demand (how much water to be irrigated). Plan of water distribution shows how much discharge is supplied to meet the water requirement to each block.

The scheme sometimes cannot supply water to meet demand of all farmers due to water availability. So water balance between supply and demand is crucial like our daily life.

Plan of water distribution is obtained as following condition

- If Expected water supply > Expected water demand
  Plan of water distribution = Expected water demand because water availability is more than water demand of the scheme.
- If Expected water supply < Expected water demand
  Plan of water distribution = Expected water supply because water availability is less than water demand of the scheme.

If the expected water supply is 600 (lit/sec) in Table 3-12 throughout the year, Initial plan of water distribution in February and March should be 600 since the water demand exceeds the expected water supply. This means some part of irrigation scheme may suffer with water shortage. One of the possible countermeasures is to improve water management to reduce water losses in the scheme (Irrigation Efficiency increased).

Calculation result is shown in Table 3-12. Initial Plan of water distribution in January is same as expected water demand, since water supply is higher than expected water demand. Initial plan of water distribution in February to March is same as expected water supply, since expected water supply is less than water demand.

Expected water supply for entire irrigation scheme will be obtained from Feasibility Study Report or it is possible to assume that it is same as the discharge of water use permit.

It is necessary to pay attention because the discharge of water use permit is just permitted amount, it is not discharge guaranteed throughout the year.

How to adjust water demand in case of Flow sharing

If expected water demand is bigger than expected water supply, modification is needed such as cropping pattern, irrigation hour, type of crop and decreasing irrigation area. Also, adjustment method of water distribution plan for each distribution method is explained below.

In the case of Flow sharing, discharge based on the Water demand of each block is supplied to each block every day in principle. In the case of a month in which the total water demand exceeds the expected water supply, the initial plan of water distribution of each block should be adjusted so that the sum of the adjusted plan of water distribution of each block does not exceed the expected water supply.

The following formula expresses the adjusted plan of water distribution

Adjusted plan of water distribution =

$$\frac{\text{Expected water demand in block}}{\text{Total water demand}} \times \text{Expected water supply}$$

Formula-5

Since there is a high possibility that water shortage will occur in the adjusted month, it is better to consider the countermeasures in advance.

Table 3-12: Example of water distribution plan in Flow Sharing

	Name of block	Crop	Area (ha)	Jan.	Feb.	Mar.	Apr.	May	Jun
Expected water demand (lit/sec)	**Block A**	Paddy	30	137	210	201	156	153	78
	Block B	Paddy	40	182	280	268	208	204	104
	Block C	Paddy	30	137	210	201	156	153	78
Total water demand (Expected water demand) (lit/sec)			100	456	700*	670*	520	510	260
Expected water supply (lit/sec)				600	600	600	600	600	600

Initial Water Distribution Plan

	Name of Block:	Crops	Area (ha)	Jan.	Feb.	Mar.	Apr.	May	Jun
Initial plan of water distribution (lit/sec)	**Block A**	Paddy	30	137	210	201	156	153	78
	Block B	Paddy	40	182	280	268	208	204	104
	Block C	Paddy	30	137	210	201	156	153	78
	Total		100	456	**700***	**670***	520	510	260

Adjusted Water Distribution Plan

	Name of Block:	Crops	Area (ha)	Jan.	Feb.	Mar.	Apr.	May	Jun
Adjusted Plan of water distribution (lit/sec)	**Block A**	Paddy	30	137	180	180	156	153	78
	Block B	Paddy	40	182	240	240	208	204	104
	Block C	Paddy	30	137	180	180	156	153	78
	Total		100	456	600	600	520	510	260

* expected water demand exceeds expected water supply.

How to adjust water demand in case of Time sharing

In case of time sharing, the water demand to each block is obtained depending on the irrigation interval which means bigger amount of water may flow in the canal (see Table 3-8 in page24).

If 3 days’ irrigation interval is applied to the scheme, the water demand is calculated as in Table 3-13. In this case, total expected water demand in February is the highest value in whole cropping period. Also some water demand of block exceeds the expected water supply.

It is recommended to check the expected water supply in your scheme first when you determine the irrigation interval. Feasibility Study report is one of information sources of this matter. In addition, Water Use Permit indicates permitted water use which may be equivalent to the expected water supply.

When the plan of water distribution is formulated, order of irrigation for each irrigation block will be decided.

Table 3-13: Example of water distribution plan in Time Sharing

	Name of block	Crop	Area (ha)	Jan.	Feb.	Mar.	Apr.	May	Jun
Expected water demand (lit/sec)	**Block A**	Paddy	30	137	210	201	156	153	78
	Block B	Paddy	40	182	280	268	208	204	104
	Block C	Paddy	30	137	210	201	156	153	78
Irrigation interval	**3 days**	3 times larger than the expected water demand							
	Name of Block:	**Crop**	**Area (ha)**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun**
Expected water demand (lit/sec)	**Block A**	Paddy	30	411	630*	603*	468	459	234
	Block B	Paddy	40	546	840*	804*	624*	612*	312
	Block C	Paddy	30	411	630*	603*	468	459	234
Total expected water demand (lit/sec)			100	546	840*	804*	624*	612*	312
Expected water supply (lit/sec)				600	600	600	600	600	600
Plan of water distribution (lit/sec)				546	600	600	600	600	312
	Name of Block:	**Order of irrigation**		**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun**
Initial plan of water distribution (lit/sec)	**Block A**	Day1		411	630*	603*	468	459	234
	Block B	Day2		546	840*	804*	624	612	312
	Block C	Day3		411	630*	603*	468	459	234
	Name of Block:	**Order of irrigation**		**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	
Adjusted plan of water distribution (lit/sec)	**Block A**	Day1		411	600	600	468	459	234
	Block B	Day2		546	600	600	600	600	312
	Block C	Day3		411	600	600	468	459	234

* expected water demand exceeds expected water supply.

Planning Step 6 Explanation of water distribution plan to IO member

Even rational water distribution plan is made, if most of farmers do not know it, what is going to happen? Notification of the water distribution plan is very important.

Without consensus of farmers to the plan, smooth operation of water distribution is impossible.

At the general assembly, the sub-committee members shall explain the water distribution plan and facilitate the discussion and obtain the consensus on the following items:

- Division of the irrigation area into irrigation blocks
- Cropping pattern
- Type of water distribution
- Irrigation schedule and water distribution plan

The plan shall be modified based on results of discussion if necessary.

It is recommended that IO management committee member and sub-committee members understand the calculation process of water distribution plan and balance of demand and supply. This shall be enhanced by the District officers. Irrigation schedule should be explained to all member of IO.

The following Table 3-14 shows example of the irrigation schedule which is displayed in IO office. The schedule is showing the duration of water supply for each block. IO member clearly and easily know when they will get water to their plot.

Table 3-14: Example of Water Distribution Plan in Iganjo Irrigation scheme

Good Practice

Time table for water distribution in Iganjo irrigation scheme

S/N	Iganjo A		S/N	Iganjo B	
	Date	Block Name		Date	Block Name
	01/06/2016 → 07/06/2016	Bustani		01/06/2016 → 04/06/2016	Ituha
	08/06/2016 → 13/06/2016	Ibala		05/06/2016 → 11/06/2016	Sinkonte
	14/06/2016 → 20/06/2016	Mwanyanje		12/06/2016 → 15/06/2016	Itete
	21/06/2016 → 27/06/2016	Bustani		16/06/2016 → 19/06/2016	Sae
	28/06/2016 → 04/07/2016	Ibala		20/06/2016 → 23/06/2016	Igoye
	05/07/2016 → 11/07/2016	Mwanyanje		24/06/2016 → 29/06/2016	Ituha
	12/07/2016 → 18/07/2016	Bustani		30/06/2016 → 04/07/2016	Sinkonte

After the formulation of water distribution plan, it will be helpful to prepare signboard to inform farmers which block shall be supplied irrigation water.

Table 3-15 is an example of signboard which shows Block No. and Name, size of block and cultivated crop on the left hand side of this signboard. And on the right hand side, the cell of the corresponding day of the week is painted in the table. For example, Water provide to Block 1 on Monday, Tuesday, Friday and first half a day on Sunday.

Table 3-15: Water distribution plan for Igomelo scheme

Good Practice

Example of signboard for water distribution

Irrigation schedule in Igomelo irrigation scheme

				Month: October			Year: 2016		
Name of canal	Canal leader	Total area (acre)	Crops	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.
1	M.Luhigo	19.5	Paddy, Maize							
2	J.Mwitike	43.0	Paddy, Maize							
3	M.chengula	32.0	Paddy, Maize							
4	F.Vahaye	166.0	Paddy, Maize, Tomato							
5	E.Mgowole	64.0	Paddy, Maize							
6	J.Nyagawa	86.0	Paddy, Maize							
7	S.Shabani	17.5	Paddy, Maize							
8	Shaluta H.	66.0	Paddy, Maize							
9	E.Lulandala	53.0	Paddy, Maize							
10	M.Shilindi	95.0	Maize, Onion							
11	R.Nyagawa	73.0	Paddy, Maize							

4 Operation of Water Distribution along the Plan

How to distribute irrigation water along the plan? The flow how to distribute the irrigation water along the formulated water distribution plan and monitor those activity and how to feedback to next season is explained in this part.

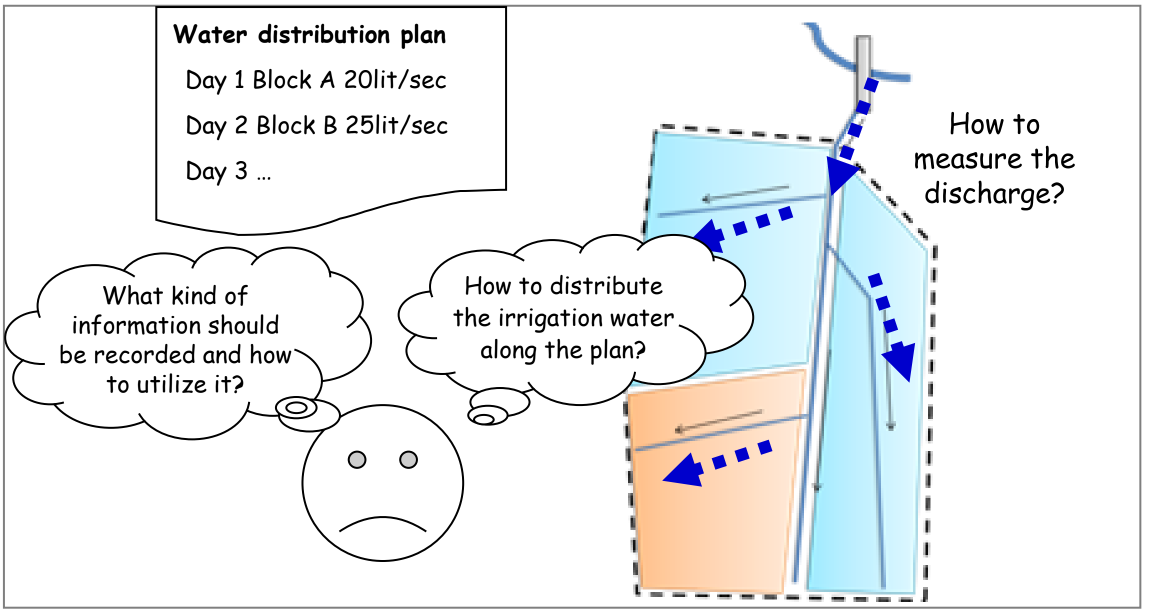
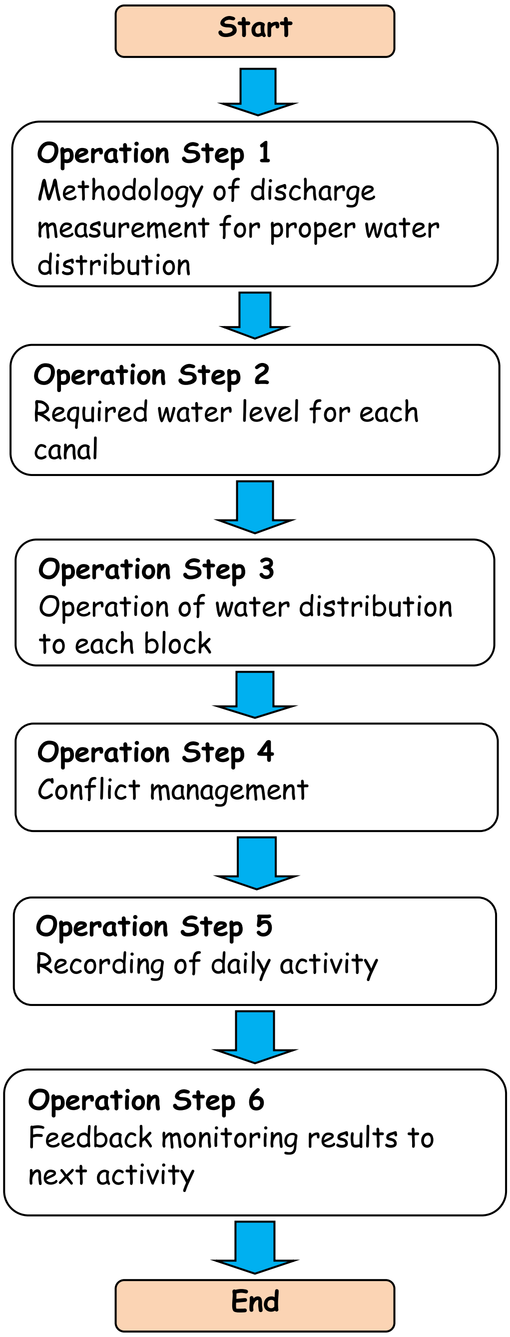


Figure 4-1: How to distribute irrigation water along the water distribution plan



It is important to know where and how to measure the discharge to distribute the water in line with water distribution plan

Then, by adjusting the water level, sufficient water to crop water requirement can be supplied to each block according to the plan.

Water master and block leaders are the main responsible person for water distribute according to the plan. Although it is important to distribute the water based on the plan, it's also important to adjust the water distribution in accordance with the actual condition of the crops.

Even if irrigation water is distributed along the plan, there is some possibility to face conflicts when a drought occurs.

To keep record is important for evaluation of the existing water distribution plan and estimation of the water fees from the irrigators within the blocks.

Monitoring results helps to improve the plan and operation of the structures for next season

Figure 4-2: Flow of operation, monitoring and feed back

Operation Step 1 Methodology of discharge measurement for proper water distribution

It is important to operate irrigation facilities in line with water distribution plan. If the operation would not be done properly, the plan becomes a white elephant.

Where should be measured discharge in the canal for water distribution?

In terms of water distribution management, it is shown in Figure 4-3 which points should be measured discharge in the irrigation system. In general, typical discharge measurement points are at the intake point to know how much water is abstracted from the water source, the points of main canal before the diversion work, and the starting point of the secondary canal to know how much water are distributed to each block.

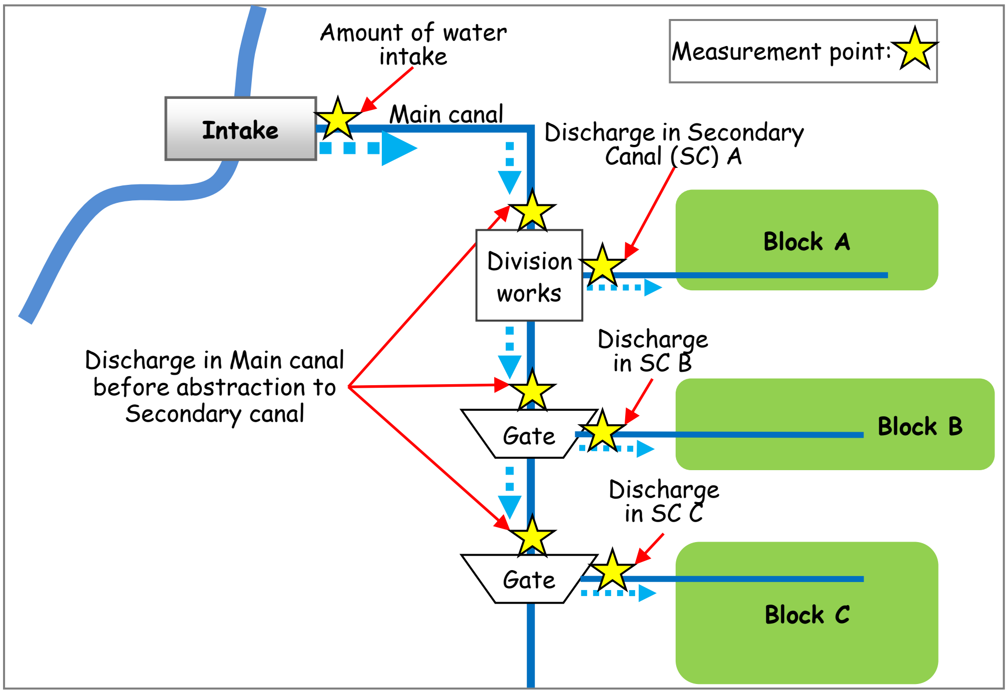


Figure 4-3: Typical discharge measurement point in irrigation scheme for water distribution

How to measure discharge in canal?

The discharge in the canal is obtained as follows with average velocity and cross section area of the canal.

Discharge in canal (m^3/sec) = Average velocity (m/sec) × Cross section area of the canal (m^2)

There are various methods for measuring discharge. Floating method is the simplest measurement method, and also described in CGL; therefore, this method is introduced in this manual.

Items for measurement:

- Tape measure
- Stop-watch
- Rod or staff gauge for measurement of depth. (Tape measure can be substituted)
- Twigs or stones to mark the start point and end point
- Floating object such as leafs, twig or something floating

Measurement procedure of velocity

1. Choose the measurement section. Straight way and minimum turbulence on a place of good visibility is preferable.
2. Set the twigs or stones at starting point and end point of measurement and measure the distance (= travel distance) between starting point and end point. It is preferable that the travel distance is about 5 to 10 meters or more. (See Figure 4-4)
3. Drop the floating object into the centre of canal upstream of the starting point.
4. Start the stop-watch when the floating object cross the start point and stop the stop-watch when the object crosses the end point.
5. Repeat the measurement at least 3 times and use the average in further calculation.
6. The surface velocity is obtained when the travel distance is divided by the travel time.
   Surface velocity (m/sec) = travel distance (m) ÷ travel time (sec)
7. Average velocity of the canal obtained as a product of surface velocity and 0.8
   Average velocity (m/sec) = Surface velocity (m/sec) ×0.8

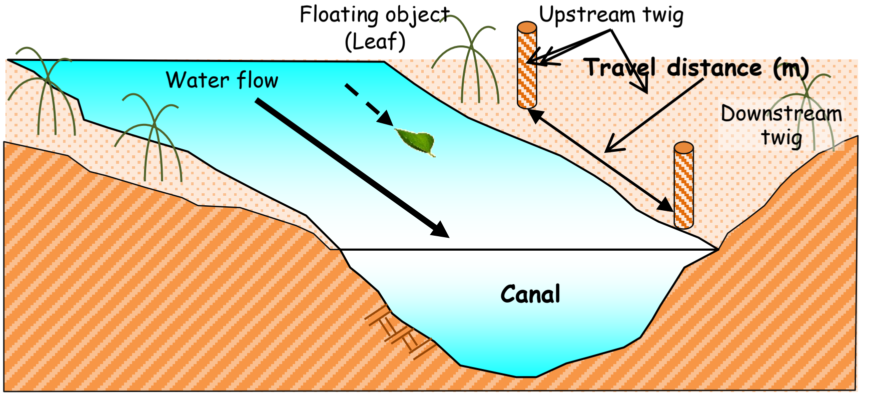


Figure 4-4: Measurement of velocity in the canal

Measurement procedure of cross section area

1) Measure the width of water surface (m) and depth of water (m) in the canal in case of rectangular cross section. (See Figure 4-5)
2) Rectangular cross section area (m^2) is obtained as a product of width of water surface (m) and depth of water (m).

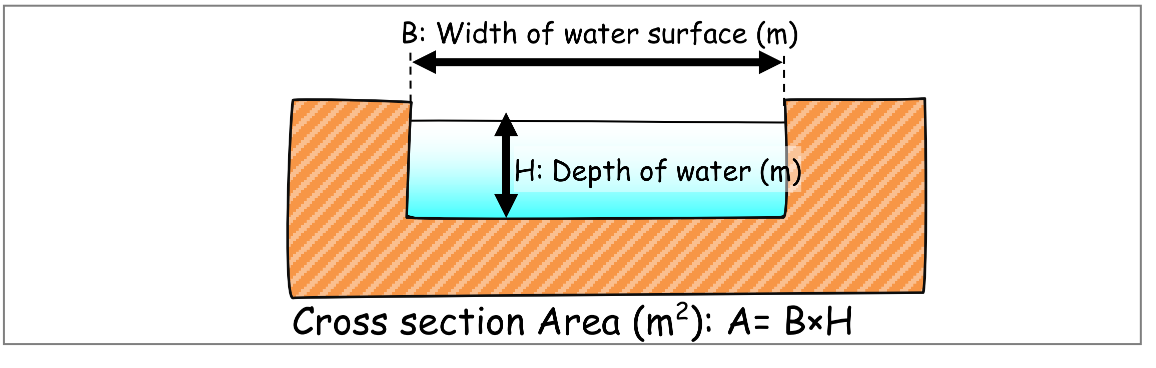


Figure 4-5 Measurement of cross section are in case of rectangular cross section

1) Measure the width of water surface (m) and canal bed (m) and depth of water (m) in the canal in case of trapezoid cross section. (See Figure 4-6)

2) Trapezoid cross section area (m^2) is obtained as a product of depth of water (m) and average width between water surface (m) and canal bed (m).

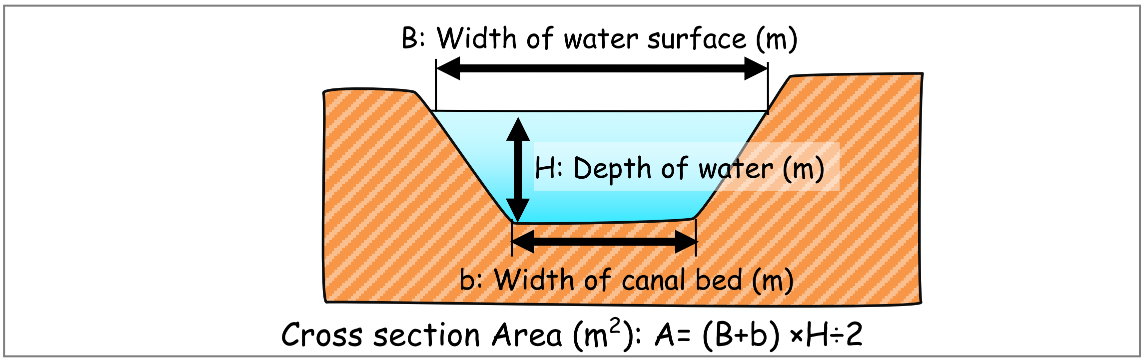


Figure 4-6: Measurement of cross section area in case of trapezoid cross section

Operation Step 2 Required Water Level for Each Canal

In order to operate irrigation structures properly, water master should know how much water is flowing in the canal. Water master can estimate discharge from water level.

Water level and discharge have correlation as shown in Figure 4-7. As the water level rises, the discharge increases. It is possible to estimate discharge from water level using this correlation.

In order to estimate the discharge, it is needed to draw a curve which has the correlation between water level and discharge. This curve is called rating curve or H-Q curve.

Each canal has different correlation due to different cross sectional area, lining condition etc. So it is necessary to draw the curve for each canal. Even the same canal, the condition will change due to scouring or sedimentation, so it is necessary to check rating curve regularly.

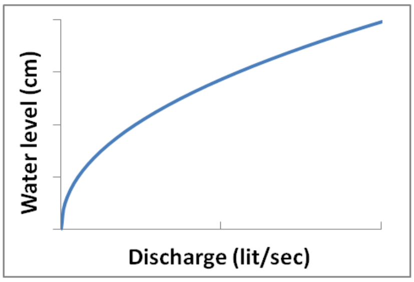


Figure 4-7: Relationship between discharge and water level (rating curve)

How to draw Rating curve (H-Q curve)?

1) Measure water flow velocity and water level at a point in a canal for different cases (at least 5 different water levels).
2) Calculate the discharge using the following formula for all measurements.

   Discharge = Water flow velocity ×Area of water flow in a canal

   Formula-6

3) Draw horizontal axis for discharge and vertical axis for water level by using ruler and write the scale referring the maximum water level and discharge for each axis. (See Figure 4-8)
4) Plot the discharge and water level on the chart based on the observed data.
5) Draw approximated curve along the plots. It is better not to connect the plots but to draw the smooth curve passing near the all plots.

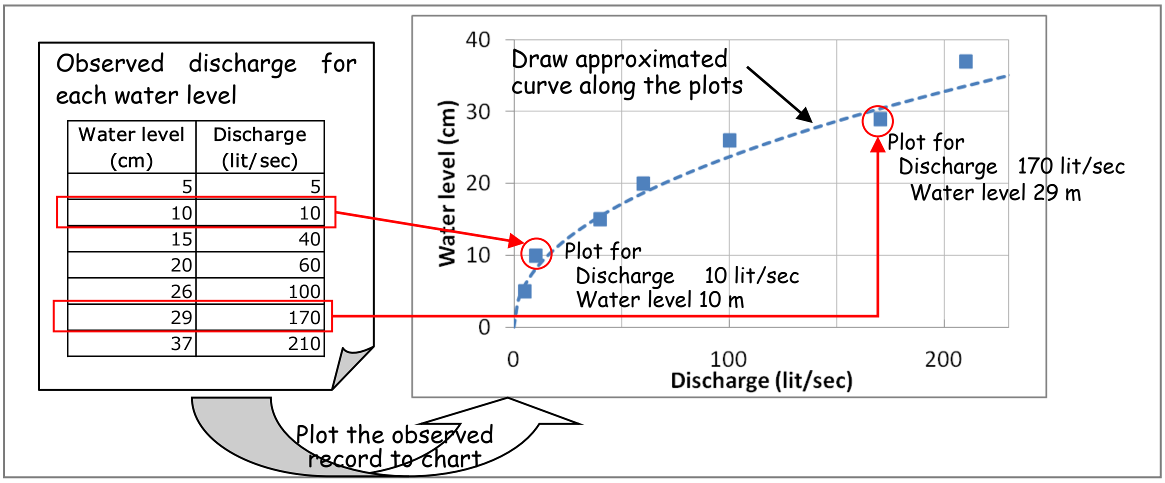


Figure 4-8: Plotting the result of measurement and drawing the curve

How to estimate discharge from water level from the rating curve (H-Q curve)?

You have already made a rating curve after field measurement as shown in Figure 4-9. And a water distribution plan says 152 lit/sec of discharge is required to Secondary canal B.

Procedure:

1. Find 152 lit/sec on discharge.
2. Vertically go up to the curve.
3. Then, go to water level.
4. Read the water level. You will get 32 cm water level.
5. Adjust water level in Secondary B canal to be 32 cm of water level.

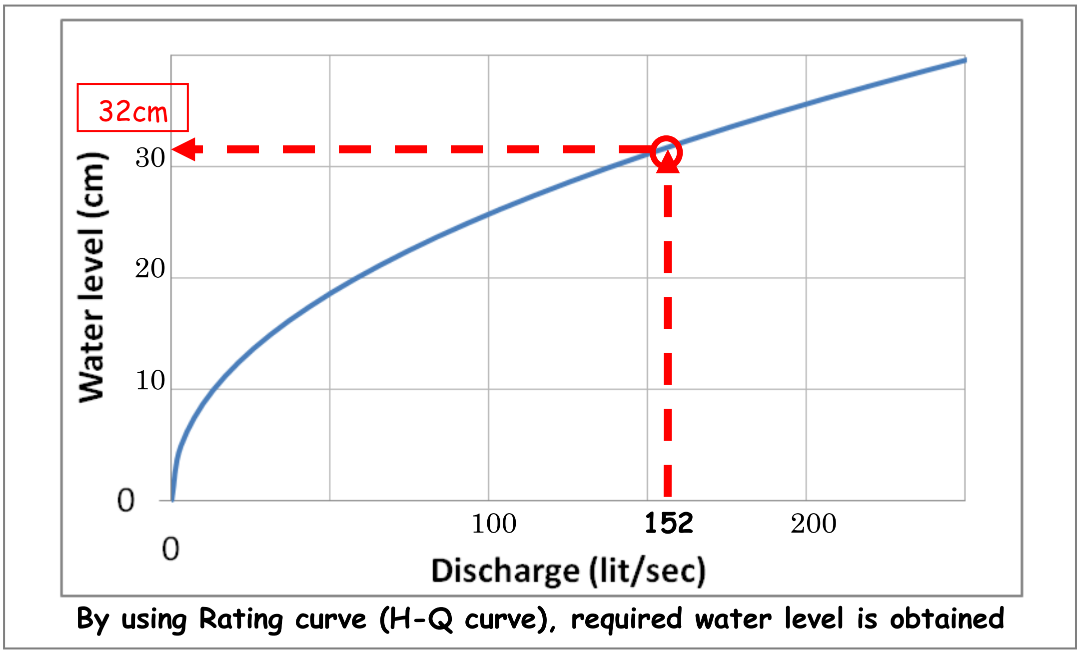


Figure 4-9: Estimation from required discharge to water level

You have gotten 32 cm to deliver 152 (lit/sec) in the canal. But you may not know how to measure the water level. There are some methods to measure water level in the field.

The most popular method is using a water gauge with calibration. You just see the water level at the gauge as shown in Figure 4-10. Also painting on the canal wall is easier to measure the water level. But paint will disappear as time goes by. Instead of painting, you can scratch (mark) the canal wall.

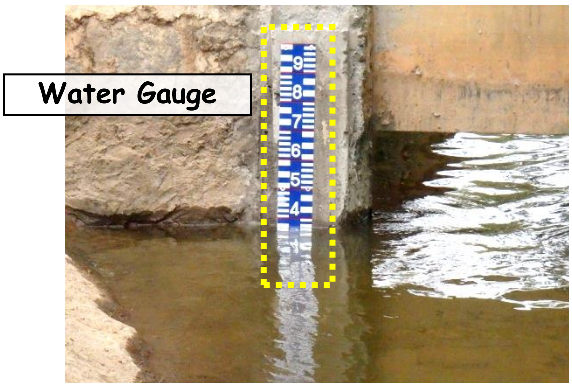


Figure 4-10: Installed Water gauge in Lemkuna irrigation scheme

There are various types of water level gauge. Figure 4-11 shows typical water level gauges and explanation how to read it. The persons in charge of the operation of the gate must understand how to read the water level gauge.

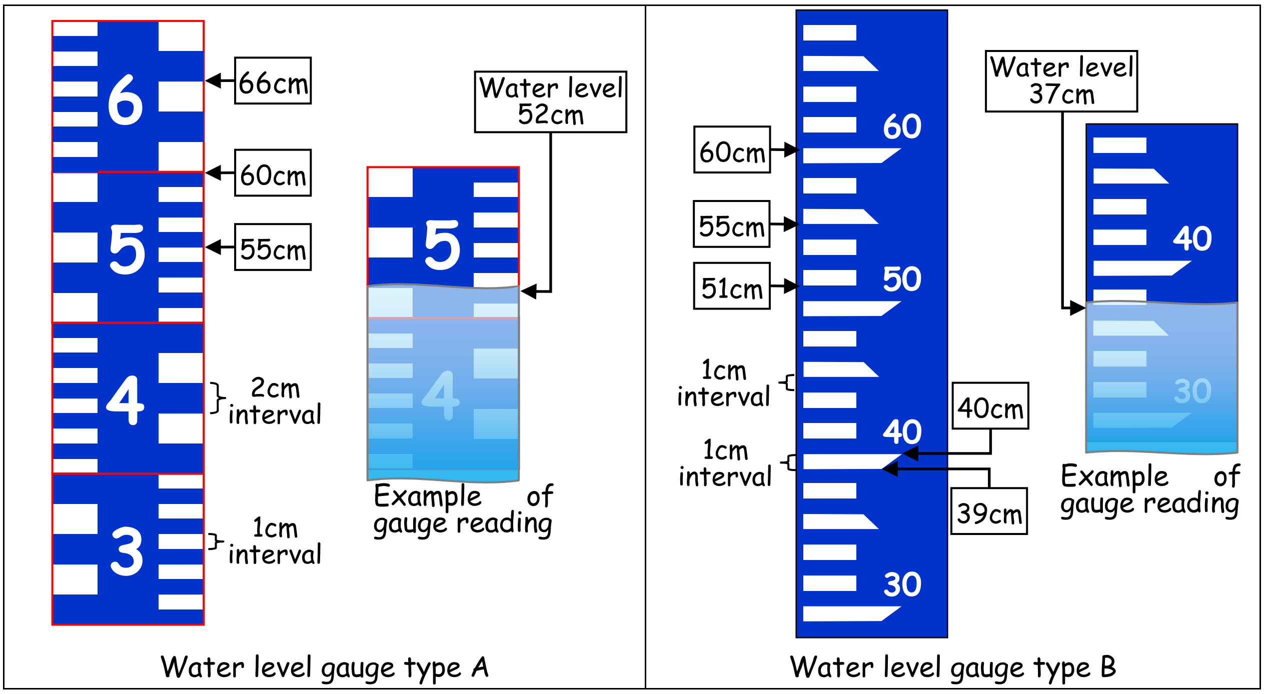


Figure 4-11 : Example of how to read water level gauge

Instead of water level gauge, water level can be measured by using bricks or stones with fixed shape. For example, when water demand is medium, the height corresponding to two bricks is sufficient water depth, and when water demand is high, the height corresponding to three bricks is also sufficient water depth (see Figure 4-12). It is very rough method but easy to applied. If the blocks or stones are too big compare to the width of the canal, it is needed to take care of influence of dam up caused by the blocks or stones.

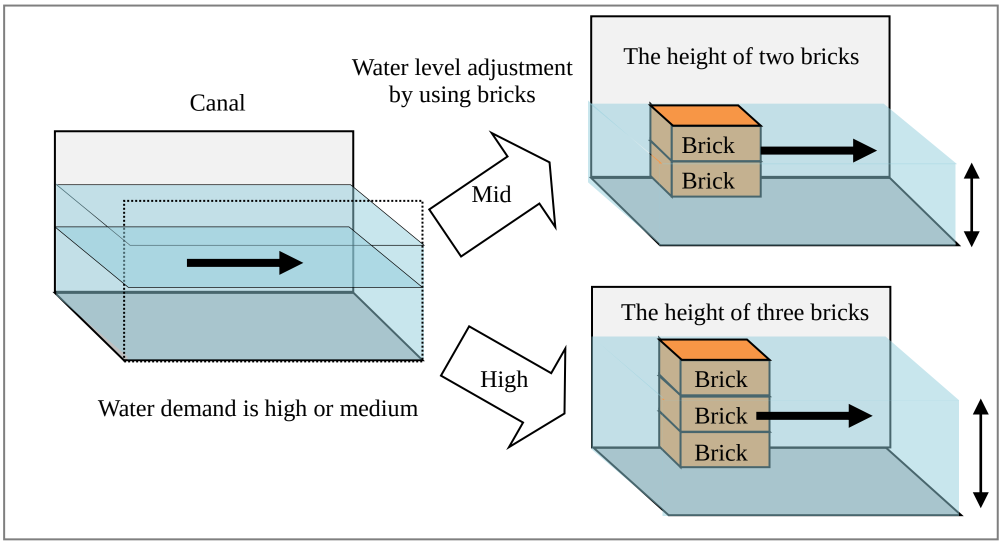


Figure 4-12: Water level adjustment by using bricks

Operation Step 3 Operation of Water Distribution to Each Block

Water master can realize fair water distribution of the scheme in collaboration with block leaders. The most important role of them is to adjust discharge in accordance with actual condition of the field.

Water master

Water master shall operate the gate along the main canal based on the water distribution plan. But, if he finds any water shortage or excess in the plots, it is needed to adjust the distributed water amount.

Since water distribution plan is formulated base on some assumption including irrigation efficiency and rainfall, there is some gap between calculated water requirement and actual water requirement in the plot. Therefore, the most important duty of water master is not only delivering water along the plan but also adjusting such gap between plan and actual water distribution.

The water master who has been in charge of water distribution for many years has a lot of knowledge and experience of water distribution within the scheme. Utilization of their experience is effective for realizing fair water distribution. If an experienced water master has been assigned in the scheme, it is recommended to fully utilize his experience in formulating water distribution plan, and also refer their advice at operation stage to respond to the actual situations at the site.

In addition, water master shall operate the intake gate. It is necessary to operate carefully not to abstract water exceeding the permitted discharge. In Iganjo irrigation scheme, the water master operates the gate so that the opening rate of the gate matches the mark indicated by the RBA to divert the permitted discharge to the irrigation scheme (see Figure 4-13).

Good Practice

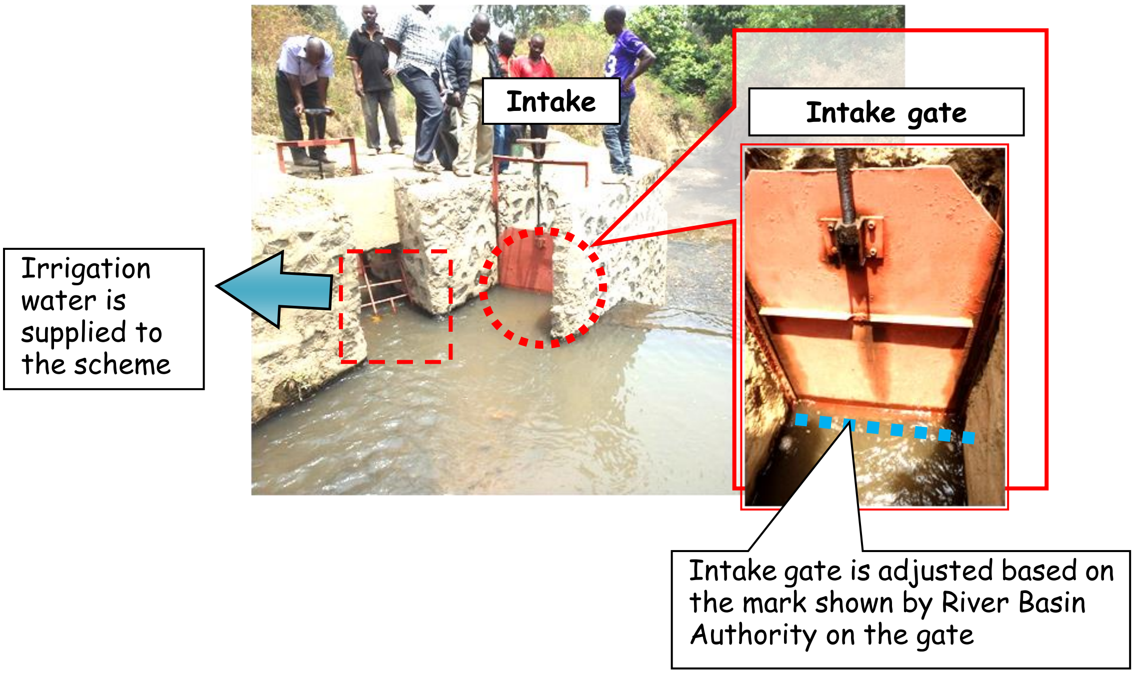


Figure 4-13: the Gate operation based on the indicator

In case of heavy rain and flooding, intake gate should be closed to protect the canals. Flooded water contains lot of sediments which might remain in the canal after flood past

Block leader and farmer

Block leaders cooperate with farmers to distribute water within each block along the water distribution plan and it is needed to distribute the water within the block considering following items.

- The amount of water distributed to each block
- Appropriate amount of water for crops
- How to distribute within the block
- The growing stage of the crop.

Although the permanent structure for water distribution is preferable for smooth operation of the structure, simple manner of water distribution is easy to apply and sustainable for farmers. Some examples for simple water distribution are shown in Figure 4-14. In Lemkuna irrigation scheme, farmers use the sand bags and stones to close the turnout from tertiary canal to field canal. In Iganjo irrigation scheme, farmers use handmade stop log to divert water from main canal to secondary canal.

Good Practice

The turnout from tertiary canal to field canal is closed using sand bags and stones in Lemukna irrigation scheme

Block leader and farmer use handmade stop log to distribute water from main canal to secondary canal in Iganjo irrigation scheme

Figure 4-14: Simple method for water distribution

Since no one can control rainfall, there is an option to change the farming system in order to minimize the damage caused by expected drought. In Iganjo irrigation scheme, an extension officer provides information on the amount of rainfall to IO. Since river discharge in dry season varies according to the amount of rainfall in wet season, it is possible to roughly anticipate the amount of river discharge for coming dry season. If the rainfall during the wet season is lower than average, it can be expected that river discharge will decrease during coming dry season. It helps farmers to make decision how to minimize the damage by the drought. Farmers would change the type of crop to other crop with less water consumption.

Operation Step 4 Conflict Management

Even if water is distributed along the planned, in some cases conflict will occur. Relevant person shall discuss the countermeasure to solve the conflict.

(CGL Volume 3, Page 4-5)

The block leaders shall solve the problems related to water distribution among farmers within the block. Therefore, it is important for block leaders to build a good relationship with farmers within the block. The good practice about water distribution within the block is shown in next page.

If there is not enough water within the block, block leader will discuss with block members how to share limited water supported by O&M or Water sub-committee and water master. The conflict among the blocks shall be solved by the sub-committee and water master. If the problem is serious and common to most farmers, general assembly shall be held to find the solution or countermeasure.

It is important to involve out-growers in the discussion for water distribution within the scheme to minimize the conflict between the scheme and out-grower. In Some irrigation scheme of Tanzania, both out-growers and the farmers within the scheme shall make an agreement how to allocate water to out-growers, and how to collect water use fee and O&M fee from out-growers. If the structure is not functional, the water amount for out-growers will be decreased.

The sub-committee is in a leading position to distribute limited water when water is not enough within the entire scheme at the time of drought. Also, in cooperation with the IO board, the sub-committee shall discuss how to correspond with external stakeholders.

If there is more than one irrigation scheme along the river which is defined as a main water source, in the case of severe drought, it is needed to gather all water users from upstream and downstream to discuss the amount of water intake for each scheme. At that time, it is needed to be involved officers from Ward or District and they will lead the discussion from a neutral standpoint for how to distribute limited water equally.

In the case that the water intake at the upstream permanently affects to the amount of available water for downstream water users, it might be needed to discuss the solution including review of the water use permit among water users with support of RBA.

How to avoid water conflicts within the scheme?

Some irrigation schemes in Tanzania have a useful operation plan under water shortage condition as follows,

1) Ward level Committee is held to discuss amount of water to be taken between upstream and downstream of the river.
2) After discussion, irrigation time is strictly arranged to be able to distribute water within the entire scheme equally
3) Moreover, water is preferentially allocated to the plot where serious water shortage is occurred if water shortage is quite serious.

Good Practice

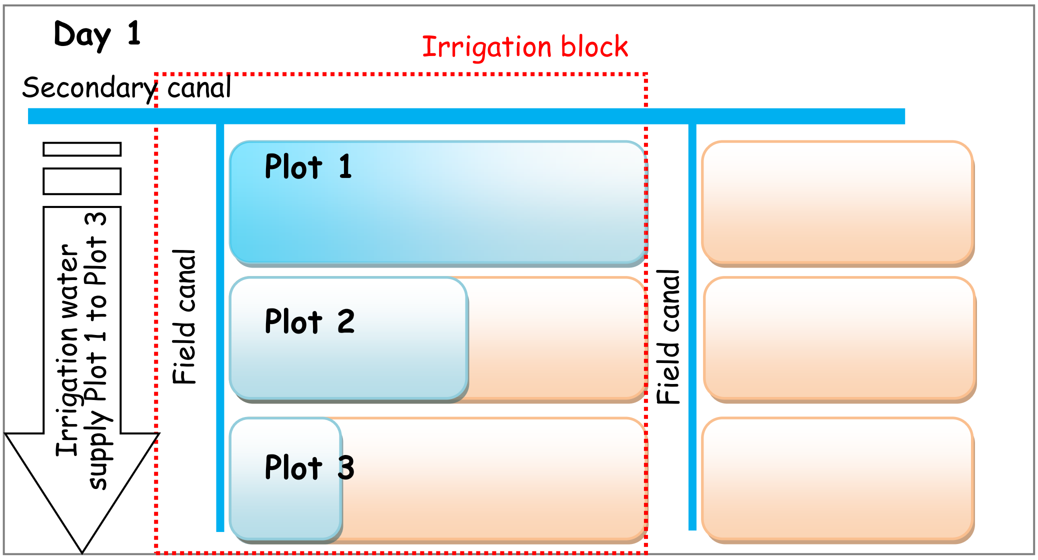
Water distribution within irrigation block

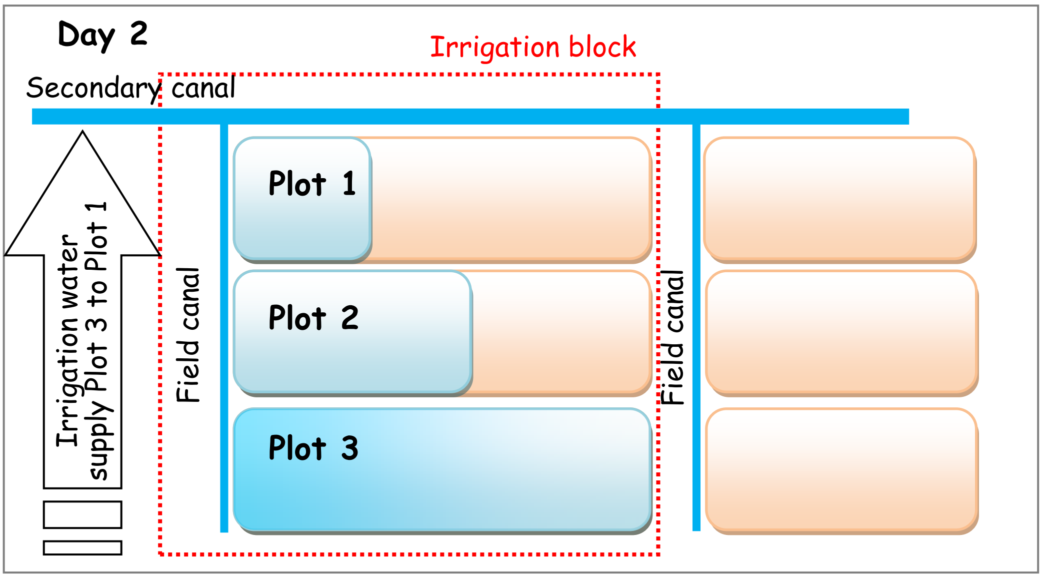
Good practice for water distribution within the block is introduced in Mawemairo irrigation scheme in Babati district.

The block leader distributes irrigation water from the upstream of field canal to downstream. Then, the order of irrigation is reversed to distribute water from downstream of field canal to upstream to ensure fair water distribution in the scheme. This method has been established based on farmers' experience.

e.g. Day 1 From the beginning to the end (Plot 1 to 3)

Day 2 From the end to beginning (Plot 3 to 1)





Operation Step 5 Daily Recording and Monitoring

Recording is not only for today but also for tomorrow. The records can be utilized to review and update the plan as a reference. So, record keeping is essential for irrigation scheme management.

It is important to record daily operation for water distribution along the plan as the accountability of Water master, O&M or Water sub-committee’s activity, and the record should be opened to all farmers. Monitoring and recording of the amount of water source such as river water level is also important to mitigate the risk of flooding and drought.

Gate operation

Daily operation of the gates should be recorded so that it will be evidence of proper operation of the facilities for water distribution along the plan. In addition, the condition of water distribution facilities such as gates should be recorded so that it will be possible to repair the facilities before it will lose their function (see **Appendix-8**).

Water level

Recording of the daily water level of water source is essential so that it enlightens the amount of available water in a season. Water level should be recorded at fixed time every day, and the data should be kept properly. Water level gauge has already been installed in some schemes, but it has not been monitored and recorded due to lack of knowledge and training opportunity (see **Appendix-8**).

Through the monitoring of water source, water master, OM or Water sub-committee can know the current available water for the scheme. It is helpful for their decision making before they will face water scarcity or flooding. Not only that, the observed water level will be utilized as an information of expected water supply in formulating water distribution plan.

Figure 4-15: Installed water level gauge.

It is recommended to use “CGL form-4 Operation record” to record the daily operation of irrigation structures by water master as well as block leaders. The record will be utilized not only operation and planning of water distribution plan but also maintenance of the facilities in order to prevent big damages.

Operation Step 6 Feedback Monitoring Results to Next Activity

Plan - Do - Check – Action cycle (PDCA cycle) is commonly adopted in irrigation scheme management. During implementation of water distribution, the scheme has to monitor and feedback to the next cropping season.

Recording is not only for the accountability but also for feedback to tomorrow's and the next season's activity.

Based on the record, farmers can discuss following topics.

- Whether current clopping pattern is appropriate or not.
- Whether current water requirement is appropriate or not.
- Is it necessary to review the water distribution plan?
- Which block faced water scarcity in this season and what is the reason?
- Is there any excess irrigation water to enlarge the irrigable area?

The result of discussion will be reflected to the next season's activity. Some of recorded data will be utilized for improving water distribution plan.

Figure 4-16 below is showing PDCA cycle on water distribution. This cycle makes the plan and irrigation scheme better.

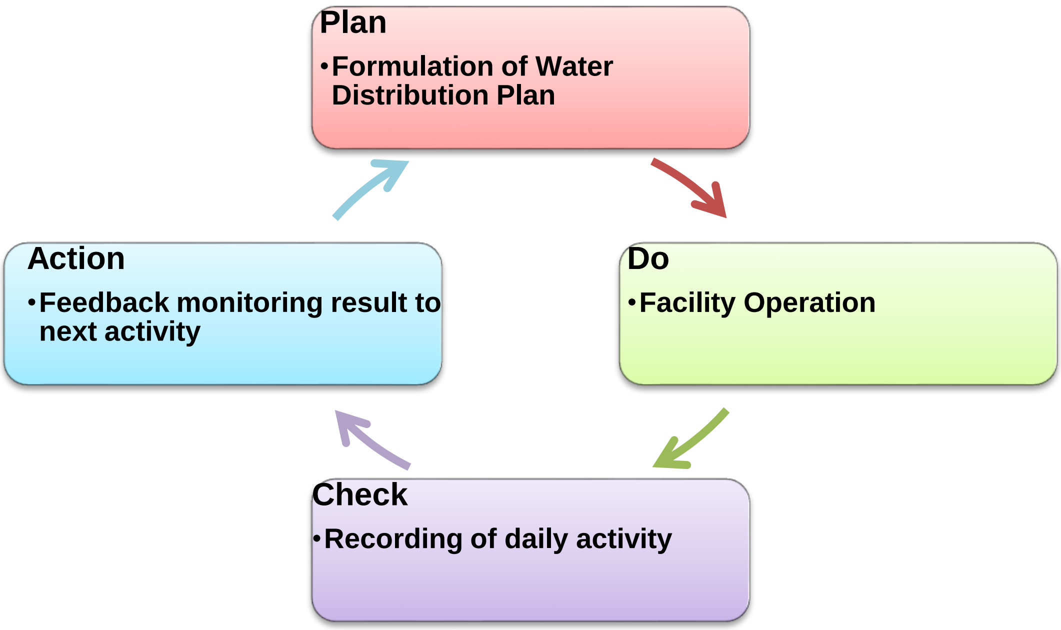


Figure 4-16: PDCA cycle for improvement of water distribution

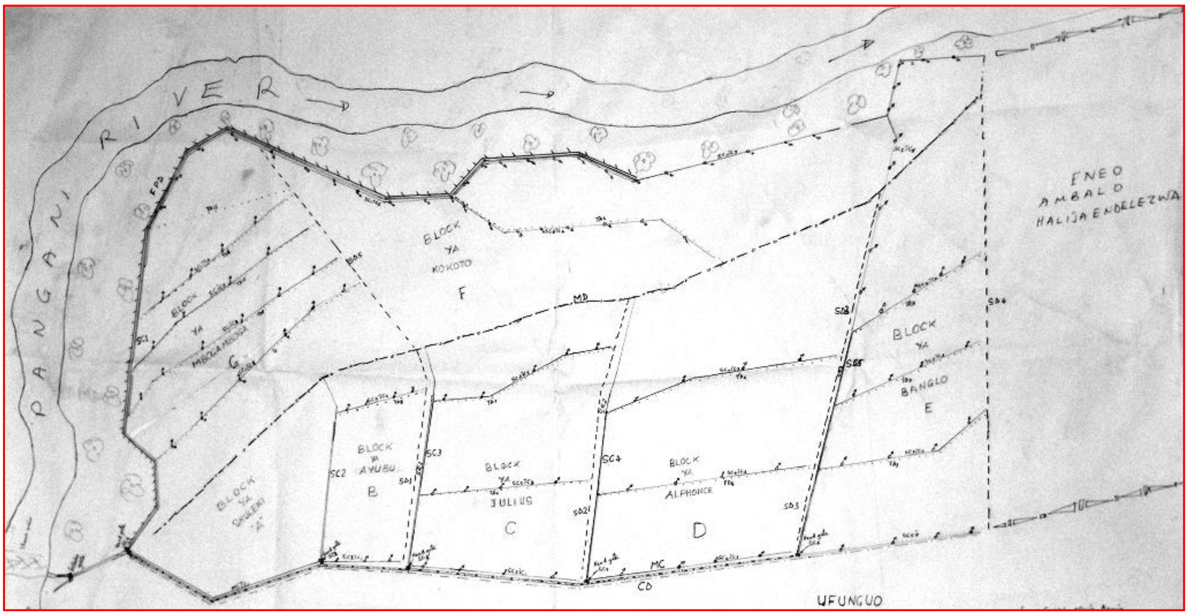
Appendix

Form-1 Basic operation plan (CGL Volume 3, Page 3-1, 3-2)

1) Division of irrigation area into several irrigation blocks

The proposed irrigation area will be divided into the following irrigation blocks. This will be a basis for water distribution planning.

Sketch of whole irrigation area divided into irrigation blocks



NOTE: Major structures, such as intake gates, head gates of secondary canals and major tertiary canals, major turnouts, and flow measuring devices, shall be drawn on this sketch.

Area of irrigation blocks

Name of irrigation block	Area (acre)	Area (ha)	Remarks
Block A: Shuleni	12	29	
Block B:Kwa Ayubu	19	48	
Block C:Kwa Julius	44	110	
Block D:Kwa Alphonce	39	98	
Block E:Bangio	70	176	
Block F:Kokoto	70	176	
Block G:Mbogamboga	72	179	
Block H:Oticha	80	200	
Total	406	1,016	

Step-1: Establishment of O&M System

2) Basic method of operation

Location / irrigation block	Gate / measuring facility	Sub Committee of IO in charge of operation	Method of operation
Block A: Shuleni	Gate: To Block A	Water sub committee Block leader	Flow sharing
Block B:Kwa Ayubu	Gate: To Block B	Water sub committee Block leader	Flow sharing
Block C:Kwa Julius	Gate: To Block C	Water sub committee Block leader	Flow sharing
Block D:Kwa Alphonce	Gate: To Block D	Water sub committee Block leader	Flow sharing
Block E:Bangio	Gate: To Block E	Water sub committee Block leader	Flow sharing
Block F:Kokoto	Gate: To Block F	Water sub committee Block leader	Flow sharing
Block G:Mbogamboga	Gate: MC to SC1 To Block G	Water sub committee Block leader	Flow sharing

NOTE: In the column of "Method of operation," the following descriptions, for example, can be entered:

- In the case of gate facilities → "operating gate in the method of time sharing or flow sharing" (See **Explanatory Note 1**.)
- In the case of measuring facilities → "Checking flow rate every day or every week

Appendix-2

Basic Information Sheet for Water Distribution
(Example)

Date:____________________

Zone	Region	District	Scheme	Name of IO
Central	Manyara	Simanjiro	Lemkuna irrigation scheme	UWALE

Number of farmer (water users) and IO member

Item	Male	Female	Total
No. of Farmer (water users)	210	192	402
No. of IO members	105	36	141

Number of farmer and Number of IO member

Season	Irradiated area (ha)	Potential Area (ha)	Planned Area (ha)	Main Crops
Rainy season	336	480	-	Paddy, Vegetables
Dry season	336	480	-	Paddy, Maize

No. and area of Irrigation blocks

No.	Name of block	Area (ha)	Crops
1	Block A: Shuleni	29	Paddy, Vegetable
2	Block B:Kwa Ayubu	48	Paddy
3	Block C:Kwa Julius	110	Paddy
4	Block D:Kwa Alphonce	98	Paddy
5	Block E:Bangio	176	Paddy
6	Block F:Kokoto	176	Vegetable
7	Block G:Mbogamboga	179	Vegetable
8	Block H:Oticha	29	Vegetable
9			
10			

Water use permit

Permitted year	Permitted Quantity	Last update
1998	500 lit/ sec	Never updated

Water management organization within the scheme

Management body	Water sub-committee

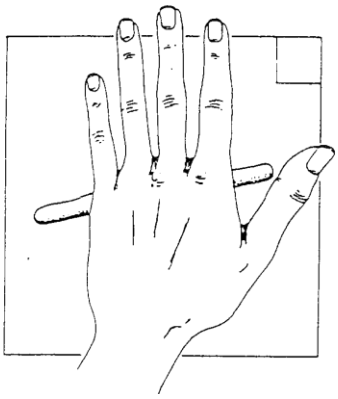
Responsible person for water distribution

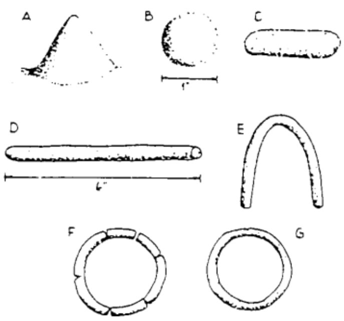
Title (No.)	Duty
Member of sub-committee (3)	Supervision of the block leaders and water master.
Water Master (1)	Operation of Intake gate, Water distribution from Main canal to Secondary canal
Block Leaders (10)	Water distribution from Secondary canal to tertiary canal and field canal

Form-4 Survey Sheet for Field Conditions Confirmation (1/7)

(CGL Volume 1, Page 3-7)

1) **Visit the survey together with village chairperson and villagers.**
   Visit the proposed area and choose typical soil in the area with the consultation of the village chairperson and villagers.
2) **Sampling of the soil**
   Gather a soil sample from the soil surface (sample should be about 10 x 10 x 10 cm).
3) **Knead the soil with water.**
   Add some water to the soil sample so it is moist but not wet. Knead it well. Pebbles should be removed.
4) **Try to create ring shapes with the soil sample and choose the most advanced shape that can be made.**





A: Soil can only be shaped into a cone. No other shapes hold together.
B: Soil can be formed into a circle, but not a rod shape.
C: Soil can be formed into a stout rod shape.
D: A thin rod (about 6 mm diameter) can be formed but not bent.
E: Thin rod can be bent without breaking
F: Circle can be formed with some breaks.
G: Complete circle with no breaks can be formed

5) **Evaluate the soil texture**
   According to the result of 4), circleoneofthedetailedsoiltexturetypes and choose a general soil texture type by conversion of the detailed soil texture type.

Detailed soil texture type			conversion	General soil texture type	
Shape A	Sand	☐	if you choose Shape A	→ Sand	☐
Shape B	Loamy sand	☐	if you choose Shape B or C	→ Sandy Loam	☐
Shape C	Silty Loam	☐			
Shape D	Loam	☐	if you choose Shape D or E	→ Clay Loam	☐
Shape E	Clay Loam	☐			
Shape F	Light Clay	☐	if you choose Shape F or G	→ Clay	☐
Shape G	Heavy Clay	☐			

Figure A- 1 : Simple method to find soil type

Appendix-4

Table A- 1 : Net Unit Water Requirement (NWR) in each Region 1/2

Unit: mm/month

Region	Crop	Soil Type	Dry Season						Rainy Season					
			Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Arusha	Paddy	Sandy Loam	637	460	502	501	-	-	686	465	484	358	390	-
		Clay Loam	432	310	352	346	-	-	481	325	329	208	235	-
		Clay	289	220	262	253	-	-	338	241	236	118	142	-
	Maize		90	112	194	191	144	-	45	124	165	58	75	-
	Bean & Veg		90	112	169	172	-	-	49	111	149	66	72	-
Kilimanjaro	Paddy	Sandy Loam	633	461	507	512	-	-	736	506	540	403	406	-
		Clay Loam	428	311	357	357	-	-	531	366	385	253	251	-
		Clay	285	221	267	264	-	-	388	282	292	163	158	-
	Maize		89	112	198	202	187	-	72	157	220	103	90	-
	Bean & Veg		89	112	172	182	-	-	72	138	193	102	85	-
Tanga	Paddy	Sandy Loam	658	456	474	470	-	-	732	500	522	374	340	-
		Clay Loam	453	306	324	315	-	-	527	360	367	224	185	-
		Clay	310	216	234	222	-	-	384	276	274	134	92	-
	Maize		85	102	166	160	139	-	70	153	203	74	23	-
	Bean & Veg		90	108	148	148	-	-	70	134	180	82	40	-
Iringa	Paddy	Sandy Loam	703	527	569	564	-	-	622	427	447	433	473	-
		Clay Loam	498	377	419	409	-	-	417	287	292	283	318	-
		Clay	355	287	329	316	-	-	274	203	199	193	225	-
	Maize		112	158	257	254	230	-	0	100	129	133	155	-
	Bean & Veg		112	158	224	228	-	-	13	89	120	123	139	-
Mbeya	Paddy	Sandy Loam	689	510	548	532	-	-	555	402	388	394	457	-
		Clay Loam	484	360	398	377	-	-	350	262	233	244	302	-
		Clay	341	270	308	284	-	-	207	178	140	154	209	-
	Maize		107	146	237	222	173	-	0	82	71	94	140	-
	Bean & Veg		107	146	206	200	-	-	0	73	74	92	125	-
Rukwa	Paddy	Sandy Loam	696	519	558	548	-	-	589	415	417	414	465	-
		Clay Loam	491	369	408	393	-	-	384	275	262	264	310	-
		Clay	348	279	318	300	-	-	241	191	169	174	217	-
	Maize		109	152	247	238	202	-	0	91	100	114	148	-
	Bean & Veg		109	152	215	214	-	-	0	81	97	107	132	-
Coast	Paddy	Sandy Loam	670	486	515	497	-	-	714	479	430	318	379	-
		Clay Loam	465	336	365	342	-	-	509	339	275	168	224	-
		Clay	322	246	275	249	-	-	366	255	182	78	131	-
	Maize		100	129	206	187	140	-	64	138	112	18	63	-
	Bean & Veg		100	129	179	170	-	-	65	121	109	37	67	-
D'Salaam	Paddy	Sandy Loam	665	484	511	491	-	-	703	478	440	347	381	-
		Clay Loam	460	334	361	336	-	-	498	338	285	197	226	-
		Clay	317	244	271	243	-	-	355	254	192	107	133	-
	Maize		96	127	202	181	151	-	53	137	122	47	64	-
	Bean & Veg		97	128	176	165	-	-	56	120	115	57	68	-
Morogoro	Paddy	Sandy Loam	627	450	485	485	-	-	673	445	426	325	381	-
		Clay Loam	422	300	335	330	-	-	468	305	271	175	226	-
		Clay	279	210	245	237	-	-	325	221	178	85	133	-
	Maize		86	104	177	175	161	-	34	111	109	25	66	-
	Bean & Veg		87	104	154	158	-	-	42	99	104	39	65	-
Lindi	Paddy	Sandy Loam	700	513	530	518	-	-	622	443	381	383	455	-
		Clay Loam	495	363	380	363	-	-	417	303	226	233	300	-
		Clay	352	273	290	270	-	-	274	219	133	143	207	-
	Maize		110	148	220	208	195	-	0	111	64	83	137	-
	Bean & Veg		111	148	192	187	-	-	6	99	71	86	125	-

Appendix-4

Net Unit Water Requirement (NWR) in each Region 2/2

Unit: mm/month

Region	Crop	Soil Type	Dry Season						Rainy Season					
			Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Mtwara	Paddy	Sandy Loam	700	513	530	518	-	-	622	443	381	383	455	-
		Clay Loam	495	363	380	363	-	-	417	303	226	233	300	-
		Clay	352	273	290	270	-	-	274	219	133	143	207	-
	Maize		110	148	220	208	195	-	0	111	64	83	137	-
	Bean & Veg		111	148	192	187	-	-	6	99	71	86	125	-
Ruvuma	Paddy	Sandy Loam	663	484	534	539	-	-	538	422	359	383	445	-
		Clay Loam	458	334	384	384	-	-	333	282	204	233	290	-
		Clay	315	244	294	291	-	-	190	198	111	143	197	-
	Maize		99	128	224	229	211	-	0	96	42	83	128	-
	Bean & Veg		99	128	195	206	-	-	0	85	54	83	115	-
Kagera	Paddy	Sandy Loam	664	451	424	357	-	-	579	361	337	242	294	-
		Clay Loam	459	301	274	202	-	-	374	221	182	92	139	-
		Clay	316	211	184	109	-	-	231	137	89	2	46	-
	Maize		97	100	117	47	8	-	0	40	20	0	0	-
	Bean & Veg		98	105	108	56	-	-	0	44	38	0	4	-
Mara	Paddy	Sandy Loam	696	509	530	478	-	-	672	453	479	365	411	-
		Clay Loam	491	359	380	323	-	-	467	313	324	215	256	-
		Clay	348	269	290	230	-	-	324	229	231	125	163	-
	Maize		109	145	220	168	118	-	43	117	160	65	94	-
	Bean & Veg		109	146	191	154	-	-	47	104	146	75	92	-
Mwanza	Paddy	Sandy Loam	713	514	528	468	-	-	625	440	461	376	443	-
		Clay Loam	508	364	378	313	-	-	420	300	306	226	288	-
		Clay	365	274	288	220	-	-	277	216	213	136	195	-
	Maize		114	149	219	158	83	-	9	109	143	76	125	-
	Bean & Veg		114	149	190	146	-	-	21	97	132	82	116	-
Shinyanga	Paddy	Sandy Loam	727	545	577	523	-	-	619	441	449	424	475	-
		Clay Loam	522	395	427	368	-	-	414	301	294	274	320	-
		Clay	379	305	337	275	-	-	271	217	201	184	227	-
	Maize		119	170	265	213	140	-	0	110	130	124	156	-
	Bean & Veg		119	170	231	192	-	-	12	97	124	120	141	-
Dodoma	Paddy	Sandy Loam	719	537	568	555	-	-	667	447	505	475	496	-
		Clay Loam	514	387	418	400	-	-	462	307	350	325	341	-
		Clay	371	297	328	307	-	-	319	223	257	235	248	-
	Maize		116	165	257	245	230	-	22	114	185	175	177	-
	Bean & Veg		116	165	223	220	-	-	34	101	166	159	158	-
Kigoma	Paddy	Sandy Loam	702	517	528	435	-	-	584	408	418	373	452	-
		Clay Loam	497	367	378	280	-	-	379	268	263	223	297	-
		Clay	354	277	288	187	-	-	236	184	170	133	204	-
	Maize		111	151	219	125	55	-	0	86	102	73	135	-
	Bean & Veg		111	151	190	118	-	-	0	77	96	77	121	-
Singida	Paddy	Sandy Loam	745	563	637	545	-	-	589	413	440	413	478	-
		Clay Loam	540	413	487	390	-	-	384	273	285	263	323	-
		Clay	397	323	397	297	-	-	241	189	192	173	230	-
	Maize		125	183	323	235	152	-	0	90	122	113	160	-
	Bean & Veg		125	183	281	212	-	-	0	80	116	110	143	-
Tabora	Paddy	Sandy Loam	745	563	637	545	-	-	589	413	440	413	478	-
		Clay Loam	540	413	487	390	-	-	384	273	285	263	323	-
		Clay	397	323	397	297	-	-	241	189	192	173	230	-
	Maize		125	183	323	235	152	-	0	90	122	113	160	-
	Bean & Veg		125	183	281	212	-	-	0	80	116	110	143	-

Table A- 2 Gross Unit Water Requirement (GWR) in each Region

Irrigation Efficiency =0.4 (40%)

Unit: lit/sec/ha

Region	Crop	Soil type	Dry Season						Rainy Season					
			Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Arusha	Paddy	Sandy Loam	5.9	4.3	4.8	4.7	-	-	6.4	4.8	4.5	3.4	3.6	-
		Clay Loam	4.0	2.9	3.4	3.2	-	-	4.5	3.4	3.1	2.0	2.2	-
		Clay	2.7	2.1	2.5	2.4	-	-	3.2	2.5	2.2	1.1	1.3	-
	Maize		0.8	1.0	1.9	1.8	1.4	-	0.4	1.3	1.5	0.5	0.7	-
	Bean & Veg		0.8	1.0	1.6	1.6	-	-	0.5	1.2	1.4	0.6	0.7	-
Kilimanjaro	Paddy	Sandy Loam	5.9	4.3	4.9	4.8	-	-	6.9	5.2	5.0	3.9	3.8	-
		Clay Loam	4.0	2.9	3.4	3.3	-	-	4.9	3.8	3.6	2.4	2.3	-
		Clay	2.7	2.1	2.6	2.5	-	-	3.6	2.9	2.7	1.6	1.5	-
	Maize		0.8	1.0	1.9	1.9	1.8	-	0.7	1.6	2.1	1.0	0.8	-
	Bean & Veg		0.8	1.0	1.6	1.7	-	-	0.7	1.4	1.8	1.0	0.8	-
Tanga	Paddy	Sandy Loam	6.1	4.3	4.6	4.4	-	-	6.8	5.2	4.9	3.6	3.2	-
		Clay Loam	4.2	2.9	3.1	3.0	-	-	4.9	3.7	3.4	2.2	1.7	-
		Clay	2.9	2.0	2.3	2.1	-	-	3.6	2.9	2.5	1.3	0.9	-
	Maize		0.8	1.0	1.6	1.5	1.3	-	0.7	1.6	1.9	0.7	0.2	-
	Bean & Veg		0.8	1.0	1.4	1.4	-	-	0.7	1.4	1.7	0.8	0.4	-
Iringa	Paddy	Sandy Loam	6.6	4.9	5.5	5.3	-	-	5.8	4.4	4.2	4.2	4.4	-
		Clay Loam	4.7	3.5	4.1	3.8	-	-	3.9	3.0	2.7	2.7	3.0	-
		Clay	3.3	2.7	3.2	3.0	-	-	2.5	2.1	1.9	1.9	2.1	-
	Maize		1.0	1.5	2.5	2.4	2.2	-	0.0	1.0	1.2	1.3	1.4	-
	Bean & Veg		1.0	1.5	2.2	2.1	-	-	0.1	0.9	1.1	1.2	1.3	-
Mbeya	Paddy	Sandy Loam	6.4	4.8	5.3	5.0	-	-	5.2	4.2	3.6	3.8	4.3	-
		Clay Loam	4.5	3.4	3.8	3.5	-	-	3.3	2.7	2.2	2.3	2.8	-
		Clay	3.2	2.5	3.0	2.7	-	-	1.9	1.9	1.3	1.5	1.9	-
	Maize		1.0	1.4	2.3	2.1	1.7	-	0.0	0.8	0.7	0.9	1.3	-
	Bean & Veg		1.0	1.4	2.0	1.9	-	-	0.0	0.8	0.7	0.9	1.2	-
Rukwa	Paddy	Sandy Loam	6.5	4.8	5.4	5.1	-	-	5.5	4.3	3.9	4.0	4.3	-
		Clay Loam	4.6	3.4	3.9	3.7	-	-	3.6	2.8	2.5	2.5	2.9	-
		Clay	3.2	2.6	3.1	2.8	-	-	2.3	2.0	1.6	1.7	2.0	-
	Maize		1.0	1.4	2.4	2.2	1.9	-	0.0	1.0	0.9	1.1	1.4	-
	Bean & Veg		1.0	1.4	2.1	2.0	-	-	0.0	0.8	0.9	1.0	1.2	-
Coast	Paddy	Sandy Loam	6.3	4.5	5.0	4.6	-	-	6.7	4.9	4.0	3.1	3.5	-
		Clay Loam	4.3	3.1	3.5	3.2	-	-	4.7	3.5	2.6	1.6	2.1	-
		Clay	3.0	2.3	2.7	2.3	-	-	3.4	2.6	1.7	0.8	1.2	-
	Maize		0.9	1.2	2.0	1.7	1.4	-	0.6	1.4	1.0	0.2	0.6	-
	Bean & Veg		0.9	1.2	1.7	1.6	-	-	0.6	1.2	1.0	0.3	0.6	-
D’Salaam	Paddy	Sandy Loam	6.2	4.5	4.9	4.6	-	-	6.6	4.9	4.1	3.4	3.6	-
		Clay Loam	4.3	3.1	3.5	3.1	-	-	4.7	3.5	2.7	1.9	2.1	-
		Clay	3.0	2.3	2.6	2.3	-	-	3.3	2.6	1.8	1.0	1.2	-
	Maize		0.9	1.2	1.9	1.7	1.4	-	0.5	1.4	1.1	0.5	0.6	-
	Bean & Veg		0.9	1.2	1.7	1.5	-	-	0.5	1.2	1.1	0.5	0.6	-
Morogoro	Paddy	Sandy Loam	5.8	4.2	4.7	4.5	-	-	6.3	4.6	4.0	3.1	3.6	-
		Clay Loam	3.9	2.8	3.2	3.1	-	-	4.4	3.2	2.5	1.7	2.1	-
		Clay	2.6	2.0	2.4	2.2	-	-	3.0	2.3	1.6	0.8	1.2	-
	Maize		0.8	1.0	1.7	1.6	1.6	-	0.3	1.2	1.0	0.2	0.6	-
	Bean & Veg		0.8	1.0	1.5	1.5	-	-	0.4	1.0	1.0	0.4	0.6	-
Lindi	Paddy	Sandy Loam	6.5	4.8	5.1	4.8	-	-	5.8	4.6	3.6	3.7	4.3	-
		Clay Loam	4.6	3.4	3.7	3.4	-	-	3.9	3.1	2.1	2.3	2.8	-
		Clay	3.3	2.5	2.8	2.5	-	-	2.5	2.3	1.2	1.4	1.9	-
	Maize		1.0	1.4	2.1	1.9	1.9	-	0.0	1.2	0.6	0.8	1.3	-
	Bean & Veg		1.0	1.4	1.9	1.7	-	-	0.1	1.0	0.7	0.8	1.2	-

Table A- 2 Gross Unit Water Requirement (GWR) in each Region

Irrigation Efficiency =0.4 (40%)

Unit: lit/sec/ha

Region	Crop	Soil type	Dry Season						Rainy Season					
			Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Mtwara	Paddy	Sandy Loam	6.5	4.8	5.1	4.8	-	-	5.8	4.6	3.6	3.7	4.3	-
		Clay Loam	4.6	3.4	3.7	3.4	-	-	3.9	3.1	2.1	2.3	2.8	-
		Clay	3.3	2.5	2.8	2.5	-	-	2.5	2.3	1.2	1.4	1.9	-
	Maize		1.0	1.4	2.1	1.9	1.9	-	0.0	1.2	0.6	0.8	1.3	-
	Bean & Veg		1.0	1.4	1.9	1.7	-	-	0.1	1.0	0.7	0.8	1.2	-
Ruvuma	Paddy	Sandy Loam	6.2	4.5	5.2	5.0	-	-	5.0	4.4	3.4	3.7	4.2	-
		Clay Loam	4.3	3.1	3.7	3.6	-	-	3.1	2.9	1.9	2.3	2.7	-
		Clay	3.0	2.3	2.8	2.7	-	-	1.8	2.1	1.0	1.4	1.9	-
	Maize		0.9	1.2	2.2	2.1	2.0	-	0.0	1.0	0.4	0.8	1.2	-
	Bean & Veg		0.9	1.2	1.9	1.9	-	-	0.0	0.9	0.5	0.8	1.1	-
Kagera	Paddy	Sandy Loam	6.2	4.2	4.1	3.3	-	-	5.4	3.7	3.2	2.3	2.7	-
		Clay Loam	4.3	2.8	2.6	1.9	-	-	3.5	2.3	1.7	0.9	1.3	-
		Clay	3.0	2.0	1.8	1.0	-	-	2.2	1.4	0.8	0.0	0.4	-
	Maize		0.9	0.9	1.1	0.4	0.1	-	0.0	0.4	0.2	0.0	0.0	-
	Bean & Veg		0.9	1.0	1.0	0.5	-	-	0.0	0.5	0.3	0.0	0.0	-
Mara	Paddy	Sandy Loam	6.5	4.7	5.1	4.5	-	-	6.3	4.7	4.5	3.5	3.8	-
		Clay Loam	4.6	3.4	3.7	3.0	-	-	4.4	3.2	3.0	2.1	2.4	-
		Clay	3.2	2.5	2.8	2.1	-	-	3.0	2.4	2.2	1.2	1.5	-
	Maize		1.0	1.4	2.1	1.6	1.1	-	0.4	1.2	1.5	0.6	0.9	-
	Bean & Veg		1.0	1.4	1.9	1.4	-	-	0.4	1.1	1.4	0.7	0.9	-
Mwanza	Paddy	Sandy Loam	6.7	4.8	5.1	4.4	-	-	5.8	4.5	4.3	3.6	4.1	-
		Clay Loam	4.7	3.4	3.6	2.9	-	-	3.9	3.1	2.9	2.2	2.7	-
		Clay	3.4	2.5	2.8	2.1	-	-	2.6	2.2	2.0	1.3	1.8	-
	Maize		1.1	1.4	2.1	1.5	0.8	-	0.1	1.1	1.3	0.7	1.2	-
	Bean & Veg		1.1	1.4	1.8	1.4	-	-	0.2	1.0	1.2	0.8	1.1	-
Shinyanga	Paddy	Sandy Loam	6.8	5.1	5.6	4.9	-	-	5.8	4.6	4.2	4.1	4.4	-
		Clay Loam	4.9	3.7	4.1	3.4	-	-	3.9	3.1	2.7	2.6	3.0	-
		Clay	3.5	2.8	3.2	2.6	-	-	2.5	2.3	1.9	1.8	2.1	-
	Maize		1.1	1.6	2.5	2.0	1.4	-	0.0	1.1	1.2	1.2	1.4	-
	Bean & Veg		1.1	1.6	2.2	1.8	-	-	0.1	1.0	1.2	1.2	1.3	-
Dodoma	Paddy	Sandy Loam	6.7	5.0	5.5	5.2	-	-	6.2	4.6	4.7	4.6	4.6	-
		Clay Loam	4.8	3.6	4.0	3.7	-	-	4.3	3.2	3.3	3.1	3.2	-
		Clay	3.5	2.8	3.2	2.9	-	-	3.0	2.3	2.4	2.3	2.3	-
	Maize		1.1	1.5	2.5	2.3	2.2	-	0.2	1.2	1.7	1.7	1.6	-
	Bean & Veg		1.1	1.5	2.1	2.1	-	-	0.3	1.0	1.6	1.5	1.5	-
Kigoma	Paddy	Sandy Loam	6.5	4.8	5.1	4.1	-	-	5.4	4.2	3.9	3.6	4.2	-
		Clay Loam	4.6	3.4	3.6	2.6	-	-	3.5	2.8	2.5	2.1	2.8	-
		Clay	3.3	2.6	2.8	1.7	-	-	2.2	1.9	1.6	1.3	1.9	-
	Maize		1.0	1.4	2.1	1.2	0.5	-	0.0	0.9	1.0	0.7	1.3	-
	Bean & Veg		1.0	1.4	1.8	1.1	-	-	0.0	0.8	0.9	0.8	1.1	-
Singida	Paddy	Sandy Loam	6.9	5.3	6.1	5.1	-	-	5.5	4.3	4.1	4.0	4.5	-
		Clay Loam	5.0	3.8	4.7	3.6	-	-	3.6	2.8	2.7	2.5	3.0	-
		Clay	3.7	3.0	3.8	2.8	-	-	2.3	2.0	1.8	1.7	2.1	-
	Maize		1.2	1.7	3.1	2.2	1.5	-	0.0	0.9	1.1	1.1	1.5	-
	Bean & Veg		1.2	1.7	2.7	2.0	-	-	0.0	0.8	1.1	1.1	1.3	-
Tabora	Paddy	Sandy Loam	6.9	5.3	6.1	5.1	-	-	5.5	4.3	4.1	4.0	4.5	-
		Clay Loam	5.0	3.8	4.7	3.6	-	-	3.6	2.8	2.7	2.5	3.0	-
		Clay	3.7	3.0	3.8	2.8	-	-	2.3	2.0	1.8	1.7	2.1	-
	Maize		1.2	1.7	3.1	2.2	1.5	-	0.0	0.9	1.1	1.1	1.5	-
	Bean & Veg		1.2	1.7	2.7	2.0	-	-	0.0	0.8	1.1	1.1	1.3	-

Table A- 3: Gross Unit Water Requirement (GWR) in each Region

Irrigation Efficiency =0.3 (30%)

Unit: lit/sec/ha

Region	Crop	Soil type	Dry Season						Rainy Season					
			Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Arusha	Paddy	Sandy Loam	7.9	5.7	6.4	6.3	-	-	8.5	6.4	6.0	4.6	4.9	-
		Clay Loam	5.4	3.9	4.5	4.3	-	-	6.0	4.5	4.1	2.7	2.9	-
		Clay	3.6	2.7	3.4	3.2	-	-	4.2	3.3	2.9	1.5	1.8	-
	Maize		1.1	1.4	2.5	2.4	1.9	-	0.6	1.7	2.0	0.7	0.9	-
	Bean & Veg		1.1	1.4	2.2	2.1	-	-	0.6	1.5	1.9	0.8	0.9	-
Kilimanjaro	Paddy	Sandy Loam	7.9	5.7	6.5	6.4	-	-	9.1	7.0	6.7	5.2	5.1	-
		Clay Loam	5.3	3.9	4.6	4.4	-	-	6.6	5.1	4.8	3.2	3.1	-
		Clay	3.5	2.7	3.4	3.3	-	-	4.8	3.9	3.6	2.1	2.0	-
	Maize		1.1	1.4	2.5	2.5	2.4	-	0.9	2.2	2.7	1.3	1.1	-
	Bean & Veg		1.1	1.4	2.2	2.3	-	-	0.9	1.9	2.4	1.3	1.0	-
Tanga	Paddy	Sandy Loam	8.2	5.7	6.1	5.9	-	-	9.1	6.9	6.5	4.8	4.2	-
		Clay Loam	5.6	3.8	4.2	3.9	-	-	6.6	5.0	4.6	2.9	2.3	-
		Clay	3.9	2.7	3.0	2.8	-	-	4.8	3.8	3.4	1.7	1.2	-
	Maize		1.0	1.3	2.1	2.0	1.8	-	0.9	2.1	2.5	1.0	0.3	-
	Bean & Veg		1.1	1.4	1.9	1.9	-	-	0.9	1.9	2.2	1.0	0.5	-
Iringa	Paddy	Sandy Loam	8.8	6.6	7.3	7.0	-	-	7.8	5.9	5.6	5.6	5.9	-
		Clay Loam	6.2	4.7	5.4	5.1	-	-	5.2	4.0	3.6	3.6	4.0	-
		Clay	4.4	3.6	4.2	3.9	-	-	3.4	2.8	2.5	2.5	2.8	-
	Maize		1.4	2.0	3.3	3.2	3.0	-	0.0	1.4	1.6	1.7	1.9	-
	Bean & Veg		1.4	2.0	2.9	2.9	-	-	0.2	1.2	1.5	1.6	1.7	-
Mbeya	Paddy	Sandy Loam	8.6	6.4	7.1	6.6	-	-	6.9	5.6	4.8	5.1	5.7	-
		Clay Loam	6.0	4.5	5.1	4.7	-	-	4.4	3.6	2.9	3.1	3.7	-
		Clay	4.2	3.4	4.0	3.5	-	-	2.6	2.5	1.7	2.0	2.6	-
	Maize		1.4	1.8	3.0	2.8	2.2	-	0.0	1.1	0.9	1.2	1.7	-
	Bean & Veg		1.4	1.8	2.7	2.5	-	-	0.0	1.0	0.9	1.2	1.5	-
Rukwa	Paddy	Sandy Loam	8.7	6.4	7.2	6.8	-	-	7.3	5.7	5.2	5.3	5.8	-
		Clay Loam	6.1	4.6	5.2	4.9	-	-	4.8	3.8	3.3	3.4	3.9	-
		Clay	4.3	3.5	4.1	3.7	-	-	3.0	2.6	2.1	2.2	2.7	-
	Maize		1.4	1.9	3.2	3.0	2.6	-	0.0	1.3	1.2	1.5	1.9	-
	Bean & Veg		1.4	1.9	2.8	2.7	-	-	0.0	1.1	1.2	1.4	1.7	-
Coast	Paddy	Sandy Loam	8.3	6.1	6.6	6.2	-	-	8.9	6.6	5.4	4.1	4.7	-
		Clay Loam	5.8	4.2	4.7	4.2	-	-	6.3	4.7	3.4	2.2	2.8	-
		Clay	4.0	3.0	3.5	3.1	-	-	4.6	3.5	2.3	1.0	1.6	-
	Maize		1.2	1.6	2.7	2.3	1.8	-	0.8	1.9	1.4	0.2	0.8	-
	Bean & Veg		1.2	1.6	2.3	2.1	-	-	0.8	1.7	1.4	0.5	0.8	-
D'Salaam	Paddy	Sandy Loam	8.3	6.0	6.6	6.1	-	-	8.8	6.6	5.5	4.5	4.7	-
		Clay Loam	5.7	4.2	4.6	4.2	-	-	6.2	4.7	3.5	2.5	2.8	-
		Clay	3.9	3.0	3.5	3.0	-	-	4.4	3.5	2.4	1.4	1.7	-
	Maize		1.2	1.6	2.6	2.2	1.9	-	0.7	1.9	1.5	0.6	0.8	-
	Bean & Veg		1.2	1.6	2.3	2.0	-	-	0.7	1.7	1.4	0.7	0.8	-
Morogoro	Paddy	Sandy Loam	7.8	5.6	6.3	6.0	-	-	8.4	6.1	5.3	4.2	4.7	-
		Clay Loam	5.2	3.7	4.3	4.1	-	-	5.8	4.2	3.4	2.2	2.8	-
		Clay	3.5	2.6	3.2	2.9	-	-	4.1	3.0	2.2	1.1	1.7	-
	Maize		1.1	1.3	2.3	2.2	2.1	-	0.4	1.5	1.4	0.3	0.8	-
	Bean & Veg		1.1	1.3	2.0	2.0	-	-	0.5	1.4	1.3	0.5	0.8	-
Lindi	Paddy	Sandy Loam	8.7	6.4	6.8	6.4	-	-	7.8	6.1	4.7	4.9	5.7	-
		Clay Loam	6.2	4.5	4.9	4.5	-	-	5.2	4.2	2.8	3.0	3.7	-
		Clay	4.4	3.4	3.7	3.4	-	-	3.4	3.0	1.7	1.9	2.6	-
	Maize		1.4	1.9	2.8	2.6	2.5	-	0.0	1.5	0.8	1.1	1.7	-
	Bean & Veg		1.4	1.9	2.5	2.3	-	-	0.1	1.4	0.9	1.1	1.5	-

Table A- 3: Gross Unit Water Requirement (GWR) in each Region

Irrigation Efficiency =0.3 (30%)

Unit: lit/sec/ha

Region	Crop	Soil type	Dry Season						Rainy Season					
			Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Mtwara	Paddy	Sandy Loam	8.7	6.4	6.8	6.4	-	-	7.8	6.1	4.7	4.9	5.7	-
		Clay Loam	6.2	4.5	4.9	4.5	-	-	5.2	4.2	2.8	3.0	3.7	-
		Clay	4.4	3.4	3.7	3.4	-	-	3.4	3.0	1.7	1.9	2.6	-
	Maize		1.4	1.9	2.8	2.6	2.5	-	0.0	1.5	0.8	1.1	1.7	-
	Bean & Veg		1.4	1.9	2.5	2.3	-	-	0.1	1.4	0.9	1.1	1.5	-
Ruvuma	Paddy	Sandy Loam	8.3	6.0	6.9	6.7	-	-	6.7	5.8	4.5	4.9	5.6	-
		Clay Loam	5.7	4.2	4.9	4.8	-	-	4.1	3.9	2.5	3.0	3.6	-
		Clay	3.9	3.0	3.8	3.6	-	-	2.4	2.7	1.4	1.9	2.5	-
	Maize		1.2	1.6	2.9	2.9	2.7	-	0.0	1.3	0.5	1.1	1.6	-
	Bean & Veg		1.2	1.6	2.5	2.5	-	-	0.0	1.2	0.7	1.1	1.4	-
Kagera	Paddy	Sandy Loam	8.3	5.6	5.4	4.4	-	-	7.2	5.0	4.2	3.1	3.7	-
		Clay Loam	5.7	3.7	3.5	2.5	-	-	4.7	3.0	2.3	1.2	1.7	-
		Clay	3.9	2.6	2.4	1.4	-	-	2.9	1.9	1.1	0.0	0.6	-
	Maize		1.2	1.2	1.5	0.6	0.1	-	0.0	0.5	0.2	0.0	0.0	-
	Bean & Veg		1.2	1.3	1.4	0.7	-	-	0.0	0.6	0.5	0.0	0.0	-
Mara	Paddy	Sandy Loam	8.7	6.3	6.8	5.9	-	-	8.4	6.3	6.0	4.7	5.1	-
		Clay Loam	6.1	4.5	4.9	4.0	-	-	5.8	4.3	4.1	2.8	3.2	-
		Clay	4.3	3.4	3.7	2.9	-	-	4.1	3.2	2.9	1.6	2.0	-
	Maize		1.4	1.8	2.8	2.1	1.5	-	0.5	1.6	2.0	0.8	1.2	-
	Bean & Veg		1.4	1.8	2.5	1.9	-	-	0.6	1.4	1.8	1.0	1.2	-
Mwanza	Paddy	Sandy Loam	8.9	6.4	6.8	5.8	-	-	7.8	6.1	5.7	4.8	5.5	-
		Clay Loam	6.3	4.5	4.9	3.9	-	-	5.2	4.1	3.8	2.9	3.6	-
		Clay	4.6	3.4	3.7	2.7	-	-	3.4	3.0	2.7	1.7	2.4	-
	Maize		1.4	1.9	2.8	2.0	1.1	-	0.1	1.5	1.8	1.0	1.5	-
	Bean & Veg		1.4	1.9	2.4	1.8	-	-	0.3	1.4	1.7	1.0	1.4	-
Shinyanga	Paddy	Sandy Loam	9.1	6.8	7.4	6.5	-	-	7.7	6.1	5.6	5.4	5.9	-
		Clay Loam	6.5	4.9	5.5	4.6	-	-	5.2	4.2	3.7	3.5	4.0	-
		Clay	4.7	3.8	4.3	3.4	-	-	3.4	3.0	2.5	2.4	2.8	-
	Maize		1.5	2.1	3.4	2.7	1.8	-	0.0	1.5	1.6	1.6	1.9	-
	Bean & Veg		1.5	2.1	3.0	2.4	-	-	0.2	1.4	1.5	1.5	1.7	-
Dodoma	Paddy	Sandy Loam	9.0	6.7	7.3	6.9	-	-	8.3	6.2	6.3	6.1	6.2	-
		Clay Loam	6.4	4.8	5.4	5.0	-	-	5.7	4.2	4.4	4.2	4.2	-
		Clay	4.6	3.7	4.2	3.8	-	-	4.0	3.1	3.2	3.0	3.1	-
	Maize		1.4	2.0	3.3	3.0	3.0	-	0.3	1.6	2.3	2.2	2.2	-
	Bean & Veg		1.4	2.0	2.9	2.7	-	-	0.4	1.4	2.1	2.0	2.0	-
Kigoma	Paddy	Sandy Loam	8.7	6.4	6.8	5.4	-	-	7.3	5.6	5.2	4.8	5.6	-
		Clay Loam	6.2	4.6	4.9	3.5	-	-	4.7	3.7	3.3	2.9	3.7	-
		Clay	4.4	3.4	3.7	2.3	-	-	2.9	2.5	2.1	1.7	2.5	-
	Maize		1.4	1.9	2.8	1.5	0.7	-	0.0	1.2	1.3	0.9	1.7	-
	Bean & Veg		1.4	1.9	2.4	1.5	-	-	0.0	1.1	1.2	1.0	1.5	-
Singida	Paddy	Sandy Loam	9.3	7.0	8.2	6.8	-	-	7.3	5.7	5.5	5.3	5.9	-
		Clay Loam	6.7	5.1	6.3	4.9	-	-	4.8	3.8	3.5	3.4	4.0	-
		Clay	4.9	4.0	5.1	3.7	-	-	3.0	2.6	2.4	2.2	2.9	-
	Maize		1.5	2.3	4.2	2.9	2.0	-	0.0	1.2	1.5	1.5	2.0	-
	Bean & Veg		1.5	2.3	3.6	2.6	-	-	0.0	1.1	1.4	1.4	1.8	-
Tabora	Paddy	Sandy Loam	9.3	7.0	8.2	6.8	-	-	7.3	5.7	5.5	5.3	5.9	-
		Clay Loam	6.7	5.1	6.3	4.9	-	-	4.8	3.8	3.5	3.4	4.0	-
		Clay	4.9	4.0	5.1	3.7	-	-	3.0	2.6	2.4	2.2	2.9	-
	Maize		1.5	2.3	4.2	2.9	2.0	-	0.0	1.2	1.5	1.5	2.0	-
	Bean & Veg		1.5	2.3	3.6	2.6	-	-	0.0	1.1	1.4	1.4	1.8	-

Table A- 4: Gross Unit Water Requirement (GWR) in each Region

Irrigation Efficiency =0.25 (25%)

Unit: lit/sec/ha

Region	Crop	Soil type	Dry Season						Rainy Season					
			Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Arusha	Paddy	Sandy Loam	9.5	6.9	7.7	7.5	-	-	10.2	7.7	7.2	5.5	5.8	-
		Clay Loam	6.4	4.6	5.4	5.2	-	-	7.2	5.4	4.9	3.2	3.5	-
		Clay	4.3	3.3	4.0	3.8	-	-	5.0	4.0	3.5	1.8	2.1	-
	Maize		1.3	1.7	3.0	2.9	2.2	-	0.7	2.0	2.5	0.9	1.1	-
	Bean & Veg		1.3	1.7	2.6	2.5	-	-	0.7	1.9	2.2	1.0	1.1	-
Kilimanjaro	Paddy	Sandy Loam	9.4	6.9	7.8	7.6	-	-	11.0	8.4	8.1	6.2	6.1	-
		Clay Loam	6.4	4.6	5.5	5.3	-	-	7.9	6.1	5.7	3.9	3.8	-
		Clay	4.3	3.3	4.1	3.9	-	-	5.8	4.7	4.4	2.5	2.4	-
	Maize		1.3	1.7	3.1	3.0	2.9	-	1.1	2.6	3.3	1.6	1.3	-
	Bean & Veg		1.3	1.7	2.6	2.7	-	-	1.1	2.3	2.9	1.6	1.3	-
Tanga	Paddy	Sandy Loam	9.8	6.8	7.3	7.0	-	-	10.9	8.3	7.8	5.8	5.1	-
		Clay Loam	6.8	4.6	5.0	4.7	-	-	7.9	6.0	5.5	3.5	2.8	-
		Clay	4.6	3.2	3.6	3.3	-	-	5.7	4.6	4.1	2.1	1.4	-
	Maize		1.3	1.5	2.5	2.4	2.1	-	1.1	2.5	3.0	1.2	0.3	-
	Bean & Veg		1.3	1.6	2.3	2.2	-	-	1.1	2.2	2.7	1.3	0.6	-
Iringa	Paddy	Sandy Loam	10.5	7.9	8.8	8.4	-	-	9.3	7.1	6.7	6.7	7.1	-
		Clay Loam	7.5	5.6	6.5	6.1	-	-	6.3	4.8	4.4	4.4	4.8	-
		Clay	5.3	4.3	5.1	4.7	-	-	4.1	3.4	3.0	3.0	3.4	-
	Maize		1.7	2.4	4.0	3.8	3.6	-	0.0	1.7	1.9	2.0	2.3	-
	Bean & Veg		1.7	2.4	3.5	3.4	-	-	0.2	1.5	1.8	1.9	2.1	-
Mbeya	Paddy	Sandy Loam	10.3	7.6	8.5	8.0	-	-	8.3	6.7	5.8	6.1	6.8	-
		Clay Loam	7.2	5.4	6.2	5.6	-	-	5.2	4.4	3.5	3.8	4.5	-
		Clay	5.1	4.0	4.8	4.3	-	-	3.1	3.0	2.1	2.4	3.1	-
	Maize		1.6	2.2	3.7	3.3	2.7	-	0.0	1.3	1.1	1.4	2.1	-
	Bean & Veg		1.6	2.2	3.2	3.0	-	-	0.0	1.2	1.1	1.4	1.9	-
Rukwa	Paddy	Sandy Loam	10.4	7.7	8.6	8.2	-	-	8.8	6.9	6.3	6.4	6.9	-
		Clay Loam	7.3	5.5	6.3	5.9	-	-	5.7	4.5	3.9	4.1	4.6	-
		Clay	5.2	4.2	4.9	4.5	-	-	3.6	3.1	2.5	2.7	3.2	-
	Maize		1.6	2.3	3.8	3.6	3.1	-	0.0	1.5	1.5	1.8	2.2	-
	Bean & Veg		1.6	2.3	3.3	3.2	-	-	0.0	1.3	1.4	1.7	2.0	-
Coast	Paddy	Sandy Loam	10.0	7.3	8.0	7.4	-	-	10.6	7.9	6.4	4.9	5.6	-
		Clay Loam	6.9	5.0	5.6	5.1	-	-	7.6	5.6	4.1	2.6	3.3	-
		Clay	4.8	3.7	4.3	3.7	-	-	5.5	4.2	2.7	1.2	1.9	-
	Maize		1.5	1.9	3.2	2.8	2.2	-	1.0	2.3	1.7	0.3	0.9	-
	Bean & Veg		1.5	1.9	2.8	2.5	-	-	1.0	2.0	1.6	0.6	1.0	-
D'Salaam	Paddy	Sandy Loam	10.0	7.2	7.9	7.3	-	-	10.5	7.9	6.6	5.4	5.7	-
		Clay Loam	6.9	5.0	5.6	5.0	-	-	7.5	5.6	4.3	3.1	3.4	-
		Clay	4.7	3.7	4.2	3.6	-	-	5.3	4.2	2.9	1.7	2.0	-
	Maize		1.4	1.9	3.1	2.7	2.3	-	0.8	2.3	1.8	0.7	1.0	-
	Bean & Veg		1.4	1.9	2.7	2.5	-	-	0.8	2.0	1.7	0.9	1.0	-
Morogoro	Paddy	Sandy Loam	9.4	6.7	7.5	7.2	-	-	10.0	7.4	6.3	5.0	5.7	-
		Clay Loam	6.3	4.5	5.2	4.9	-	-	7.0	5.0	4.0	2.7	3.4	-
		Clay	4.2	3.1	3.8	3.5	-	-	4.9	3.7	2.6	1.3	2.0	-
	Maize		1.3	1.6	2.7	2.6	2.5	-	0.5	1.9	1.6	0.4	1.0	-
	Bean & Veg		1.3	1.6	2.4	2.4	-	-	0.6	1.6	1.6	0.6	1.0	-
Lindi	Paddy	Sandy Loam	10.5	7.6	8.2	7.7	-	-	9.3	7.3	5.7	5.9	6.8	-
		Clay Loam	7.4	5.4	5.9	5.4	-	-	6.3	5.0	3.4	3.6	4.5	-
		Clay	5.3	4.1	4.5	4.0	-	-	4.1	3.6	2.0	2.2	3.1	-
	Maize		1.6	2.2	3.4	3.1	3.0	-	0.0	1.9	1.0	1.3	2.0	-
	Bean & Veg		1.7	2.2	3.0	2.8	-	-	0.1	1.6	1.1	1.3	1.9	-

Table A- 4: Gross Unit Water Requirement (GWR) in each Region

Irrigation Efficiency =0.25 (25%)

Unit: lit/sec/ha

Region	Crop	Soil type	Dry Season						Rainy Season					
			Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Mtwara	Paddy	Sandy Loam	10.5	7.6	8.2	7.7	-	-	9.3	7.3	5.7	5.9	6.8	-
		Clay Loam	7.4	5.4	5.9	5.4	-	-	6.3	5.0	3.4	3.6	4.5	-
		Clay	5.3	4.1	4.5	4.0	-	-	4.1	3.6	2.0	2.2	3.1	-
	Maize		1.6	2.2	3.4	3.1	3.0	-	0.0	1.9	1.0	1.3	2.0	-
	Bean & Veg		1.7	2.2	3.0	2.8	-	-	0.1	1.6	1.1	1.3	1.9	-
Ruvuma	Paddy	Sandy Loam	9.9	7.2	8.2	8.1	-	-	8.1	7.0	5.4	5.9	6.7	-
		Clay Loam	6.9	5.0	5.9	5.7	-	-	5.0	4.7	3.1	3.6	4.4	-
		Clay	4.7	3.7	4.5	4.4	-	-	2.8	3.3	1.7	2.2	3.0	-
	Maize		1.5	1.9	3.5	3.4	3.2	-	0.0	1.6	0.6	1.3	1.9	-
	Bean & Veg		1.5	1.9	3.0	3.1	-	-	0.0	1.4	0.8	1.3	1.7	-
Kagera	Paddy	Sandy Loam	9.9	6.7	6.5	5.3	-	-	8.7	6.0	5.0	3.8	4.4	-
		Clay Loam	6.9	4.5	4.2	3.0	-	-	5.6	3.7	2.7	1.4	2.1	-
		Clay	4.7	3.1	2.8	1.6	-	-	3.5	2.3	1.3	0.0	0.7	-
	Maize		1.4	1.5	1.8	0.7	0.1	-	0.0	0.6	0.3	0.0	0.0	-
	Bean & Veg		1.5	1.6	1.7	0.8	-	-	0.0	0.7	0.6	0.0	0.0	-
Mara	Paddy	Sandy Loam	10.4	7.6	8.2	7.1	-	-	10.0	7.5	7.2	5.6	6.2	-
		Clay Loam	7.3	5.4	5.9	4.8	-	-	7.0	5.2	4.9	3.3	3.8	-
		Clay	5.2	4.0	4.5	3.4	-	-	4.9	3.8	3.5	1.9	2.5	-
	Maize		1.6	2.2	3.4	2.5	1.8	-	0.6	1.9	2.4	1.0	1.4	-
	Bean & Veg		1.6	2.2	3.0	2.3	-	-	0.7	1.7	2.2	1.2	1.4	-
Mwanza	Paddy	Sandy Loam	10.6	7.7	8.1	7.0	-	-	9.4	7.3	6.9	5.8	6.6	-
		Clay Loam	7.6	5.4	5.8	4.7	-	-	6.3	5.0	4.6	3.5	4.3	-
		Clay	5.5	4.1	4.4	3.3	-	-	4.1	3.6	3.2	2.1	2.9	-
	Maize		1.7	2.2	3.4	2.4	1.3	-	0.1	1.8	2.1	1.2	1.9	-
	Bean & Veg		1.7	2.2	2.9	2.2	-	-	0.3	1.6	2.0	1.3	1.7	-
Shinyanga	Paddy	Sandy Loam	10.9	8.1	8.9	7.8	-	-	9.3	7.3	6.7	6.5	7.1	-
		Clay Loam	7.8	5.9	6.6	5.5	-	-	6.2	5.0	4.4	4.2	4.8	-
		Clay	5.6	4.5	5.2	4.1	-	-	4.0	3.6	3.0	2.8	3.4	-
	Maize		1.8	2.5	4.1	3.2	2.2	-	0.0	1.8	1.9	1.9	2.3	-
	Bean & Veg		1.8	2.5	3.6	2.9	-	-	0.2	1.6	1.9	1.9	2.1	-
Dodoma	Paddy	Sandy Loam	10.7	8.0	8.8	8.3	-	-	10.0	7.4	7.5	7.3	7.4	-
		Clay Loam	7.7	5.8	6.4	6.0	-	-	6.9	5.1	5.2	5.0	5.1	-
		Clay	5.6	4.4	5.0	4.6	-	-	4.8	3.7	3.8	3.6	3.7	-
	Maize		1.7	2.5	4.0	3.7	3.6	-	0.3	1.9	2.8	2.7	2.6	-
	Bean & Veg		1.7	2.5	3.4	3.3	-	-	0.5	1.7	2.5	2.5	2.4	-
Kigoma	Paddy	Sandy Loam	10.5	7.7	8.1	6.5	-	-	8.7	6.8	6.3	5.7	6.8	-
		Clay Loam	7.4	5.5	5.8	4.2	-	-	5.6	4.4	3.9	3.4	4.4	-
		Clay	5.3	4.1	4.4	2.8	-	-	3.5	3.1	2.5	2.0	3.1	-
	Maize		1.7	2.3	3.4	1.9	0.8	-	0.0	1.4	1.5	1.1	2.0	-
	Bean & Veg		1.7	2.3	2.9	1.8	-	-	0.0	1.3	1.4	1.2	1.8	-
Singida	Paddy	Sandy Loam	11.1	8.4	9.8	8.1	-	-	8.8	6.9	6.6	6.4	7.1	-
		Clay Loam	8.1	6.2	7.5	5.8	-	-	5.7	4.5	4.3	4.1	4.8	-
		Clay	5.9	4.8	6.1	4.4	-	-	3.6	3.1	2.9	2.7	3.4	-
	Maize		1.9	2.7	5.0	3.5	2.4	-	0.0	1.5	1.8	1.8	2.4	-
	Bean & Veg		1.9	2.7	4.4	3.1	-	-	0.0	1.3	1.7	1.7	2.1	-
Tabora	Paddy	Sandy Loam	11.1	8.4	9.8	8.1	-	-	8.8	6.9	6.6	6.4	7.1	-
		Clay Loam	8.1	6.2	7.5	5.8	-	-	5.7	4.5	4.3	4.1	4.8	-
		Clay	5.9	4.8	6.1	4.4	-	-	3.6	3.1	2.9	2.7	3.4	-
	Maize		1.9	2.7	5.0	3.5	2.4	-	0.0	1.5	1.8	1.8	2.4	-
	Bean & Veg		1.9	2.7	4.4	3.1	-	-	0.0	1.3	1.7	1.7	2.1	-

Preparation of Water Distribution Diagram

Water distribution diagram shows canal network, spatial distribution of irrigation blocks and diversion facilities and how much water is required at each block and diversion facility. This diagram is useful to know how much water should be divided at each diversion structure and how much water should be supplied to each block. By using unit Gross water requirement which is explained in Planning Step 3 and area of each block, water distribution diagram is able to be prepared.

Example of preparation of water distribution diagram

For example, Water distribution diagram is prepared based on the sketch map of the scheme shown in below figure.

In this example, Gross water requirement of paddy and maize are 6.9 and 0.7 (lit/sec/ha) respectively. The example of water distribution diagram is shown below. Water demand of each block (Q) is obtained as products of Area of irrigation block (A) and Gross unit water requirement for each crop. Therefore each water demand is calculated as follows:

Water demand (Q) for Block A (30ha) = 6.9 (lit/sec/ha) × 30 (ha) = 207 (lit/sec)
Water demand (Q) for Block B (40ha) = 6.9 (lit/sec/ha) × 40 (ha) = 276 (lit/sec)
Water demand (Q) for Block C (30ha) = 0.7 (lit/sec/ha) × 30 (ha) = 21 (lit/sec)

Also, for each facility such as Intake, division box, area under the facility (Command area) and Water demand at the each facility is calculated as a sum of area and Water demand of command area.

Area (A) of command area at Intake =A at Block A 30 (ha) + A at Block B 40 (ha) +A at Block C 30 (ha) = 100 (ha)
Water demand (Q) for Intake = Q at Block A 207 (lit/sec) + Q at Block B 270 (lit/sec) + Q at Block C 21 (lit/sec) = 498 (lit/sec)

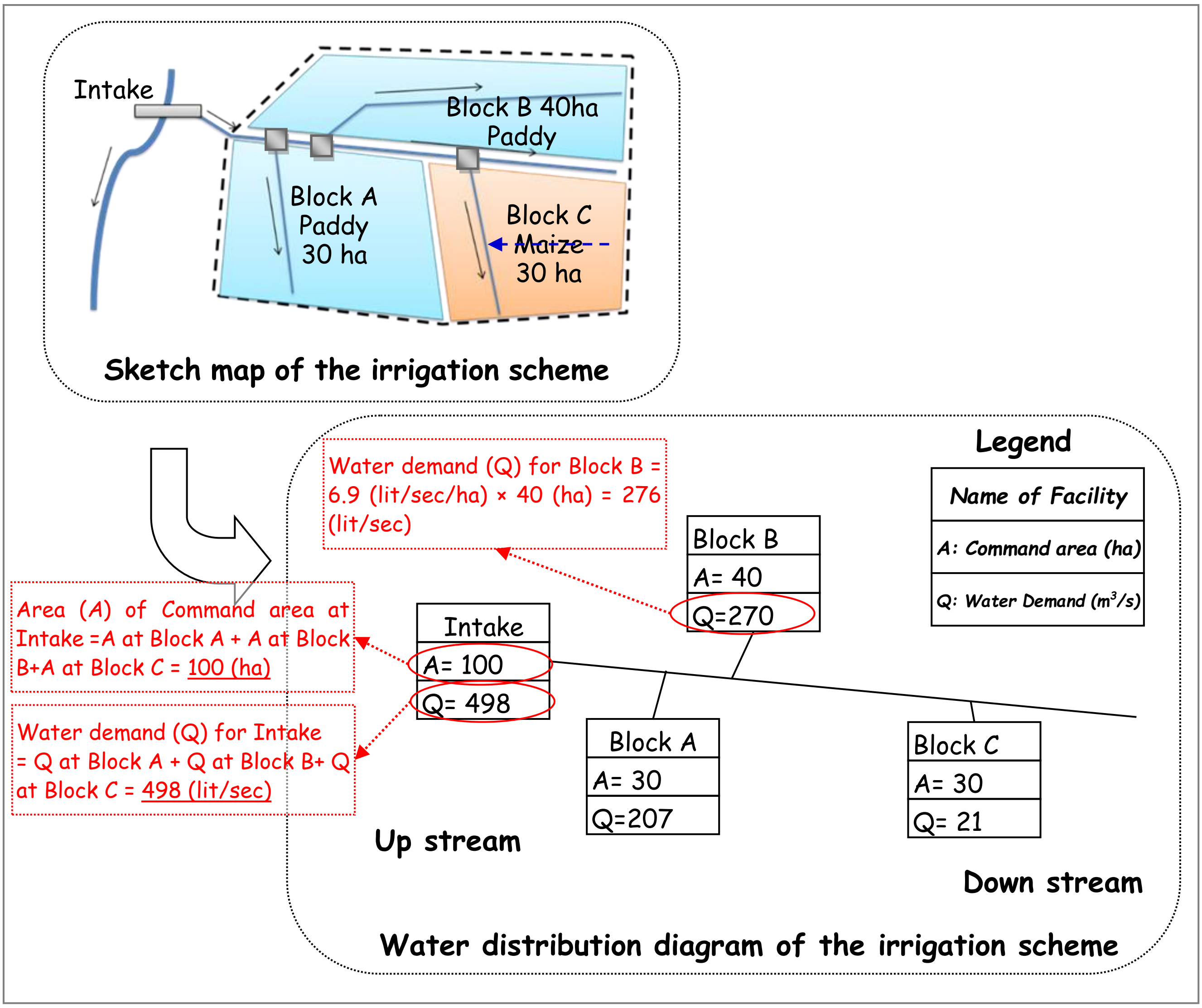


Figure: Example of water distribution diagram

Calculation of discharge for different irrigation hour

This part explains how discharge change against the irrigation hours.

Under conditions of location is in Kilimanjaro region, soil type is Sandy loam, irrigation period is in January, irrigation efficiency is 0.4, your calculation of gross unit water requirement for paddy shows 6.9 (lit/sec/ha) as explained in page 18.

When the irrigation hour is 24hours, discharge for 30 ha is calculated as follows.

<u>In case of 24 hours irrigation</u>

6.9 lit/sec/ha × 30ha = 207 lit /sec

Supposing your scheme agreed irrigation start at 6 AM and ends at 6 PM. This means 12 hour irrigation therefore adjustment for discharge is needed. If irrigation hour is 6 hours, adjusted discharge is calculated following formula (same as Formula-4).

Adjusted Discharge

$$= \text{Gross unit water requirement} \times \text{area} \times \frac{\text{Irrgation hour}}{24 \text{ hour}}$$

<u>In case of 12 hours irrigation (6:00 - 18:00)</u>

6.9 lit/sec/ha × 30ha × 24hour ÷ 12hour

$$= 6.9 \frac{\frac{\text{lit}}{\text{sec}}}{\text{ha}} \times 30\text{ha} \times \frac{24 \text{ hour}}{12 \text{ hour}} = 414 \text{ lit/sec}$$

<u>In case of 6 hour irrigation (for example, 9:00-15:00)</u>

6.9 lit/sec/ha × 30ha ×24hour ÷ 6hour

$$= 6.9 \text{ lit/sec/ha} \times 30\text{ha} \times \frac{24\text{hour}}{6\text{hour}} = 828 \text{ lit/sec}$$

Figure A- 2Figure A- 2 explains difference between 3 cases. Along with irrigation hours, height of rectangular is different like the shorter irrigation hour the taller discharge.

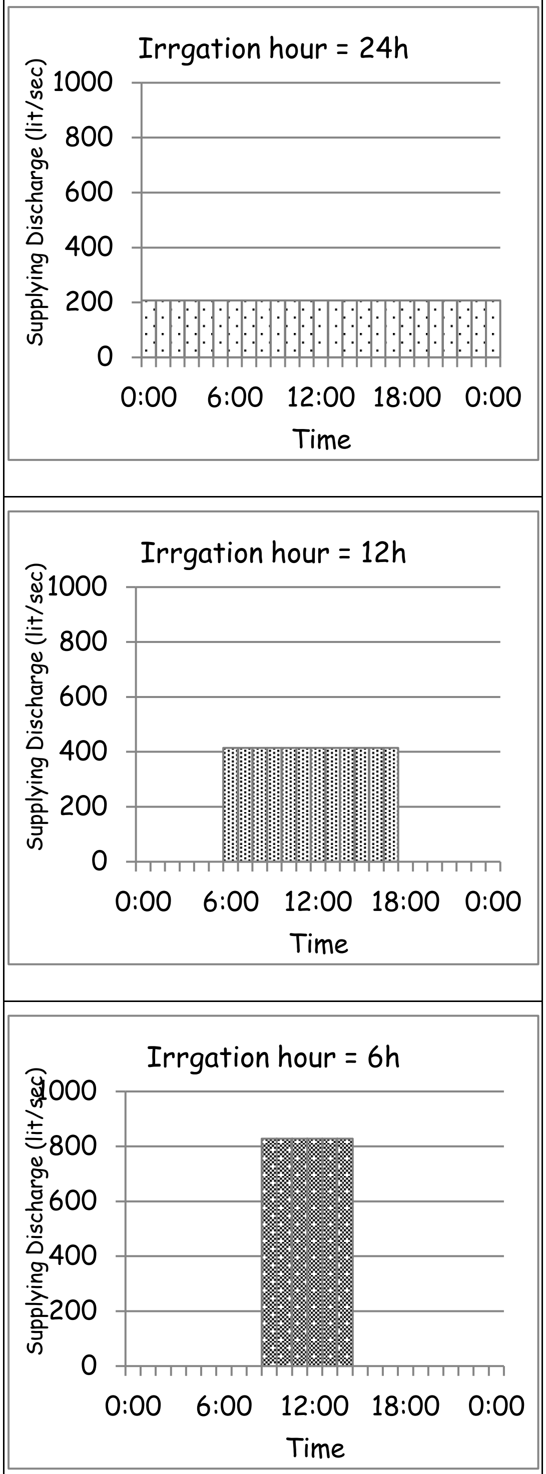


Figure A- 2 : Difference of the supplying discharge

Appendix-8

Operation record of irrigation facilities

Recorded by Blok leader Mr.XXX________________

Date	Activities	Observations
23 Nov.2016	turn out to Tertiary Canal (TC) 1 is closed and Turnout TC2 is opened	
24 Nov.2016	Farmer in TC3 complained about water distribution	Middle of TC3 is damaged by livestock
25 Nov.2016	The condition of canal is informed to O&M sub-committee	

NOTE: Water management subcommittee members and each of the gate operators – shall keep the operation record using this format.
The contents of work, place of work, etc., should be described in the column of "Activities".
The situations of the fields, canals, gates and other facilities and location of observation measured flow rate and its location should be described in the column of "Observation".

Appendix-8

Operation record of irrigation facilities

Recorded by Water **master Mr.YYY**

Date	Activities	Observations
23 Nov.2016		Water level at intake is 1.2m at 7:30
24 Nov.2016	Intake gate was opened to adjust water level	Water level at intake is 1.1m before adjustment water level Water level after adjustment is 1.2 at 8:00
25 Nov.2016	The gate bulb was greased	Water level at intake is 1.2m at 7:30
26 Nov.2016	Dusts around intake gate was removed	Water level at intake is 1.2m at 7:30

NOTE: Water management subcommittee members and each of the gate operators – shall keep the operation record using this format.
The contents of work, place of work, etc., should be described in the column of "Activities".
The situations of the fields, canals, gates and other facilities and location of observation measured flow rate and its location should be described in the column of "Observation".

Appendix-9

Formulation of Water Distribution Plan

– Simple version –

This version aims to simplify Formulation of Water Distribution Plan of the manual for easy understanding

Appendix-9

This version explains the following steps described in the main text in a simple way for easer understanding.

Start

↓

Step 1
Division of irrigation area into irrigation blocks

At first, the scheme is divided into several irrigation blocks which are a basic water distribution unit.

↓

Step 2
Preparation of cropping calendar & pattern

Then, cropping calendar and pattern should be made in consideration of actual farming practice to know different water demand by crops in line with calendar and pattern.

↓

Step 3
Calculation of Gross unit water requirement

After establishing the cropping calendar and pattern, it should be clear how much water is needed along the crop growth stages. Gross water requirement is amount of water needed in the scheme.

↓

Step 4
Selection of water distribution method

In order to distribute water to the irrigation block, two type of water distribution method is selected such as Flow sharing and Time sharing based on water availability.

↓

Step 5
Formulation of Irrigation schedule and water distribution plan

After determining the water distribution method, water distribution schedule is made in consideration of water balance between supply and demand and frequency of irrigation of each irrigation block.

↓

Step 6
Explanation of water distribution plan to IO members

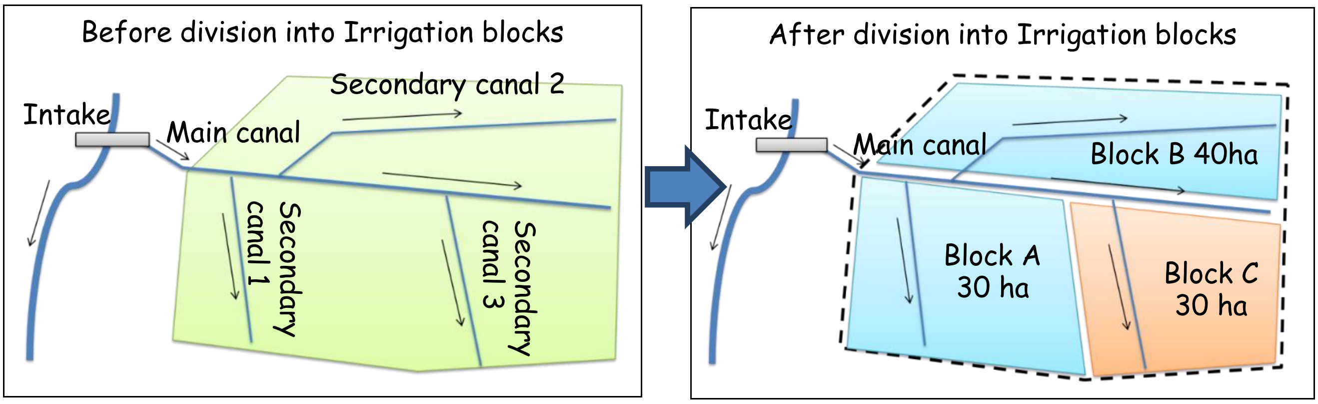
Once water distribution plan is formulated, the plan should be open to all water users to follow it. IO management committee or sub-committee concerned should be in charge of this matter.

↓

End

Step-1: Division of irrigation area into irrigation blocks

At first, divide the irrigated area into several blocks using Scheme Map. In general, the scheme shall be divided into irrigation blocks are based on secondary canals or tertiary canals. The example below shows division by secondary canals.



A summary of division by blocks is shown in the table below.

Block name	Area (acre)	Area (ha)
A	74	30
B	98	40
C	74	30
Total	246	100

If your scheme has 10 blocks, 10 names of block is listed. Some schemes recommend appropriate block size is 10 – 40 ha but it is depending on the scheme. The Bigger size of blocks is hard to distribute water fairly while the smaller size of blocks with many block leaders may result in less cooperation among them.

The scheme map is very important to do this step. It is better to start drawing main facilities such as intake and main canal then go to details.

Step-2: Preparation of cropping pattern

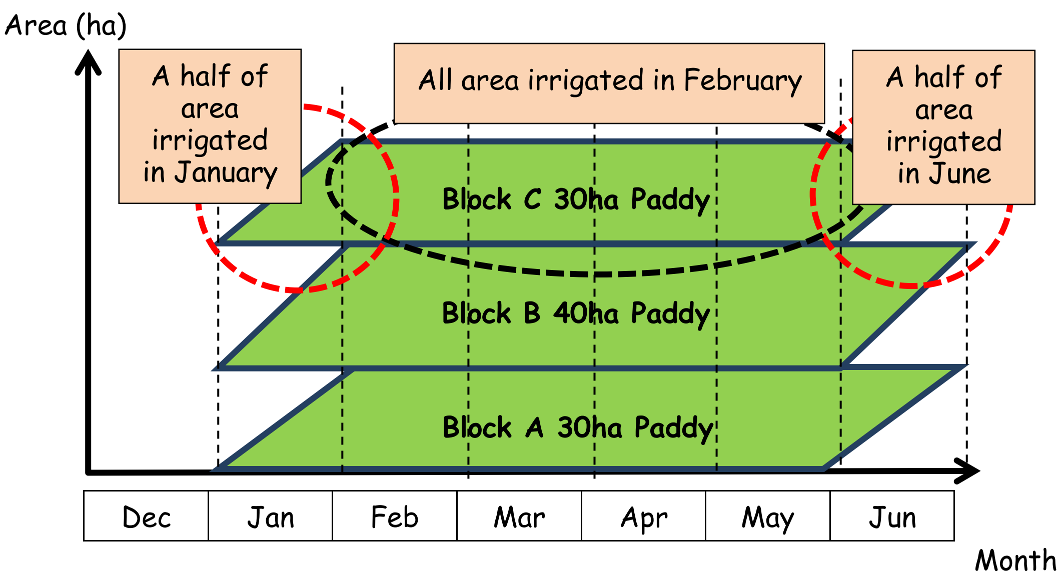
Next, make a cropping pattern based on cropping calendar. The next table is an example of cropping calendar.

Example of cropping calendar

Month	Jan				Feb				Mar				Apr				May				Jun				Jul				Aug				Sep				Oct			
Week	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Period	Rain season																				Dry season																			
Activity																																								
Plough and Cultivation	■	■																																						
Preparation of nursery and Irrigating nursery bed			■	■																																				
Transplanting					■																																			
Application of fertilizer									■							■																								
Weeding										■	■						■	■																						
Harvesting																				■																				

Next figure shows a cropping pattern which indicates when the crops will be planted and when the crops will be harvested in line with the cropping calendar. Vertical axis indicates area while horizontal axis indicates cropping period.

Generally all farmers do not start cultivation at same time (same date) therefore in January and June in the figure below, a half of total area of block is irrigated whereas full area is irrigated form February to May in case that there is a month time lag among farmers.



Cropping pattern

Appendix-9

Step-3: Calculation of Gross unit water requirement

At first, you find data of Net water requirement of your region from the table below.

For example, if you selected Arusha region, crop is paddy and Soil type is Clay Loam, data you select are surrounded by rectangular.

Net Unit Water Requirement (NWR) in each Region

Unit: mm/month

Region	Crop	Soil Type	Dry Season						Rainy Season					
			Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Arusha	Paddy	Sandy Loam	637	460	502	501	-	-	686	465	484	358	390	-
		Clay Loam	432	310	352	346	-	-	481	325	329	208	235	-
		Clay	289	220	262	253	-	-	338	241	236	118	142	-
	Maize		90	112	194	191	144	-	45	124	165	58	75	-
	Bean & Veg		90	112	169	172	-	-	49	111	149	66	72	-
Kilimanjaro	Paddy	Sandy Loam	633	461	507	512	-	-	736	506	540	403	406	-
		Clay Loam	428	311	357	357	-	-	531	366	385	253	251	-
		Clay	285	221	267	264	-	-	388	282	292	163	158	-
	Maize		89	112	198	202	187	-	72	157	220	103	90	-
	Bean & Veg		89	112	172	182	-	-	72	138	193	102	85	-
Tanga	Paddy	Sandy Loam	658	456	474	470	-	-	732	500	522	374	340	-
		Clay Loam	453	306	324	315	-	-	527	360	367	224	185	-
		Clay	310	216	234	222	-	-	384	276	274	134	92	-
	Maize		85	102	166	160	139	-	70	153	203	74	23	-
	Bean & Veg		90	108	148	148	-	-	70	134	180	82	40	-
Iringa	Paddy	Sandy Loam	703	527	569	564	-	-	622	427	447	433	473	-
		Clay Loam	498	377	419	409	-	-	417	287	292	283	318	-
		Clay	355	287	329	316	-	-	274	203	199	193	225	-
	Maize		112	158	257	254	230	-	0	100	129	133	155	-
	Bean & Veg		112	158	224	228	-	-	13	89	120	123	139	-
Mbeya	Paddy	Sandy Loam	689	510	548	532	-	-	555	402	388	394	457	-
		Clay Loam	484	360	398	377	-	-	350	262	233	244	302	-
		Clay	341	270	308	284	-	-	207	178	140	154	209	-
	Maize		107	146	237	222	173	-	0	82	71	94	140	-
	Bean & Veg		107	146	206	200	-	-	0	73	74	92	125	-
Rukwa	Paddy	Sandy Loam	696	519	558	548	-	-	589	415	417	414	465	-
		Clay Loam	491	369	408	393	-	-	384	275	262	264	310	-
		Clay	348	279	318	300	-	-	241	191	169	174	217	-
	Maize		109	152	247	238	202	-	0	91	100	114	148	-
	Bean & Veg		109	152	215	214	-	-	0	81	97	107	132	-
Coast	Paddy	Sandy Loam	670	486	515	497	-	-	714	479	430	318	379	-
		Clay Loam	465	336	365	342	-	-	509	339	275	168	224	-
		Clay	322	246	275	249	-	-	366	255	182	78	131	-
	Maize		100	129	206	187	140	-	64	138	112	18	63	-
	Bean & Veg		100	129	179	170	-	-	65	121	109	37	67	-
D'Salaam	Paddy	Sandy Loam	665	484	511	491	-	-	703	478	440	347	381	-
		Clay Loam	460	334	361	336	-	-	498	338	285	197	226	-
		Clay	317	244	271	243	-	-	355	254	192	107	133	-
	Maize		96	127	202	181	151	-	53	137	122	47	64	-
	Bean & Veg		97	128	176	165	-	-	56	120	115	57	68	-
Morogoro	Paddy	Sandy Loam	627	450	485	485	-	-	673	445	426	325	381	-
		Clay Loam	422	300	335	330	-	-	468	305	271	175	226	-
		Clay	279	210	245	237	-	-	325	221	178	85	133	-
	Maize		86	104	177	175	161	-	34	111	109	25	66	-
	Bean & Veg		87	104	154	158	-	-	42	99	104	39	65	-

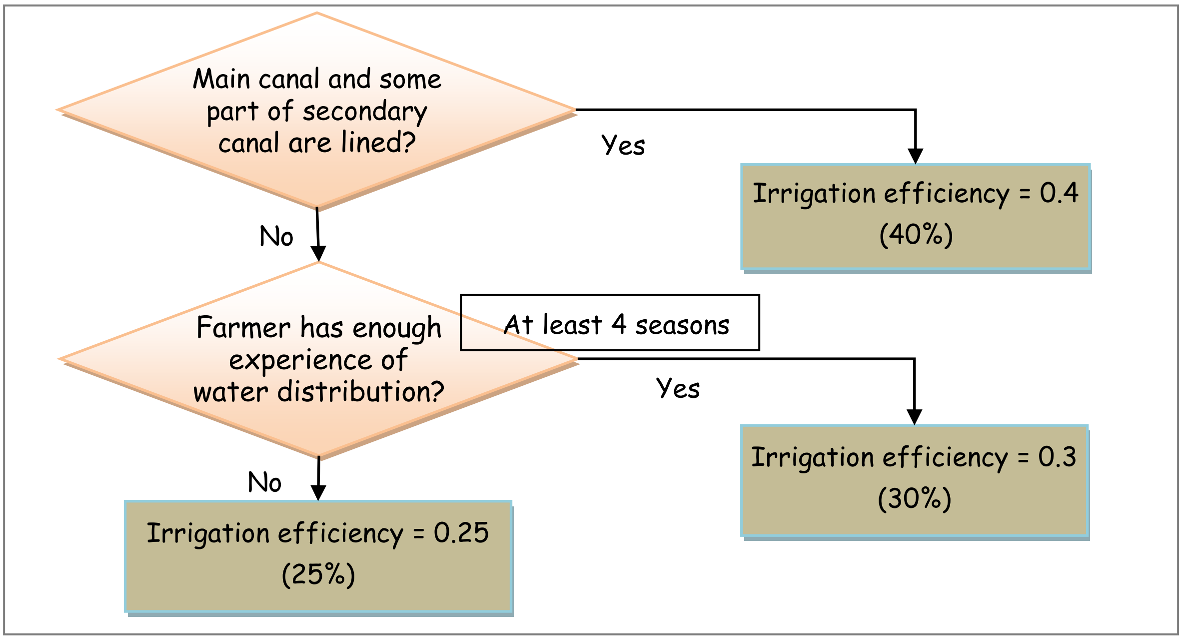
Lindi	Paddy	Sandy Loam	700	513	530	518	-	-	622	443	381	383	455	-
		Clay Loam	495	363	380	363	-	-	417	303	226	233	300	-
		Clay	352	273	290	270	-	-	274	219	133	143	207	-
	Maize		110	148	220	208	195	-	0	111	64	83	137	-
	Bean & Veg		111	148	192	187	-	-	6	99	71	86	125	-
Mtwara	Paddy	Sandy Loam	700	513	530	518	-	-	622	443	381	383	455	-
		Clay Loam	495	363	380	363	-	-	417	303	226	233	300	-
		Clay	352	273	290	270	-	-	274	219	133	143	207	-
	Maize		110	148	220	208	195	-	0	111	64	83	137	-
	Bean & Veg		111	148	192	187	-	-	6	99	71	86	125	-
Ruvuma	Paddy	Sandy Loam	663	484	534	539	-	-	538	422	359	383	445	-
		Clay Loam	458	334	384	384	-	-	333	282	204	233	290	-
		Clay	315	244	294	291	-	-	190	198	111	143	197	-
	Maize		99	128	224	229	211	-	0	96	42	83	128	-
	Bean & Veg		99	128	195	206	-	-	0	85	54	83	115	-
Kagera	Paddy	Sandy Loam	664	451	424	357	-	-	579	361	337	242	294	-
		Clay Loam	459	301	274	202	-	-	374	221	182	92	139	-
		Clay	316	211	184	109	-	-	231	137	89	2	46	-
	Maize		97	100	117	47	8	-	0	40	20	0	0	-
	Bean & Veg		98	105	108	56	-	-	0	44	38	0	4	-
Mara	Paddy	Sandy Loam	696	509	530	478	-	-	672	453	479	365	411	-
		Clay Loam	491	359	380	323	-	-	467	313	324	215	256	-
		Clay	348	269	290	230	-	-	324	229	231	125	163	-
	Maize		109	145	220	168	118	-	43	117	160	65	94	-
	Bean & Veg		109	146	191	154	-	-	47	104	146	75	92	-
Mwanza	Paddy	Sandy Loam	713	514	528	468	-	-	625	440	461	376	443	-
		Clay Loam	508	364	378	313	-	-	420	300	306	226	288	-
		Clay	365	274	288	220	-	-	277	216	213	136	195	-
	Maize		114	149	219	158	83	-	9	109	143	76	125	-
	Bean & Veg		114	149	190	146	-	-	21	97	132	82	116	-
Shinyanga	Paddy	Sandy Loam	727	545	577	523	-	-	619	441	449	424	475	-
		Clay Loam	522	395	427	368	-	-	414	301	294	274	320	-
		Clay	379	305	337	275	-	-	271	217	201	184	227	-
	Maize		119	170	265	213	140	-	0	110	130	124	156	-
	Bean & Veg		119	170	231	192	-	-	12	97	124	120	141	-
Dodoma	Paddy	Sandy Loam	719	537	568	555	-	-	667	447	505	475	496	-
		Clay Loam	514	387	418	400	-	-	462	307	350	325	341	-
		Clay	371	297	328	307	-	-	319	223	257	235	248	-
	Maize		116	165	257	245	230	-	22	114	185	175	177	-
	Bean & Veg		116	165	223	220	-	-	34	101	166	159	158	-
Kigoma	Paddy	Sandy Loam	702	517	528	435	-	-	584	408	418	373	452	-
		Clay Loam	497	367	378	280	-	-	379	268	263	223	297	-
		Clay	354	277	288	187	-	-	236	184	170	133	204	-
	Maize		111	151	219	125	55	-	0	86	102	73	135	-
	Bean & Veg		111	151	190	118	-	-	0	77	96	77	121	-
Singida	Paddy	Sandy Loam	745	563	637	545	-	-	589	413	440	413	478	-
		Clay Loam	540	413	487	390	-	-	384	273	285	263	323	-
		Clay	397	323	397	297	-	-	241	189	192	173	230	-
	Maize		125	183	323	235	152	-	0	90	122	113	160	-
	Bean & Veg		125	183	281	212	-	-	0	80	116	110	143	-
Tabora	Paddy	Sandy Loam	745	563	637	545	-	-	589	413	440	413	478	-
		Clay Loam	540	413	487	390	-	-	384	273	285	263	323	-
		Clay	397	323	397	297	-	-	241	189	192	173	230	-
	Maize		125	183	323	235	152	-	0	90	122	113	160	-
	Bean & Veg		125	183	281	212	-	-	0	80	116	110	143	-

To calculate the Gross unit water requirement, you also need irrigation efficiency.

Irrigation Efficiency by Scheme Condition

Canal condition	Lined	Unlined	
Farmers' experience	-	Sufficient	Poor
Irrigation efficiency	0.4	0.3	0.25

To find irrigation efficiency just follow the flowchart below.



In this manual, Irrigation Efficiency is adopted 0.3 (30%) as an example.

You are better to make a table below using the equation in the next page.

		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
①	Net water requirement (mm/month)	432	310	352	346	-	-	481	325	329	208	235	-
②	Irrigation efficiency	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
②	Number of days in month (days)	31	31	30	31	30	31	31	28	31	30	31	30
④	Conversion coefficient*	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64
Gross unit water requirement (lit/sec/ha)													

*Conversion coefficient 8.64 is constant.

Appendix-9

$$\text{Gross unit water requirement} = \frac{①}{② \times ③ \times ④}$$

Just substitute data into the equation then you can get Gross unit water requirement.

		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
①	Net water requirement (mm/month)	432	310	352	346	-	-	481	325	329	208	235	-
②	Irrigation efficiency	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
③	Number of days in month (days)	31	31	30	31	30	31	31	28	31	30	31	30
④	Conversion coefficient	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64
Gross unit water requirement (lit/sec/ha)		5.4	3.9	4.5	4.3	-	-	6.0	4.5	4.1	2.7	2.9	-

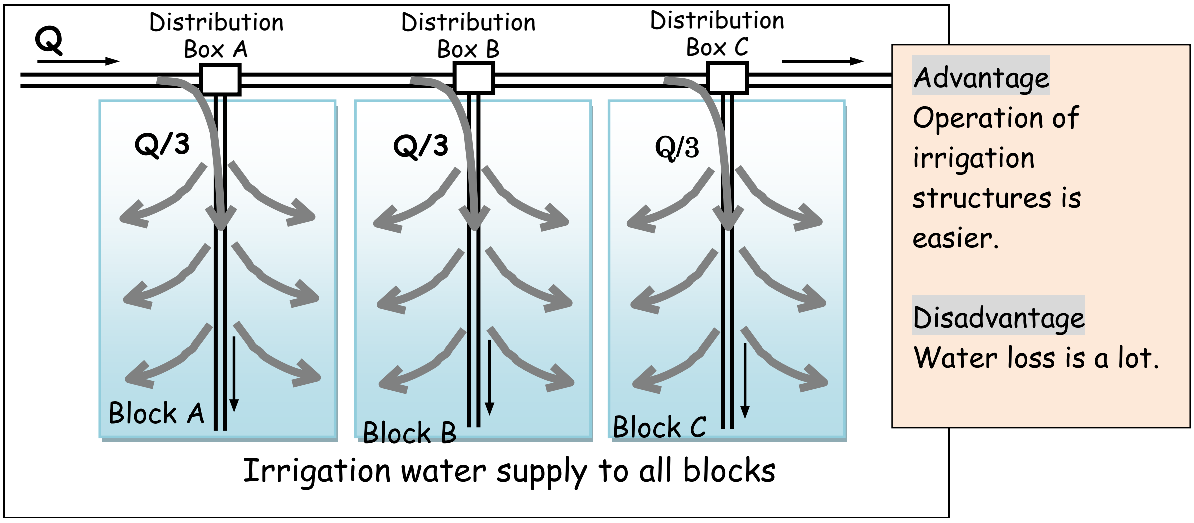
Data of November, December and June are missing but do not worry. Simply neighbouring data can be substituted like data of October for November, January to December and May for June. The following table has data of June accordingly.

		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
①	Net water requirement (mm/month)	432	310	352	346	-	-	481	325	329	208	235	235
②	Irrigation efficiency	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
②	Number of days in month (days)	31	31	30	31	30	31	31	28	31	30	31	30
④	Conversion coefficient	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64
Gross unit water requirement (lit/sec/ha)		5.4	3.9	4.5	4.3	-	-	6.0	4.5	4.1	2.7	2.9	3.0

Step-4 Selection of water distribution method

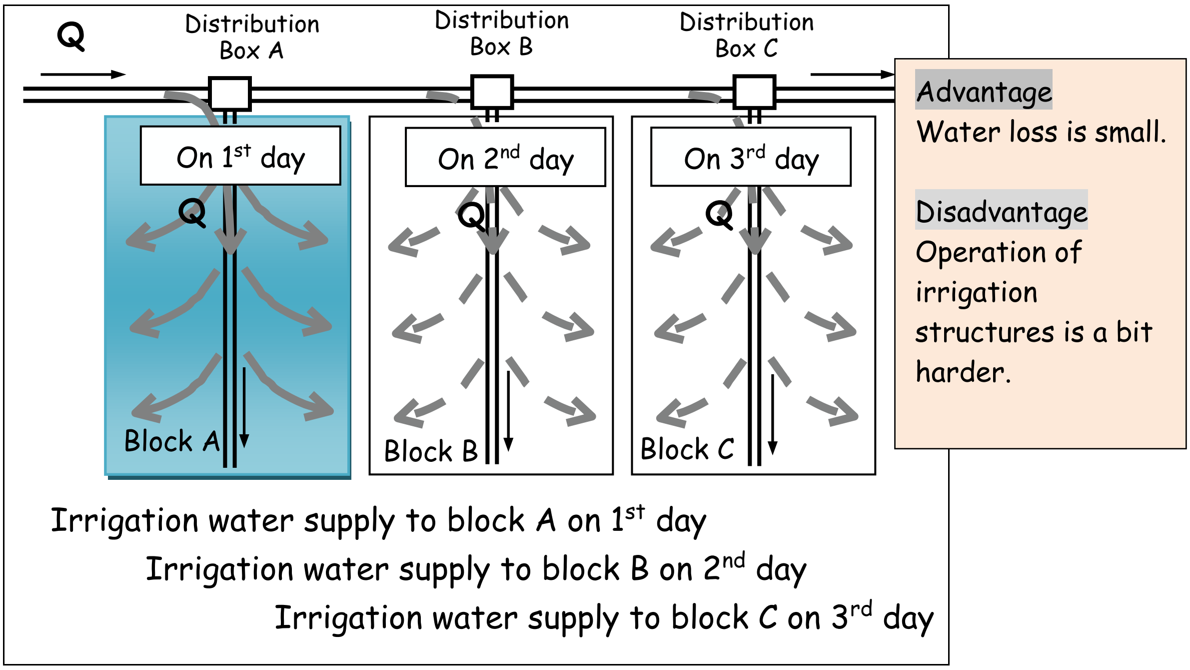
Two (2) major method of water distribution are called Flow sharing and Time sharing.

Flow sharing method means the scheme distributes water to all irrigation blocks at same time in accordance with area of each block.



Flow sharing method

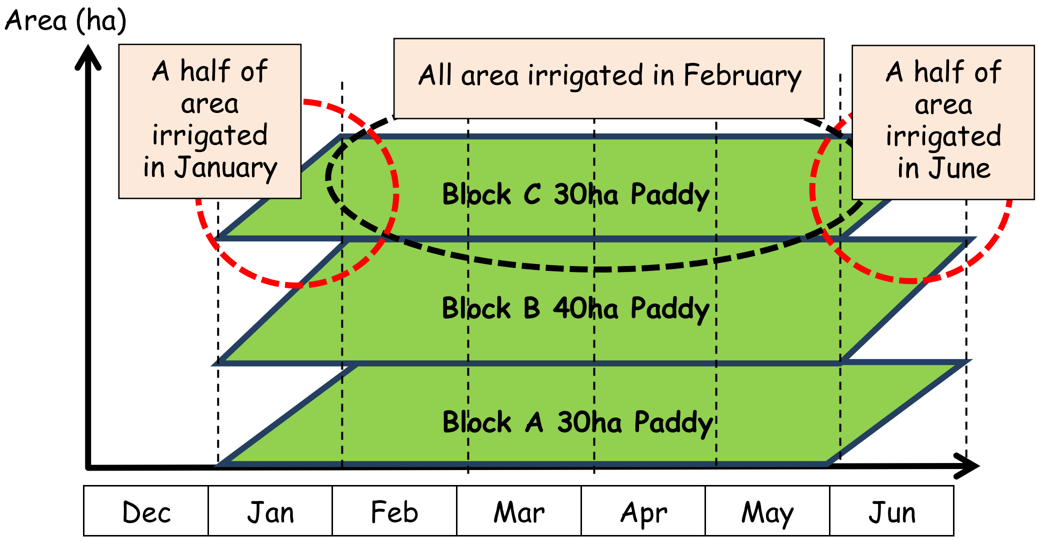
Time sharing method means the scheme distributes water by block rotation



Time sharing method

Step-5 Formulation of Water Distribution Plan

Before to make water distribution plan, confirm the cropping pattern and cropping period as explained in Step-2.



Cropping pattern

Cropping period of each block

Block name	Area (ha)	Crop	Period
Block A	30	Paddy	January to June (6 months)
Block B	40	Paddy	January to June (6 months)
Block C	30	Paddy	January to June (6 months)

The following equation is to calculate the water demand (lit/sec) of block.

Water demand = Gross unit water requirement × area of block

The following table shows a plan of water distribution of the scheme. Plan of water distribution means capacity of the irrigation scheme to irrigate in consideration of the balance between supply (how much water to be taken from water source) and demand (how much water to be irrigated).

The scheme sometimes cannot supply water to meet demand of all farmers due to inadequate water availability. So water balance between supply and demand is crucial like income and expenditure in our daily life.

If you do not know how much the expected water supply is, you can refer to the feasibility study report otherwise discharge stipulated in Water Use Permit. Here we assume 400 (lit/sec) for calculation.

Plan of water distribution is obtained as following condition

Case-1 If Expected water supply > Expected water demand
Plan of water distribution = Expected water demand because the scheme can satisfy the water demand of blocks.

Case-2 If Expected water supply < Expected water demand
Plan of water distribution = Expected water supply because the scheme cannot satisfy the water demand of blocks.

Calculation for plan of water distribution

Block	Name of block	Jan	Feb	Mar	Apr	May	Jun
Block A	Gross unit water requirement (lit/sec/ha)	6.0	4.5	4.1	2.7	2.9	3.0
	Area (ha)	15	30	30	30	30	15
	Water demand (lit/sec)	90	134	123	80	88	45
Block B	Gross unit water requirement (lit/sec/ha)	6.0	4.5	4.1	2.7	2.9	3.0
	Area (ha)	20	40	40	40	40	20
	Water demand (lit/sec)	120	179	164	107	117	60
Block C	Gross unit water requirement (lit/sec/ha)	6.0	4.5	4.1	2.7	2.9	3.0
	Area (ha)	15	30	30	30	30	15
	Water demand (lit/sec)	90	134	123	80	88	45
Total water demand (Expected water demand) (lit/sec)		300*	447	410	267	293	150
Expected water supply (lit/sec)		400	400	400	400	400	400
Plan of water distribution (lit/sec)		300	400	400	267	293	150

*300 = 90 + 120 + 90

Consideration of Irrigation Hour

The water demand is calculated with an assumption of 24 hours irrigation. But some schemes do not follow this practice but 12 hours or 6 hours or others. In this case, the water demand should be increased. The shorter irrigation hours is applied the bigger water demand is needed.

For example, looking at the table above, if the scheme applies 12 hours irrigation, the water demand in January for Block A is 90 x 2 = 180 (lit/sec), Block B is 240 (lit/sec) and Block C is 180 (lit/sec) respectively then 600 (lit/sec) in total.

As you may notice the irrigation hours is very influential value for the plan of water distribution and size of canals. Design of canals should be considered the irrigation hours. The shorter the irrigation hour is the bigger size of canal is needed.

Adjustment of plan of water distribution in case of Flow Sharing

In Case-2 in the previous page, Adjustment of Plan of Water Distribution is needed and the equation for the calculation is shown below. In Case-1, the adjustment is not necessary because the scheme can be able to supply the expected water demand.

Adjusted plan of water distribution =

$$\frac{\text{Water demand in block}}{\text{Total water demand}} \times \text{Expected water supply}$$

Adjusted water distribution plan of Flow Sharing

	Name of block	Crop	Area (ha)	Jan	Feb	Mar	Apr	May	Jun
Expected water demand (lit/sec)	Block A	Paddy	30	90	134	123	80	88	45
	Block B	Paddy	40	120	179	164	107	117	60
	Block C	Paddy	30	90	134	123	80	88	45
Total expected water demand (lit/sec)			100	300	447*	410*	267	293	150
Expected water supply (lit/sec)			100	400	400	400	400	400	400

Adjusted Water Distribution Plan

	Name of Block:	Crops	Area (ha)	Jan	Feb	Mar	Apr	May	Jun
Adjusted Plan of water distribution (lit/sec)	Block A	Paddy	30	90	120	120	80	88	45
	Block B	Paddy	40	120	160	160	107	117	60
	Block C	Paddy	30	90	120	120	80	88	45
	Total		100	300	400	400	267	293	150

* Total expected water demand exceeds expected water supply.

Consideration of Irrigation Interval

In case of the time sharing method, irrigation interval should be considered. Supposing the scheme applies 3 days' irrigation interval, the expected water demand of each block should be triple of the calculated one because you have to irrigate water for 3 days in a day (you cannot irrigate tomorrow and day after tomorrow).

The irrigation interval is 3 days therefore each expected water demand should be multiplied by 3. Therefore the water demand under 3 days' interval is calculated as follows.

	Name of Block:	Crop	Area (ha)	Jan	Feb	Mar	Apr	May	Jun
Expected water demand (lit/sec)	Block A	Paddy	30	270	402	369	240	264	135
	Block B	Paddy	40	360	537*	492*	321	351	180
	Block C	Paddy	30	270	402*	369	240	264	135
Total expected water demand (lit/sec)			100	360	537*	492	321	351	180
Expected water supply (lit/sec)			100	400	400	400	400	400	400

* Expected water demand exceeds expected water supply.

If your scheme considers the irrigation hours too, the expected water demand should be multiplied. In case of 12 hours, multiplied by 2 and in case of 6 hours, multiplied by 3.

The total expected water demand in the above table is same as the biggest water demand among the blocks in each month. As you can see, block B has the biggest water demand because area of block is the biggest.

Adjustment of plan of water distribution in case of Time Sharing

To adjust the plan of water distribution where the expected water demand exceeds the expected water supply, all expected water demand exceeding the expected water supply 400 (lit/sec) should be replaced with 400 because the scheme cannot be able to irrigate more than the expected water supply. If it is less than the expected water supply, it can be accepted without adjustment.

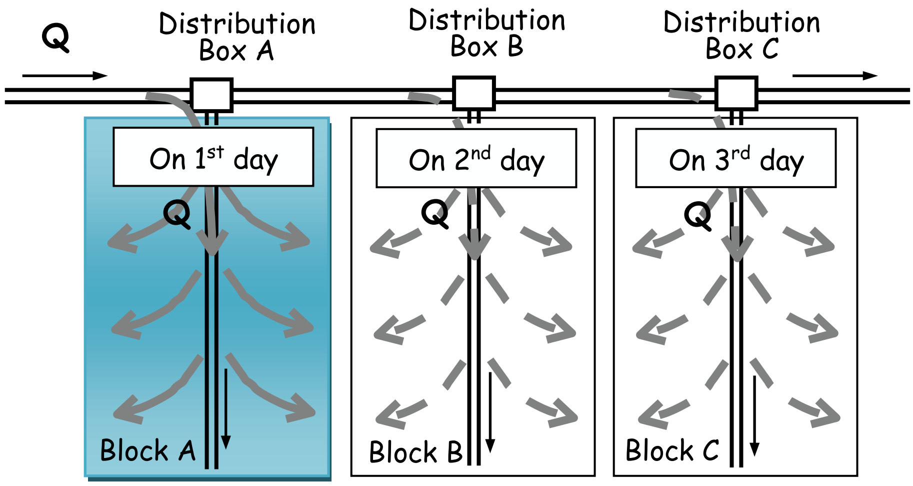
The following table shows the adjusted water distribution plan.

Adjusted water distribution plan in case of Time Sharing

	Name of Block:	Order of irrigation	Jan	Feb	Mar	Apr	May	Jun
Adjusted plan of water distribution (lit/sec)	Block A	1st day	270	400	369	240	264	135
	Block B	2nd day	360	400	400	321	351	180
	Block C	3rd day	270	400	369	240	264	135

* Expected water demand exceeds expected water supply.

This plan is saying that in May the scheme is supplying 369 (lit/sec) to block A on 1st day, then supplying 400 (lit/sec) to block B on 2nd day, then supplying 369 (lit/sec) to block C on 3rd day.



Step-6 Explanation of water distribution plan to IO member

At the general assembly, the sub-committee members should explain the water distribution plan and facilitate discussion and decision on the followings:

- Division of the irrigation area into irrigation blocks
- Cropping pattern
- Type of water distribution
- Water distribution plan (irrigation schedule)

The following picture shows example of the irrigation schedule which is displayed at an IO office. The schedule is showing the duration of water supply for each block therefore IO members clearly and easily know when they will get water to their plot.

Example of signboard for water distribution

Irrigation schedule in Igomelo irrigation scheme

Month: October							Year: 2016			
Name of canal	**Canal leader**	**Total area (acre)**	**Crops**	**Man**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
1	M.Luhigo	19.5	Paddy, Maize							
2	J.Mwitike	43.0	Paddy, Maize							
3	M.chengula	32.0	Paddy, Maize							
4	F.Vahaye	166.0	Paddy, Maize, Tomato							
5	E.Mgowole	64.0	Paddy, Maize							
6	J.Nyagawa	86.0	Paddy, Maize							
7	S.Shabani	17.5	Paddy, Maize							
8	Shaluta H.	66.0	Paddy, Maize							

In the Igomelo scheme, in Mbarali district, the scheme divides irrigation timeframe into the morning and afternoon on Sunday.