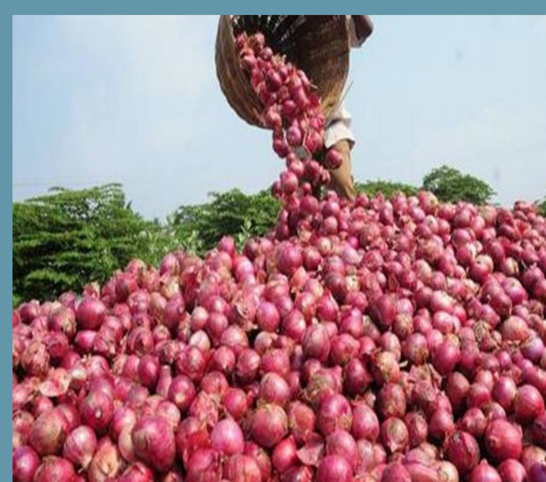
SSIGL 8

NATIONAL GUIDELINES

For Small Scale Irrigation Development in Ethiopia

Irrigation Agronomy and Agricultural Development Plan



November 2018

Addis Ababa

MINISTRY OF AGRICULTURE

National Guidelines for Small Scale Irrigation Development in Ethiopia

SSIGL 8: Irrigation Agronomy and Agricultural Development Plan

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FORWARD

Ministry of Agriculture, based on the national strategic directions is striving to meet its commitments in which modernizing agriculture is on top of its highest priorities to sustain the rapid, broad-based and fair economic growth and development of the country. To date, major efforts have been made to remodel several important strategies and national guidelines by its major programs and projects.

While efforts have been made to create access to irrigation water and promoting sustainable irrigation development, several barriers are still hindering the implementation process and the performance of the schemes. The major technical constrains starts from poor planning and identification, study, design, construction, operation, and maintenance. One of the main reasons behind this outstanding challenge, in addition to the capacity limitations, is that SSIPs have been studied and designed using many ad-hoc procedures and technical guidelines developed by various local and international institutions.

Despite having several guidelines and manuals developed by different entities such as MoA (IDD)-1986, ESRDF-1997, MoWIE-2002 and JICA/OIDA-2014, still the irrigation professionals follow their own public sources and expertise to fill some important gaps. A number of disparities, constraints and outstanding issues in the study and design procedures, criteria and assumptions have been causing huge variations in all vital aspects of SSI study, design and implementation from region to region and among professionals within the same region and institutions due mainly to the lack of agreed standard technical guidelines. Hence, the SSI Directorate with AGP financial support, led by Generation consultant (GIRDC) and with active involvement of national and regional stakeholders and international development partners, these new and comprehensive national guidelines have been developed.

The SSID guidelines have been developed by addressing all key features in a comprehensive and participatory manner at all levels. The guidelines are believed to be responsive to the prevalent study and design contentious issues; and efforts have been made to make the guidelines simple, flexible and adaptable to almost all regional contexts including concerned partner institution interests. The outlines of the guidelines cover all aspects of irrigation development including project initiation, planning, organizations, site identification and prioritization, feasibility studies and detail designs, contract administration and management, scheme operation, maintenance and management.

Enforceability, standardization, social and environmental safeguard mechanisms are well mainstreamed in the guidelines, hence they shall be used as a guiding framework for engineers and other experts engaged in all SSI development phases. The views and actual procedures of all relevant diverse government bodies, research and higher learning institutions, private companies and development partners has been immensely and thoroughly considered to ensure that all stakeholders are aligned and can work together towards a common goal. Appropriately, the guidelines will be familiarized to the entire stakeholders working in the irrigation development. Besides, significant number of experts in the corresponding subject matter will be effectively trained nationwide; and the guidelines will be tested practically on actual new and developing projects for due consideration of possible improvement. Hence, hereinafter, all involved stakeholders including government & non-governmental organizations, development partners, enterprises, institutions, consultants and individuals in Ethiopia have to adhere to these comprehensive national guidelines in all cases and at all level whilst if any overlooked components are found, it should be documented and communicated to MOA to bring them up-to-date.

Therefore, I congratulate all parties involved in the success of this effort, and urge partners and stakeholders to show a similar level of engagement in the implementation and stick to the guidelines over the coming years.

H.E. Dr. Kaba Urgessa
State Minister, Ministry of Agriculture

SMALL SCALE IRRIGATION DEVELOPMENT VISION

Transforming agricultural production from its dependence on rain-fed practices by creating reliable irrigation system in which smallholder farmers have access to at least one option of water source to increase production and productivity as well as enhance resilience to climate change and thereby ensure food security, maintain increasing income and sustain economic growth.

ACKNOWLEDGEMENTS

The preparation of SSIGLs required extensive inputs from all stakeholders and development partners. Accordingly many professionals from government and development partners have contributed to the realization of the guidelines. To this end MOA would like to extend sincere acknowledgement to all institutions and individuals who have been involved in the review of these SSIGLs for their comprehensive participation, invaluable inputs and encouragement to the completion of the guidelines. There are just too many collaborators involved to name exhaustively and congratulate individually, as many experts from Federal, regional states and development partners have been involved in one way or another in the preparation of the guidelines. The contribution of all of them who actively involved in the development of these SSIGLs is gratefully acknowledged. The Ministry believes that their contributions will be truly appreciated by the users for many years to come.

The Ministry would like to extend its appreciation and gratitude to the following contributors:

- Agriculture Growth Program (AGP) of the MoA for financing the development and publication of the guidelines.
- The National Agriculture Water Management Platform (NAWMP) for overseeing, guidance and playing key supervisory and quality control roles in the overall preparation process and for the devotion of its members in reviewing and providing invaluable technical inputs to enrich the guidelines.
- Federal Government and Regional States organizations and their staff for their untiring effort in reviewing the guidelines and providing constructive suggestions, recommendations and comments.
- National and international development partners for their unreserved efforts in reviewing the guidelines and providing constructive comments which invaluably improved the quality of the guidelines.
- Small-scale and Micro Irrigation Support Project (SMIS) and its team for making all efforts to have quality GLs developed as envisioned by the Ministry.

The MOA would also like to extend its high gratitude and sincere thanks to AGP's multi development partners including the International Development Association (IDA)/World Bank, the Canada Department of Foreign Affairs, Trade and Development (DFATD), the United States Agency for International Development (USAID), the Netherlands, the European Commission (EC), the Spanish Agency for International Development (AECID), the Global Agriculture and Food Security Program (GAFSP), the Italy International Development Cooperation, the Food and Agriculture Organization (FAO) and the United Nations Development Program (UNDP).

Moreover, the Ministry would like to express its gratitude to Generation Integrated Rural Development Consultant (GIRDC) and its staff whose determined efforts to the development of these SSIGLs have been invaluable. GIRDC and its team drafted and finalized all the contents of the SSIGLs as per stakeholder suggestions, recommendations and concerns. The MoA recognizes the patience, diligence, tireless, extensive and selfless dedication of the GIRDC and its staff who made this assignment possible.

Finally, we owe courtesy to all national and International source materials cited and referred but unintentionally not cited.

Ministry of Agriculture

DEDICATIONS

The National Guidelines for Small Scale Irrigation Development are dedicated to Ethiopian smallholder farmers, agro-pastoralists, pastoralists, to equip them with appropriate irrigation technology as we envision them empowered and transformed.

LIST OF GUIDELINES

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ACRONYMS

AEZ	Agro-ecological Zone
AI/ha	Active ingredient
ATA	Ethiopian Agricultural Transformation agency
oC	degree centigrade
CA	Total cultivated land
CD	Compact Disc
CFSR	Climate Forecast System Re-analysis
CI	Crop Intensity
cm	Centimeter
CS	Crop Sequence
CSA	Central Statistic Agency
Cw	Consumptive use
CWR	Crop water requirement
DA	Development Agent
DAP	Dai Ammonium sulfate
DP	Deep percolation
ETo	Reference Evapo-transpiration
ET	Evapo-transpiration
EC	Electrical conductivity
Pe	Effective rainfall
E.C.	Emulsifiable concentrate
UNFAO	United Nation Food Agriculture Organization
FAO I&D	Food Agriculture Organization Irrigation and Drainage
FC	Field Capacity
FGD	Focus Group Discussion
Fig	Figure
GIRDC	Generation Integrated Rural Development Consultant
GPS	Geographical Position system
GTP	Growth and Transformation Program
Hr	hour
Ha	hectare
HH	household
HHI	Household Irrigation
HHS	Household Survey
IR	Irrigation water
Kc	Crop Coefficient
Kg	kilogram
KII	Key Informant Interview
Km	Kilometer
kPa	Kilopascal
LGP	Length of growing period

Lt	liter
Lt/hd/day	liter per head per day
m.s.a.l	meter above sea level
mm	milimeter
meq	milliequvalent
Max	Maximum
MD	Man-day
PD	Person-Day
m.a.s.l.	meter above sea level
Min	Minimum
ml/ha	milliliter per hectare
mm/day	millimeter per day
mm/month	millimeter per month
m/sec	meter per second
MoA	Ministry of Agriculture
MoALR	Ministry of Agriculture & Livestock Resource
MoANR	Ministry of Agriculture and Natural Resources
N	Nitrogen
OD	Oxen-Day
P	Precipitation
Pe	Effective rainfall
PET	Potential Evapotranspiration
pH	Power of hydrogen
ppm	Parts per million
PWP	Permanent wilting Point
Qt	quintal
Rad	Radiation
RH	Relative Humidity
SEIA	Social & environmental Impact Assessment
SSIGL	Small scale irrigation Guideline
SSIP	Small scale irrigation project
Sun	Sunshine hours
TAM	Total available Moisture
Temp	Temperature

PREFACE

While irrigation development is at the top of the government's priority agendas as it is key to boost production and improve food security as well as to provide inputs for industrial development. Accordingly, irrigated land in different scales has been aggressively expanding from time to time. To this end, to enhance quality delivery of small-scale irrigation development planning, implementation and management, it has been decided to develop standard SSI guidelines that must be nationally applied. In September 2017 the Ministry of Agriculture (MoA) had entrusted Generation Integrated Rural Development Consultant (GIRDC) to prepare the National Small-scale Irrigation Development Guidelines (SSIGLs).

Preparation of the SSIGLs for enhancing development of irrigated agriculture is recognized as one of the many core initiatives of the MoA to improve its delivery system and achieve the targets in irrigated agriculture and fulfill its mission for improving agricultural productivity and production. The core objective of developing SSIGLs is to summarize present thinking, knowledge and practices to enable irrigation practitioners to properly plan, implement and manage community managed SSI schemes to develop the full irrigation potential in a sustainable manner.

As the SSIGLs are prepared based on national and international knowledge, experiences and practices, and describe current and recommended practice and set out the national standard guides and procedures for SSI development, they serve as a source of information and provide guidance. Hence, it is believed that the SSIGLs will contribute to ensuring the quality and timely delivery, operation and maintenance of SSI schemes in the country. The SSIGLs attempt to explain and illustrate the important concepts, considerations and procedures in SSI planning, implementation and management; and shall be used as a guiding framework for professionals engaged in SSI development. Illustrative examples from within the country have been added to enable the users understand the contents, methodologies presented in the SSIGLs.

The intended audiences of the SSIGLs are government organizations, NGOs, CSOs and the private sector involved in SSI development. Professionally, the SSIGLs will be beneficial for experienced and junior planners, experts, contractors, consultants, suppliers, investors, operators and managers of SSI schemes. The SSIGLs will also serve as a useful reference for academia and researchers involved and interested in SSI development. The SSIGLs will guide to ensure that; planning, implementation and management of SSI projects is formalized and set procedures and processes to be followed. As the SSIGLs provide information and guides they must be always fully considered and applied by adapting them to the local specific requirements.

In cognizance with the need for quality SSIGLs, the MoA has duly considered quality assurance and control during preparation of the guidelines. Accordingly, the outlines, contents and scope of the SSIGLs were thoroughly discussed, reviewed and modified by NAWMP members (senior professionals from public, national and international stakeholder) with key stakeholders in many consultative meetings and workshops. Moreover, at each milestone of SSIGL preparation, resource persons from all stakeholders reviewed and confirmed that SSIGLs have met the demands and expectations of users.

Moreover, the Ministry has mobilized resource persons from key Federal, National Regional States level stakeholders and international development partners for review, validation and endorsement of the SSIGLs.

Several hundreds of experienced professionals (who are very qualified experts in their respective fields) from government institutions, relevant private sector and international development partners have significantly contributed to the preparation of the SSIGLs. They have been involved in all aspects of the development of SSIGLs throughout the preparation process. The preparation process included a number of consultation meetings and workshops: (i) workshop to review inception report, (ii) workshop on findings of review of existing guidelines/manuals and proposed contents of the SSIGLs, (iii) meetings to review zero draft SSI GLs, (iv) review workshop on draft SSI GLs, (v) small group review meetings on thematic areas, (vi) small group consultation meetings on its final presentation of contents and layout, (vii) consultation mini-workshops in the National States on semi-final versions of the SSIGLs, and (viii) final write-shop for the appraisal and approval of the final versions of SSIGLs.

The deliberations, concerns, suggestions and comments received from professionals have been duly considered and incorporated by the GIRD Consultant in the final SSIGLs.

There are 34 separate guidelines which are categorized into the following five parts concurrent to SSI development phases:

Part-I. Project Initiation, Planning and Organization Guideline which deals with key considerations and procedures on planning and organization of SSI development projects.

Part-II. Site Identification and Prioritization Guideline which treats physical potential identification and prioritization of investment projects. It presents SSI site selection process and prioritization criteria.

Part-III. Feasibility Study and Detail Design Guidelines for SSID dealing with feasibility study and design concepts, approaches, considerations, requirements and procedures in the study and design of SSI systems.

Part-IV. Contract Administration and Construction Management Guidelines for SSI development presents the considerations, requirements, and procedures involved in construction of works, construction supervision and contract administration.

Part-V. SSI Scheme Management, Operation and Maintenance Guidelines which covers SSI Scheme management and operation.

Moreover, Tools for Small Scale Irrigation development are also prepared as part of SSIGLs.

It is strongly believed and expected that; the SSIGLs will be quickly applied by all stakeholders involved in SSI development and others as appropriate following the dissemination and familiarization process of the guidelines in order to ensure efficient, productive and sustainable irrigation development.

The SSIGLs are envisioned to be updated by incorporating new technologies and experiences including research findings. Therefore, any suggestions, concerns, recommendations and comments on the SSIGLs are highly appreciated and welcome for future updates as per the attached format below. Furthermore, despite efforts in making all types of editorial works, there may still errors, which similarly shall be handled in future undated versions.

.

UPDATING AND REVISIONS OF GUIDELINES

The GLs are intended as an up-to-date or a live document enabling revisions, to be updated periodically to incorporate improvements, when and where necessary; may be due to evolving demands, technological changes and changing policies, and regulatory frameworks. Planning, study and design of SSI development interventions is a dynamic process. Advancements in these aspects are necessary to cope up with the changing environment and advancing techniques. Also, based on observation feedbacks and experiences gained during application and implementation of the guidelines, there might be a need to update the requirements, provisions and procedures, as appropriate. Besides, day-by-day, water is becoming more and more valuable. Hence, for efficient water development, utilization and management will have to be designed, planned and constructed with a new set up of mind to keep pace with the changing needs of the time. It may, therefore, be necessary to take up the work of further revision of these GLs.

This current version of the GLs has particular reference to the prevailing conditions in Ethiopia and reflects the experience gained through activities within the sub-sector during subsequent years. This is the first version of the SSI development GLs. This version shall be used as a starting point for future update, revision and improvement. Future updating and revisions to the GLs are anticipated as part of the process of strengthening the standards for planning, study, design, construction, operation and management SSI development in the country.

Completion of the review and updating of the GLs shall be undertaken in close consultation with the federal and regional irrigation institutions and other stakeholders in the irrigation sub-sector including the contracting and consulting industry.

In summary, significant changes to criteria, procedures or any other relevant issues related to technological changes, new policies or revised laws should be incorporated into the GLs from their date of effectiveness. Other minor changes that will not significantly affect the whole nature of the GLs may be accumulated and made periodically. When changes are made and approved, new page(s) incorporating the revision, together with the revision date, will be issued and inserted into the relevant GL section.

All suggestions to improve the GLs should be made in accordance with the following procedures:

I. Users of the GLs must register on the MOA website: Website: www.moa.gov.et
II. Proposed changes should be outlined on the GLs Change Form and forwarded with a covering letter or email of its need and purpose to the Ministry.
III. Agreed changes will be approved by the Ministry on recommendation from the Small-scale Irrigation Directorate and/or other responsible government body.
IV. The release date of the new version will be notified to all registered users and authorities.

Users are kindly requested to present their concerns, suggestions, recommendations and comments for future updates including any omissions and/or obvious errors by completing the following revisions form and submitting it to the Ministry. The Ministry shall appraise such requests for revision and will determine if an update to the guide is justified and necessary; and when such updates will be published. Revisions may take the form of replacement or additional pages. Upon receipt, revision pages are to be incorporated in the GLs and all superseded pages removed.

Suggested Revisions Request Form (Official Letter or Email)

To: ---
From: ---
Date: ---
Description of suggested updates/changes: Include GL code and title, section title and # (heading/subheading #), and page #.

GL Code and Title	Date	Sections/ Heading/Subheading/ Pages/Table/Figure	Explanation	Comments (proposed change)

Note that be specific and include suggested language if possible and include additional sheets for comments, reference materials, charts or graphics.

GLs Change Action

Suggested Change	Recommended Action	Authorized by	Date

Director for SSI Directorate**:** ________________________**Date:** ________________

The following table helps to track initial issuance of the guidelines and subsequent Updates/Versions and Revisions (Registration of Amendments/Updates).

Revision Register

Version/Issue/Revision No	Reference/Revised Sections/Pages/topics	Description of revision (Comments)	Authorized by	Date

1 BACKGROUND

Agricultural transformation from subsistence agriculture to commercialization has given a top priority in the development agenda of the Government of Ethiopia. To this effect, promotion of market-oriented irrigated agriculture, with particular emphasis on production of high value irrigated crops is expected to play a very significant role in transforming the smallholder subsistence agriculture to commercialization. The agricultural transformation agenda is the major concern reflected in the second five-year Growth and Transformation Plan of Ethiopia, which aimed at reaching the lower middle-income status by 2025. In the GTP-II, the agriculture sector still remained to be the main contributor to sustainably increasing agricultural production and productivity to reduce poverty and improve food and nutrition security while conserving the natural resources to meet the demand of the current and future generations.

The smallholder farming is still contributing and remains to be the dominant farming system and an important economic sector in the national economy of Ethiopia to secure fast and reliable agricultural growth. However, smallholder-farming is constrained by various factors that challenge attaining of the goals set for the sector ensuring food self-sufficiency, reducing poverty, and realizing sectoral transformation. Therefore, coordinated efforts of all stakeholders are highly essential to overcome these challenges and further sustain the agricultural growth and contribute towards reducing poverty and improve food and nutrition security.

It has been found taha; lack of standard godliness in Irrigation agronomy and Agricultural development plan is one of the challenge, thus lead to initiation and predation of the guidelines.

This guideline has been structured in thirteen chapters. Chapters one, two and three are dealing with background, objective, scope, data collection methodologies and procedures to be applied for the study of irrigation agronomy and agricultural development. Chapters four and five are dealing how to assess the existing agricultural resources and practices of both rainfed and irrigated agriculture and agro-climatic analysis of the project area including the need of documenting constraints and opportunities, which will be serving as basis in order to develop appropriate proposals. Chapters six, seven, eight and nine are emphasizing on the improved cropping pattern, crop selection criteria, cropping intensity, estimation of crops water requirements, irrigation scheduling and estimation of agricultural inputs requirements. Similarly, chapters ten, eleven, twelve and thirteen are dealing with the analysis of the projects in terms of yield, projection, production and crop budget. At last, the guideline also provides information on improved and good agricultural practices for major irrigated crops and possible development interventions and highlights in brief the need of strengthening the extension services for irrigated agriculture.

2 OBJECTIVES AND SCOPE OF THE GUIDELINE

2.1 OBJECTIVES

The main objective of this study guideline is to establish a more simplified, comprehensive and standardized agronomic procedures, criteria and stepwise approaches to be used in data collection, analysis and interpretation in the preparation of irrigation agronomy and agricultural development feasibility study and analysis to be treated as an integral part for the preparation of small-scale irrigation development projects.

2.2 SCOPE OF THE GUIDELINE

In the preparation of this guideline, a detailed review has been made both on local and international procedures and guidelines used for agronomic feasibility studies in irrigation projects. Based on the detailed review made, critical constraints and gaps identified in the respective guidelines developed and used in the past by different actors in conducting agronomic feasibility studies in Ethiopia. This guideline is therefore, prepared to provide an overall guidance to readers or end users to properly conduct a feasibility study on irrigation agronomy and agricultural development to be treated as an integral part for the preparation of small-scale irrigation development projects. Therefore, in the current guideline included all important components, update agronomic information and procedures to be applied for irrigation agronomic feasibility studies to be integrated with the series of multi-sectoral SSID studies.

This irrigation agronomy and agricultural development feasibility study guideline is developed targeting the young graduate staff at all levels to enable them to successfully conduct the feasibility study of small-scale irrigation projects by adopting the recommended assessment and analysis procedures and guidelines described herewith. The guideline is designed in such a way as to deliver some basic and useful information to readers that will assist them to undertake a rapid assessment of community managed irrigation schemes.

Therefore, the approaches and procedures mentioned in this guideline are aimed at providing basic guidance to end users on standardized procedures and guidelines to be used in irrigation agronomic feasibility study and analysis, with particular emphasis on data collection, analysis and interpretation of results of the existing agricultural practices of the project area, determining the need of reliable agricultural inputs supply system, assessing the more feasible improved agronomic practices to be recommended and identifying potential development interventions to be proposed. Moreover, it provides essential inputs to make a thorough analysis of social, environmental and financial project feasibility in order to come up with concrete recommendations by taking into account location specific conditions. The irrigation agronomic feasibility study should be conducted in a more participatory manner with active involvement of direct beneficiary communities and other stakeholders in all stages of implementation.

3 DATA COLLECTION PROCEDURES AND METHODOLOGIES

3.1 GENERAL

The methodology section describes the rationale for the application of specific procedures or techniques to be used to identify, assess, and analyze information in the context of irrigated agriculture. The methodology section of a feasibility study should answer two main questions: (i) What standardized methodologies to be used for data collection for feasibility study and; (ii) How the data quality is assessed and analyzed.

The primary data is directly acquired from direct beneficiaries and field surveys while the secondary data is collected from secondary data sources such as study documents, progress or annual reports, research outputs, experts and decision maker opinions, CSA statistical data sources, and others.

The following data collection tools such as focus group discussion, household survey, direct field observation using transect walk and key informant interview are recommended for primary data collection while stakeholder consultation; desk review and study team consultation are advised to be used for secondary data collection.

Box 1
Properly written methodology section should: • *Introduce the overall methodological approach: Is your study qualitative or quantitative or a combination of both?* • *Indicate how the approach fits the overall study design or the objective of the feasibility study* • *Describe the specific methods of data collection you are going to use* • *Explain how you intend to analyze your results.* • *Provide a justification for sample selection and sampling procedure. For instance, if you propose to conduct interviews, how do you intend to select the sample population? If you are using statistics, why is this set of statistics being used? If other data sources exist, explain why the data you chose is most appropriate to addressing the study issues.* • *Describe potential limitations.*

3.2 DESK WORK AND REVIEW

- Before the commencement of the fieldwork, the irrigation agronomist is expected to undertake the followings activities as part of the preparatory works:
- Prepare precise and manageable checklists for focus group discussion (FGD) session, key informant interview (KII), multi-sectoral household survey (HHS), stakeholder consultation, and field observation;
- Proper literature review and identify the data gaps and additional data requirements;
- Identify potential stakeholders at all levels (region, zone, wereda and kebele levels);
- Estimate number of focus groups to be held depending on typology and size of the command area and key informant interviews to be conducted at all levels;
- Prepare tentative working schedule on daily basis in consultation with other team members;
- Make sure that the required logistics involving transportation facility, field materials and budget are available and ready.

3.3 PRIMARY DATA COLLECTION PROCEDURES

The primary data can be collected from the community using structured and/or semi-structured checklists and/or household survey. Prior to the fieldwork, the checklists should be prepared by taking into account the objectives of the study and importance of the data for the intended purposes. Primary data required for description and analysis of development constraints and potentials agricultural interventions are collected using the following data collection methods or survey tools: (i) Focus Group Discussion (FGD);(ii) Key informant interview (KII); (iii) Household survey (HHS); (iv) Stakeholders' consultation and (v) Field observations using transect walk. For better understanding, each method briefly described hereunder.

3.3.1 Focus group discussion (FGD)

A focus group discussion is a qualitative data collection method in which the expert (s) and beneficiary groups/stakeholders meet as a group to discuss a given issue, in which the participants are responding to open-ended questions, which are expected to be raised by the expert (s) as facilitate the discussion.

Focus group discussion should focus on various issues related to the existing situation, constraints, opportunities, farming experiences and potential development interventions. The number of focus group discussions required for data collection is ranging from 2-3 groups depending on the size of the command area and socio-cultural setup. The groups should be organized from different parts of the command area (middle-tail or head-middle, head-tail of the command area). If the command area is located in different Kebeles and the focus group discussion shall be undertaken in each project Kebele.

Additional group can be organized if the agronomist decides to include a special group to deal particular issues like traditional irrigation users. It is more helpful to discuss with traditional irrigation user independently to acquire deep information on their problems and irrigation experiences.

Focus groups work best when conducted by two persons. One could act as a facilitator and the second person will be a note taker. The facilitator is responsible to facilitate the focus group discussion, posing all questions specified in the focus group question guide, keeping the discussion on track, and encouraging all participants to contribute their views to the discussion.

Selecting participants for FGD: The richness of the data is emerging from the group members' diversity because of difference in age, gender, farming experiences, technology exposure, access to resources, landholding size and other factors. Different views will likely be expressed by participants own diversified socio-economic and cultural backgrounds.

The number of households participating in focus group sessions shall be ranging from 10 – 12 households or beneficiaries representing different socio-economic groups like women headed households, elders, youth group, model farmers and traditional irrigation users (if any). The facilitator has to be recruited from the project wereda or Kebele. Local level facilitators are fluent in their local language. If this is not applicable a translator is required to assist the lead interviewer in translating the discussion points to the participants and briefly communicating back to the interviewer responses directly captured from participants.

FGD session time span: FGD sessions usually last from 1-2 hours and should include time for participants to take health breaks and allow them to interact to each other entertaining certain common issues. As you begin the discussion, consider how much time you are likely to have and set realistic goals for covering all the questions in the checklists. Allocate timeframe for each discussion point. It is advisable to be precise in asking questions to clearly set what is being asked and to briefly capture the main essence of replies.

Self-introduction: In conducting focus group discussion, it is important to start by welcoming participants and briefly introduce yourself and the team, the purpose of the focus group discussion in order to establish clear understanding among participants and encourage smooth flow of ideas. Explain the main purpose of study as to understand the overall farming system and potential entry points for development interventions with particular focus on small-scale irrigation development. So that participants are free and expected to share experiences, opinions and points for consideration and confirm that the responses will be used for preparing small-scale irrigation development projects.

Issues expected to be covered but not limited to*:* The main issues to be discussed during focus group discussion are assessing the existing agricultural production systems, input utilization experience, prominent existing cropping pattern, cultivated land use, irrigation scheduling, irrigation water managements; their crop preference for the anticipated project, agricultural development constraints, possible recommendations for the improvements of crop production, and farmers' comments on type of irrigation structure.

Debriefing session*:* Debriefing session should take place immediately after the completion of focus group session to summarize the findings to develop common understanding and their acceptance. Please refer the checklists in Appendix I attached herewith.

3.3.2 Key informant interview

Key informant interviews (KIIs) suggested to be carried out with selected knowledgeable and informative farmers to capture very important information on critical points. The agronomist should interview only limited key informants taking into account the information gaps required to be covered and enriching the collected data or information The Key informant interviews are qualitative and in-depth interviews with purposely-selected individuals. It allows a free flow of ideas and information.

Purpose: This method is useful to collect mainly qualitative data or information in identification, and feasibility study phases of SSIP. The key informant interview could enrich and support the information obtained from farmers during focus group discussions and can fill the data gap, which is supposed and difficult to get by other data collection tools.

Participant: Key informants are selected for their specialized knowledge on agriculture and socio-cultural issues. In the context of irrigated agriculture development study, the potential key informants could be irrigation user, elders, innovative and knowledgeable farmers, and women farmers. In addition, in the selection process for key informant interview, it is important to balance the gender mix, youth group and model farmers with better experience.

The number of participants for key informant interview at project site should not exceed more than 3-4 informants. Because this tool is designed to complement data collected through other methods. It is also important to note that the number of KIIs to be conducted in each project site depends on the size of the command area, beneficiary Kebeles (representing near the head, middle and downstream of the command area) and socio-economic setting of the project area under consideration.

Self-introduction: As briefly described under FGD, it is important to introduce yourself to the interviewee or discussants, clearly explain the objectives of the assessment without raising expectations. Start by thanking the key informant for agreeing to the interview. It is good to start the interview with more simplified version of guiding questions such as what, why, how and when, without diving in trying to provide long explanations. Always it is important to combine your interview skills (ask, probe, confirm) with other techniques such as observations and taking of photos. However, when you decided to take photos as evidence of proof, ask permission to do so and document. At the end of each interview, the person who sacrificed his/her time in providing information should be thanked for the information shared and the time spent for the interview.

Issues to be covered: Existing crop production system, development constraints, good and bad irrigation experience, historical trends on prevalence of pest infestation, rainfall pattern, flood occurrence, experience in agricultural input utilization, recommendations for improvement, and other issues to be raised from local conditions.

Time required: It is recommended to spend 15-25 minutes with each participant for key informant interview.

Data analysis: Prepare interview summary sheet to compile the information based on the pre-determined topics and additional issues raised and discussed. Some of the points that should be noted, in summary sheet are: Name of key informant, key informant position, main points discussed, summary of important points and recommendations. Refer the sample checklist for interview in Appendix Ia attached herewith.

3.3.3 Multi- sectoral household Survey

The household survey will be undertaken to address some important issues in collaboration with the socio-economist by integrating the agronomic questions in socio-economic survey questionnaires. Considering the time given for fieldwork, the importance of the data required and the efficiency of other data collection tools, the household sample survey (agronomical issues/data) could be very selective and focused on essential issues. The agronomist will select important questions to be covered through household survey and provide to the socio-economist to integrate in multi-sectoral survey questionnaires.

Some of the important agronomic questions include but not limited to are:

- Cultivated land covered by major crops;
- Average landholding size in and outside the command area;
- Major inputs utilized;
- Crop preference for irrigated agriculture;
- Crop yield and production;
- Livestock holding, and
- Major constraints of agricultural development.

The findings of household survey also be used for triangulation or crosschecking information gathered through different methods and sources. The entire procedures for household survey are described in socio-economy study guideline. (Please, refer SSIGL A7: SSIP Guideline for Socio-Economic Study).

3.3.4 Field transect walk observation

During transect walk observation, the agronomist should focus on current conditions of land resources, performance of crops on the field, occurrence of water logging and land degradation, cropland utilization, pest incidence and frequency and experience in pest management, constraints for implementation of irrigated agriculture and others.

Moreover, field observation needs to be held to familiarize yourself with the farmers' experiences and existing agricultural practices. In line with the above-mentioned issues, the farmers and development agents can be consulted about current agricultural activities, market opportunity of cultivated crops, pest occurrence, crop preference for irrigated agriculture, and other issues.

3.4 SECONDARY DATA COLLECTION

3.4.1 Stakeholders' consultation

Stakeholders' consultation is a most valuable information source for SSIP feasibility study. The consultation undertaken at different levels from the grass root up to zonal office levels as required. Water users' committees, wereda experts and concerned Regional Bureau and agency experts need to be consulted on various issues including policy issue, agricultural production practices, input supply system, availability and accessibility of improved technologies, potential irrigable crops, agricultural marketing, potential agro-processing activities and others.

During the inception phase, potential stakeholders should be identified at all levels (regional, zonal, wereda and kebele) for consultation and data collection. In this connection, at all administrative levels the Agriculture and Natural Resource Bureaus, Water Resources Bureaus, Irrigation Development Agencies, Investment Bureaus, Agricultural Research Institutes, Regional Seed Enterprises, and Farmer Service Cooperatives and Unions are potential institutions to be consulted during the field survey.

Consultation and data collection can be handled in selected offices together with other study team members to discuss the issues from different aspects. The stakeholder checklists should be prepared to use as a guidance to conduct discussions with experts and concerned bodies. Checklists for selected stakeholders are attached in Appendix II and III (See Appendix II and III).

3.4.2 Review on-going sectoral studies

The findings from other sectoral studies within the on-going feasibility study such as soil survey and land evaluation study, engineering, hydrology, socio-economy, environmental and social impact assessment; and watershed need to be inter-changed for analysis and recommendations. Before the commencement of the fieldwork, the agronomist should provide list of data required from each sector study.

3.4.3 Review of reports and research outputs

Secondary data obtained from different stakeholders, periodical reports and research outputs and proceedings shall be referred to, and valuable data need to be noted. The research institution around the project area can provide the available research outputs released for specific localities, which are very important data to come up with concrete recommendations to inform smallholder farmers engaged and/or to be engaged in the future in irrigated agriculture.

Relevant agro-climatic data such as rainfall, temperature, relative humidity, sunshine hours, radiation and wind speed will be collected from relevant meteorological stations or can be interchanged with the hydrologist in the study team.

3.5 DATA COMPILATION AND ANALYSIS

Periodical data from primary and secondary sources will be compiled by production year and activities. Further the average, minimum and maximum data will be computed depending on the quality of the raw data. Some of the parameters to be analyzed in the feasibility study are: existing yield and production trend analysis; existing cropping pattern; ETo computation; crop water requirement and duty determination; computing net and gross irrigation requirements; determination of irrigation interval and depth; agricultural input requirements; crop budget with and without project; and crop yield and production projection.

3.6 MATERIALS REQUIRED FOR THE STUDY

The agronomist as a study crew member requires the following listed materials to manage the assignment successfully:

- List of stakeholders at different administrative levels to be consulted for data collection;
- Data collection checklists and questionnaires;
- Note book, CD or Flash for note taking and/or record keeping/documentation;
- Topographic map of the project area and/or hard copy of satellite imagery of the project site;
- GPS;
- Field soil and water parameters test tools (pH meter, wash bottles, etc);
- Camera/recorder;
- Computer

3.7 INTERDISCIPLINARY DATA EXCHANGE REQUIREMENTS

3.7.1 Data required from different sector studies

a. Engineering study

- Recommended type of irrigation application systems: surface or pressurized or spate;

- Command area geographic location;
- Major irrigation and drainage structure features including length of water distribution structures and drainage system; number of blocks;
- Size of gross and net command area after consultation with soil experts;

b. Socio-economy study

The irrigation agronomist may require from the socio-economic study mainly the economic condition of the project area such as average landholding per household and details of primary and secondary livelihood basis of beneficiaries.

- Social and public service infrastructure
  - ➢ The availability and accessibility of social and public infrastructure including health, water supply and education facilities; veterinary clinics; telephone services.
  - ➢ Road infrastructure and accessibility of the command and headwork sites; and means of transportation.
  - ➢ Input supply and credit service provider partners (formal and informal)
- Beneficiaries, Population and Demographic Characteristics:
  - ➢ Estimated number of household heads, population, population density
  - ➢ Average family Size
  - ➢ Farm labour or number of active population group.
- Marketing
  - ➢ Marketing channels; marketing size and structures;
  - ➢ Prices of agricultural inputs and outputs
  - ➢ Marketing constraints;
  - ➢ Household agricultural product utilization for consumption, market and reserve;
  - ➢ Local and export market potentials for project production

c. Soils survey and land suitability Evaluation

- Descriptions/characterization of land and soil resources
  - ➢ Major types of soils and area coverage in the command area
  - ➢ Gross and net command area sizes
  - ➢ Land form and topographic condition,
  - ➢ Natural Vegetation and Land Use,
  - ➢ External Drainage & flooding status,
  - ➢ Status of Soil Erosion;
  - ➢ Climate and Depth of Ground Water Table
- Soil Physical Characteristics
  - ➢ Effective Soil Depth;
  - ➢ Soil texture and Structures;
  - ➢ Drainage characteristics
  - ➢ Infiltration rate and hydraulic conductivity
  - ➢ Soil moisture condition including field capacity (FC), permanent wilting point (PWP), bulk density
  - ➢ Depth of Soft Weathering Rock
- Soil Chemical Characteristics
  - ➢ Soil acidity and alkalinity; Electrical Conductivity;
  - ➢ Cation Exchange Capacity and Base Saturation;
  - ➢ Exchangeable Cautions;
  - ➢ Organic Matter and Organic Carbon; Total N;
  - ➢ Cationic Ratios Exchangeable Sodium Percentage,

- Available Phosphorus; Carbonates;
- Toxic elements; Salts
- Water Quality Analysis (for heavy metals, suitability for irrigation);

- Soil /Land and crop suitability Evaluation for Irrigation system
  - Land suitability analysis results by soil mapping unit
  - Land suitability map
  - Crop suitability analysis
  - Crop suitability map
- Soil and Land Management
  - Recommended Land and soil status improving management practices
  - Soil and water conservation measures, and
  - Combating salinity, sodicity and acidity problems...etc.

d. Climatic and Hydrologic Data

- Monthly rainfall data (mm)
- Mean Monthly Minimum and Maximum temperatures (oc)
- Mean Monthly Sunshine hours (hr.)
- Mean Monthly Wind speed (m/sec)
- Mean Monthly Relative Humidity (%)
- Mean monthly flows
- Water Balance Analysis (at watershed and command area scales)

3.7.2 *Data expected from irrigation agronomy study to other sectors*

e. Description of current agricultural activities and resources of the project area

- Major farming system practiced in the project area
- Major crops grown in the project area
- Existing cropping patterns for without project analysis
- Existing input utilization experiences in terms of rate of application
- Yield estimates of major crops grown in the command area
- Major limiting factors or constraints of crop production system

f. Proposed irrigated agriculture development data

- List of proposed crops for irrigated agriculture development
- Proposed cropping patterns for supplementary and full irrigation seasons
- Monthly irrigation requirements, peak demand in l/s/ha, irrigation water requirement for actual cultivated land for each month of the cropping season in mm and total annual irrigation requirement of the project. these data to be used for determining command area size, water supply and distribution capacity, water balance analysis and others
- Irrigation depth and schedule by crop
- Types and quantity of recommended agricultural inputs mainly for SEIA and financial analysis sectors
- Price of the recommended agricultural inputs (those used in crop budget analysis)
- Crop budget analysis results for financial and economic analysis
- Yield projection and estimates of project production

4 EXISTING AGRICULTURAL SITUATION OF THE PROJECT AREA

The project area assessment is one of the basic pillars of the small-scale irrigation project study that gives reliable baseline data to understand the bio-physical, climate and agricultural experiences of the specific local communities. In the context of irrigated agriculture development, the agricultural resources including the bio-physical resources, climatic conditions and human skills are the prime focus of this chapter. The required data and information to be used for the existing situation analysis are agro-ecology, length of growing period, climate, land use/cover, farming system, agricultural practices and input utilization, agricultural potential and others relevant factors to the specific areas.

The main objective of the project area assessment and description is providing important baseline data for designing appropriate irrigated agriculture interventions. The baseline assessment can be obtained from different sources and should focus on the following subjects:

- Agro-ecology and Length of growing determination
- Agro-climate assessment and analysis (rainfall pattern, temperature, humidity, wind speed, sunshine hours)
- Physical features of the land resources (topography/slope, land use/cover, soil, water and land suitability),
- Community experience (farming system, cropping system, input utilization, crop yield and production)
- Agricultural development constraints and irrigated agriculture opportunities

4.1 LOCATION OF THE PROJECT AREA

The location of the project area should be indicated with their administrative name including name of the region, zone, woreda, kebele and sub-kebele. In addition to this, geographic location in coordinates, accessibility of the site and distance from the Woreda capital should be indicated. The location of the command area required to be shown on a location map.

4.2 AGRO-ECOLOGY OF THE PROJECT AREA

Agro-ecological zoning (AEZ), as applied in FAO studies, defines zones on the basis of combinations of soil, landform and climatic characteristics. The particular parameters used in the definition focus on the climatic and edaphic requirements of crops and on the management systems under which the crops are grown. Each zone has a similar combination of constraints and potentials for land use, and serves as a basis for the targeting of recommendations designed to improve the existing land-use situation, either through increasing production or by limiting land degradation. The agronomist should give considerable attention in identifying and characterizing the agro-ecology of the project area. It helps to identify typical constraints associated with environment, agriculture and land use systems; and helps to draw workable development strategies, which will enable planners to take advantage of the development opportunities.

According to the Ethiopian agro-ecology classification, there are 32 major agro-ecological zones, as each ecological zone has typical characteristics that provide basic information for crop production potential and multi sectoral analysis (for details refer Appendix XI). The correlation between the agro-ecology and crop adaptation, which demonstrated in Table 4.2, indicates the potential crops adapted for specific agro-ecology.

Table 4-1: Major Agro-ecological Zones of Ethiopia

No	Major Agro-ecological zones		No	Major Agro-ecological zones	
1	A_1	Hot arid lowland plains	17	M_5	Cold moist sub-afro-alpine to afro-alpine
2	A_2	Warm arid lowland plains	18	M_6	Very cold moist sub-afro-alpine to afro-alpine
3	A_3	Tepid arid mid highlands	19	SH_1	Hot sub-humid lowlands
4	SA_1	Hot semi-arid lowlands	20	SH_2	Warm sub-humid lowlands
5	SA_2	Warm semi-arid lowlands	21	SH_3	Tepid sub-humid mid highlands
6	SA_3	Tepid semi-arid mid highlands	22	SH_4	Cool sub-humid mid highlands
7	SM_1	Hot sub-moist lowlands	23	SH_5	Cold sub-humid sub-afro-alpine to afro-alpine
8	SM_2	Warm sub-moist lowlands	24	SH_6	Very cold sub-humid sub-afro alpine to afro-alpine
9	SM_3	Tepid sub-moist mid highlands	25	H_2	Warm humid lowlands
10	SM_4	Cool sub-moist mid highlands	26	H_3	Tepid humid mid highlands
11	SM_5	Cold sub-moist mid highlands	27	H_4	Cool humid mid highlands
12	SM_6	Very cold sub-moist mid highlands	28	H_5	Cold humid sub-afro-alpine to afro-alpine
13	M_1	Hot moist lowlands	29	H_6	Very cold humid sub-afro-alpine
14	M_2	Warm moist lowlands	30	PH_1	Hot per-humid lowlands
15	M_3	Tepid moist mid highlands	31	PH_2	Warm Per-humid lowlands
16	M_4	Cool moist mid highlands	32	PH_3	Tepid Per-humid mid highland

Source: Revised agro-ecological classification, former MoA, 2005

In identification of the agro-ecology of specific project area, the altitudinal ranges is a primary indicator integrated with temperature ranges intensify the classification units. The altitude range data of the project area can be obtained from engineers to avoid data inconsistency, while the temperature data obtain from representative meteorology dataset representing the project area. The major agro-ecological characteristics including altitude, type of soils and vegetation cover are summarized in Appendix XI.

Thermal zone describes the temperature conditions that prevail during the growing season and in the region, which are very closely correlated with altitude. The crops, which are suitable for each thermal zone can be used as reference to make crop matching with project area temperature and altitude ranges. Therefore the altitude and temperature data of the project area can indicate the thermal zone where it belongs then the crops could be easily identified for further suitable analysis and crop selection. Refer Appendix XV for map of agro-ecological zones of Ethiopia.

Table 4-2: Major crops adapted to different Thermal zones and altitude ranges in Ethiopia

Thermal zone	Temperature range	Altitude range m.a.s.l	Common crops grown
TI	over 27.5 ^{0}c	under 500	Millet, maize, sorghum, rice, cowpea, sesame,
TII	22.5 to 27.5^{0}c	500 to 1300m	Millet, maize, sorghum, rice, cowpea, sunflower, safflower, sesame, haricot bean
TIII	17.5 to 22.5^{0}c	1301 to 2200	wheat, barley, teff, oats, cowpea, sunflower, haricot bean, chickpea, lentil, faba bean, field pea, niger seed
TIV	12.5 to 17.5^{0}C	2201 to 3000	Wheat, barley, teff, oats, sunflower, chick pea, lentils, faba bean, field pea, linseed, rapeseed
TV	under 12.5^{0}c	over 3000	Wheat, barley, oats, faba bean, field pea, linseed, rapeseed

4.3 LENGTH OF GROWING PERIOD IN THE PROJECT AREA (LGP)

Length of growing period (LGP) defines as the growing time period when moisture supply exceeds half potential evapotranspiration and includes the time required to evapo-transpire up to 100 mm of soil moisture storage.

As demonstrated in Fig 4.1, the LGP of a given project area can be characterized from any of the three graphs. The expert should draw the graph using the data of precipitation, Evapo-transpiration and ½ of ET.

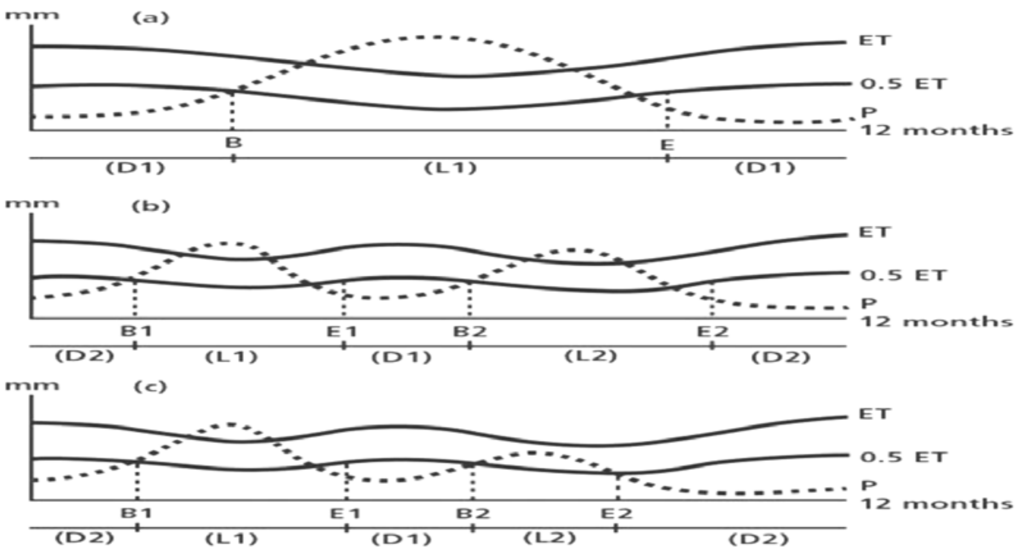


Figure 4-1: Length of growing period in different rainfall patterns

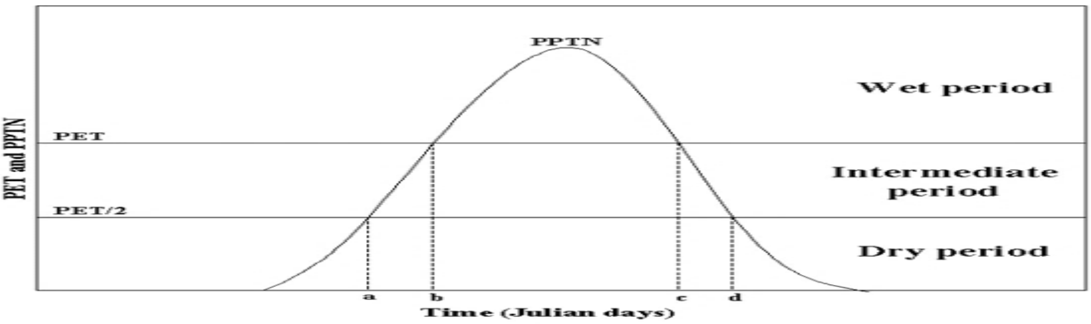


Figure 4-2: Inter-correlation of precipitation, potential Evapo-transpiration and LGP

Source: http://www.fao.org/nr/climpag/cropfor/lgp_en.asp

In areas characterized with bi-modal rainfall patterns (last two graphs of Fig 4-1), the precipitation (p) may exceed ET or ET/2 for two or more distinct periods in the year, resulting in more than one LGP per year. In North-west, Eastern and South- east parts of Ethiopia where the areas characterized by bi-modal rainfall patterns have two LGPs due to main and short-term rainfall patterns.

There are generally six categories of growing periods in which the agronomist can describe the project area based on the following peculiar characteristics of LGP types.

Table 4-3: Type of length of growing period and their descriptions

Type of LGP	Description
Type 1 LGP < 60 days	Cropping is usually not practiced as the growing period is too unreliable
Type 2 LGP 60-90 days	Cropping practiced with fast maturing, drought resistant crops; but success is limited to, on average, 5 years in every 10.
Type 3 LGP 91-120 days	Cropping practiced with short season crops and varieties, successful 8 years in every 10.
Type 4 LGP 121-150 days	Cropping reasonably secure in all but the worst drought years
Type 5 LGP 151-210 days	Cropping is secure for all practical purposes.
Type 6 LGP > 210 days	Cropping is secure for annual crops; perennial crops begin to appear suitable above this threshold.

4.3.1 Purpose of LGP assessment

The main purpose of the length of growing period determination is to provide preliminary information on the capacity of the precipitation and stored soil moisture maintaining the growth of crops in defined growing period. The analysis result indicates the possible number of cropping season per year, which can be once, twice or triple cropping seasons. In this section, the expert should focus on the analysis of the length of growing period of the project area not necessarily specific to the individual crops.

4.3.2 Length of growing period determination

Length of growing period is determined by agro-climatic parameters in comparison with precipitation distribution. ***The effectiveness of early rains increases considerably once precipitation is equal to, or exceeds, half ET***. The growing period continues beyond the rainy season, when crops often mature on moisture reserves stored in the soil profile. Soil moisture storage capacity should therefore, be considered in defining the length of the growing period.

The length of growing period can be determined using the following methods:

a) Community consultation

The agronomist can identify the LGP of the project area with focus group participants by defining crop growing favorable periods in months. The knowledge of the communities on rainfed cropping season enable to roughly estimate the length of growing period.

The agronomist has to define the cropping seasons in local language and interpret to Ethiopian calendar format or directly to European calendar format for reporting purpose.

b) LGP determination based on climate data

The calculation of the growing period is based on a simple water balance model, comparing water availability with crop water demand (precipitation with PET), using monthly values. A "normal" growing period is characterized by a long dry period, a moist period and a wet (or humid period) (see Fig 4-2)

Option 1: Using the Excel spreadsheet

Step 1: calculate the monthly potential evapo-transpiration of the area using Pen-manteith method or it can be available from Class I Meteorology station; or New-LocClim V1-10 software. However, it is advisable to calculate the ETo with site specific climate data.

Step 2: Calculate 50% of ETo monthly values

Step 3: Insert the mean monthly rainfall data in tables

Step 4: calculate simple water balance by subtracting 50% of ETo values (crop water demand) from monthly Rainfall (water availability), and identify the months with deficits (-)

Step 5: determine the number of days with surplus water balance months and add-up that gives length of growing period of the project suitable for crop production under rainfed conditions

Table 4-4: LGP determination for Pawi Area SSIP area

	Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	ETo, mm	116	127	154	147	142	117	99.9	93.3	102	104	104	104.7
2	ETo*0.5	58	63.5	77	73.5	71	58.5	49.95	46.65	51	52	52	52.35
3	Rainfall, mm	1.2	0.8	6.9	22.7	106.7	291.2	354.7	415	243.2	130.5	13.5	1.2
4	(3-2)	-56.8	-62.7	-70.1	-50.8	35.7	232.7	304.75	368.35	192.2	78.5	-38.5	-51.15
5	LGP, days					31	30	31	31	30	31		
	LGP Period					**~184 days**							

Option 2: Graphic determination of growing period

Step 1: Insert the monthly ETo, water demand data or (ETo /2) and Monthly average rainfall data from the same source into Excel as above illustration and draw a graph then

Step 2: Select the required data and make active for further tasks, then

Step 3: On the same sheet click “insert” on main tools bar

Step 4: choose different graph options from “chart layout” and click. Then the graph will appear and you can edit the formats and data

Step 5: identify the months where the water availability / rainfall line crossing the water demand (ETo/2) line.

Step 6: indicate the month in graph as demonstrated below (Fig 4-3) and sum up the days above the crossing points’ value that indicate the length of growing period. The monthly values below the value of crossing points tend to be deficit months those require irrigation water.

According to the illustrated example below, the dry season of the project area ranging from first week of November to end of April, which extends for about six months. The dry season in the project area has sufficient period to undertake irrigated agriculture with higher possibility to practice two-season irrigation. The agronomist should think of the option to have triple cropping season for this area if the location specific factors and crop types permit, otherwise, two cropping seasons are ideal including the rainfed agriculture.

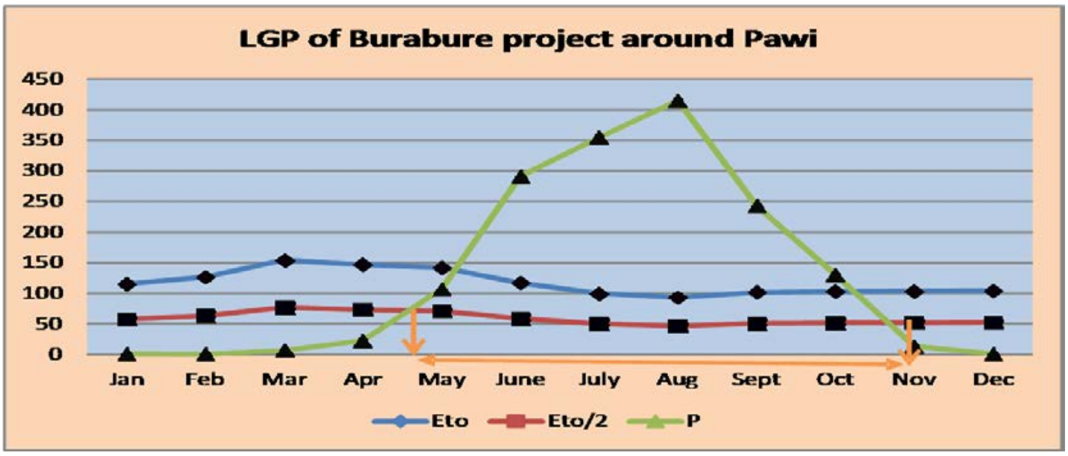


Figure 4-3: LGP determination graph for SSIP around Pawi area in Amhara Region

4.4 AGRO-CLIMATIC ANALYSIS OF THE PROJECT AREA

Agro-climatic parameters to be employed for irrigation water use prediction are rainfall, temperature, humidity, wind speed and sunshine hour. Proper agro-climate data source selection and analysis of the available data have critical importance in computing the precipitation deficit and for efficient utilization of water resource. Major agro-climate parameters are described in the following sub-sections, which focus in proposing the potential data sources and method of applications for agronomic feasibility study.

4.4.1 Sources of climate data

For analysis of agro-climate condition of the project area with respect to irrigation development potential, the required data from Class "I" meteorology station shall be accessed from nearby station. Class I station is recording rainfall, temperature, sunshine duration, wind speed and direction, cloud amount, soil temperature, Pan Evaporation, and Pitche evaporation data.

Class III station collects only air temperature and rainfall; and class IV collect only rainfall. The agronomist in collaboration with the hydrologist should identify appropriate meteorological station to use as reference center. This station shall be located in similar agro-ecology of the project area to reflect more appropriate climate information. Due to sparse distribution of meteorological stations and occurrence of significant missed data in met-station database, the agronomist require to search other options to describe the agro-climate condition of the project area and further to use for analysis. In such case, the satellite based verified datasets like Climate Forecast System Re-analysis (CFSR) daily rainfall dataset can be a reliable source, which is developed with ~ 38 km spatial resolution of a 32 year (1979 -2010), which tends to be frequently updated. Currently there other data source verified satellite based datasets for Ethiopian context could be used for analysis and area description.

- **Rainfall pattern and intensity determination:**

The usual on-set and cessation of rainfall at or around the project area should be investigated and recorded in months range. It's an important input to set cropping calendar for proposed cropping seasons. The agronomist can investigate the rainfall pattern and intensity through:

- Rainfall data analysis
- Stakeholder consultation at grass root level including farmers and development agents

The first method for rainfall pattern and intensity assessment is relying on long-term mean monthly rainfall data which can be collected from meteorology station or adopted from other global and regional climate dataset. The seasonality of rainfall in the project area can be analyzed by ***mean monthly rainfall ratio with that of rainfall module*** as rainfall coefficient (UNFAO (1965) adopted by Daniel Gemechu, 1977. Rainfall module is one-twelve value of the annual rainfall value.

Table 4-5: Rainfall coefficient classification

	Rainfall Coefficient	Designation
1	< 0.6	Dry season
2	0.6 to 0.9	Small rains
3	≥ 1	Big Rains
3.1	1 to 1.9	Moderate
3.2	2 to 2.9	High
3.3	≥ 3	Very high

Source: Daniel Gemechu 1977 "Aspects of climate and water budget in Ethiopia

The project area can be described based on calculated rainfall coefficient values to identify the months with different rainfall intensity, once this information is available, ***the agronomist able to use as an input for determination of cropping calendar and cropping patterns***.

Table 4-6: Seasonal Rainfall Distribution and Intensity for Pawi, Awi zone area

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Rainfall Module
Rainfall, mm	1.2	0.8	6.9	22.7	106.7	291.2	354.7	415	243.2	130.5	13.5	51.2	136.5
Rainfall Coefficient	0.01	0.01	0.05	0.17	0.78	2.13	2.60	3.04	1.78	0.96	0.10	0.38	

In general, the months with less than 0.6 rainfall coefficient are said to be dry season, accordingly the months from November to end of April are dry season for Pawi area. Moreover, the remaining months from May to October are rainy season with different intensity. Detail discussion on the rainfall intensity should be undertaken based on rainfall coefficient description in Table 4-5. In reference with the tabulated illustration, the agronomist could roughly determine the months for irrigation season. Accordingly, the months November to April can be considered as a dry season, which are appropriate for running irrigation activities in these months of the year in the given locality.

4.4.2 Temperature data collection, compiling and description

Air temperature influences plant growth through photosynthesis and respiration, affects soil temperature, and controls available water in the soil. As temperature increases the rate of respiration increase, then analyzing the temperature condition of the project area with other climatic factors significantly contribute to crop selection, cropping pattern formulation and computation of crop water requirement.

The data sources identified for rainfall data are also applicable for temperature data collection. In the absence of the location specific meteorological station database, at least it will be possible to use New LocClim V1.10 software and satellite based data sets as possible sources for long-term monthly average data.

Based on long-term average data of maximum, minimum and mean temperature the agronomist can determine the suitability of the crops by correlating the optimum temperature requirement with actual temperature of the project area.

For instance the optimum mean daily temperature for tomato is recommended to be within 18^oC and 25^oC, therefore the project area mean monthly temperature data should coincide within the indicated ranges in order to recommend tomato in the cropping pattern. The most important contribution of temperature data in irrigated agriculture development planning or study is being one of the agro-climate inputs for estimation of reference evapotranspiration, which is a basis for determining crop water requirement.

4.4.3 Relative humidity data assessment and compiling

Relative humidity with other climatic parameters is used for estimating the potential evapo-transpiration. Moreover, it is an important indicator for agricultural potential of the area and pest occurrence probability. The relative humidity affects the opening and closing of the stomata, which regulates loss of water from the plant through transpiration as well as photosynthesis, which in turn affects the crop productivity.

During feasibility study, the agronomist is expected to analyze the mean monthly relative humidity (RH) to compute PET and describe the project area with range of RH values. According to FAO Irrigation & Drainage No 24 paper the area with < 40% RH can be designate as Low humid; area within the range of 40% to 70% are moderately humid and when RH is > 70% the area is grouped as high humid.

Very high or very low relative humidity is not conducive, for instance, very high relative humidity reduces evapotranspiration, increase heat load and stomata closure, reduce CO_2 uptake. On the contrary, low relative humidity increases the evapo-transpiration. In most cases, moderately high RH of 60-70% is beneficial for most crops. For instance, the relative humidity data presented in Table 4-8 for Shor SSIP located in South Bench wereda of SNNPR with range of 52% to 73% indicates the area has moderately humid condition, which is most suitable for crop growth. The long- term mean relative humidity data could be collected from the same sources cited for rainfall data but only from Class I met-stations.

4.4.4 Wind speed data assessment and compiling

Wind speed parameter is one of the climate parameters input for computing evapo-transpiration. The higher wind speed accelerates the rate of evaporation and transpiration that increases the crop water requirement.

In order to determine the wind condition of the project area, use the following classification:< 175km/day – Light; 175km/day – 425 km/day moderate; 425km/day to 700km/day – strong; and wind speed > 700km/day considered as very strong. With these ranges, the agronomist can characterize the project area and the description will support for better recommendations in crop selection and agricultural interventions. Ten-day or monthly average of daily wind speed data measured at 2 m height (U2) is recommended for irrigated agriculture climate analysis. Wind speed data should be compiled in monthly basis to be used for computation (see Table 4-8).

4.4.5 Sunshine hour data assessment and compiling

Sunshine hours or solar radiation, which measured by different methodology is an input to compute the potential evapotranspiration accompanied with other climate parameters. Where solar radiation is not measured, it can also be estimated from sunshine hours data or measured hours of bright sunshine. If you apply the CROPWAT software it generates the ten-days and monthly average solar radiation from sunshine hour data by default.

According to Blaney –Criddle method based on the extent of daily sunshine hours the cloudiness rate classified into low, medium and high and can be used to describe the project area in terms of sunshine period.

Table 4-7: solar radiation correlation with sunshine hours

Cloudiness	Radiation, oktas*	Daytime hours descriptions
Low	<4	50% of the sky covered all daytime hours by clouds or half of a daytime hours the sky is fully clouded
Moderate	1.5 – 4	
High	>1.5	Less than 20% of the sky covered all daytime hours by cloud or each day the sky has full cloud cover for some 2 hours

* okta is a unit of measurement used to describe the amount of cloud cover at any given location

Table 4-8: Climate data and ETo estimation for Shor SSIP in South Bench zone of SNNPR

	Unit	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Average
Min Temp	°C	17.2	18.2	18.1	17.1	16.2	15.3	14.6	15	15.7	15.9	16.2	16.5	16.3
Max Temp	°C	23.1	24.1	24.1	22.8	21.8	20.5	19.5	20	21	21.4	21.9	22.2	21.9
Humidity	%	52	53	58	67	72	73	71	71	66	72	64	60	65
Wind	km/day	95	104	173	130	104	104	95	104	86	95	69	69	102
Sunshine	hours	7.3	6.5	6.5	7.5	4.8	5.1	4.5	2.5	4.5	6.1	7	7.5	5.8
Raiation	MJ/m²/day	18.8	18.6	19.4	21	16.4	16.4	15.7	13.1	16.2	18.1	18.5	18.6	17.6
ETo	mm/day	3.69	3.93	4.42	4.15	3.27	3.15	2.97	2.71	3.18	3.36	3.34	3.34	3.46
	mm/month	114.4	110.1	137.1	124.5	101.4	94.5	92.1	84	95.4	104.2	100.2	103.5	105.1

4.5 EXISTING LAND RESOURCE ASSESSMENT AND DESCRIPTION

4.5.1 Description of topography of the project area

Land topography of the irrigable land affects type of irrigation system, magnitude of labor requirement, irrigation efficiency, drainage, erosion, size and shape of fields, range of possible crops, and land development. From the observed and measured data of topographic features, which should be collected from engineering and soil study findings, the agronomist can analyze the followings:

- Land suitability for proposed irrigation system and associated crop type;
- Drainage situation and probability of waterlogging;
- Susceptibility to land degradation
- Land management practices

Source of Data: Acquire the slope distribution data of the command area with respective land area coverage from soils and land evaluation expert.

Based on the available data, classify and characterize the command area in terms of slope range in reference with slope ranges presented in Table 4-9 and their area coverage in hectare.

Table 4-9: Slope classification and Range in percentage

No	Slope class	Range (%)
1	Flat or almost flat	0 – 3
2	Gently sloping	3-8
3	Sloping	8-15
4	Moderately steep	15-30
5	Steep	30-50
6	Very steep	>50

Source: Community Based Participatory Watershed Development: A Guideline Part II, MoARD 2005

Discuss the findings from different perspectives such as appropriateness of the command area to the intended irrigation system, requirement of land management practices, possibility of conservation based agriculture or/and hillside irrigation.

If the agronomist has GIS software knowledge, the slope distribution or topographic features can be determined by Digital Elevation Model (DEM software). Preferably the agronomist can get the data from Soil expert or GIS expert of the study team.

Box 3

The topographic features give background information for crop selection, cropland allocation or cropping pattern, and for recommendation of land management interventions

4.5.2 Land use/ land cover assessment and description

The land use/cover data of the command area is expected to be obtained from soil survey and land evaluation study investigation. However, the agronomist needs to make transect walk across the command area to assess the land resource and suitability for irrigated agriculture from agronomic point of view.

Accordingly, the main purposes of the land use/cover assessment undertaken by the agronomist are: to investigate the dominant land uses experienced within the command area; to visualize level of soil fertility from crop performance, to examine the extent of water logging problem, and vulnerability to erosion. The assessment results will be used to complement the land use/cover classification and descriptions of soil survey and land evaluation study in which the agronomist will able to explain from agronomic point of view.

Land use /cover assessment shall be concentrated within command area boundary. It has been experienced in some small-scale irrigation project studies that the project areas were described with kebele and wereda data which is not appropriate and misleading for small-scale irrigation development studies. Therefore, more emphasis shall be paid for command area to have detail data on: area coverage of each land use/cover; impacts or contribution of the existing land use/cover units on crop production, input utilization, irrigation scheme design, and water management. If the command area constitutes grazing land, the agronomist should in detail describe the fertility and waterlogging condition of the project area.

Obtain the accurate area estimation and types of land uses from soil survey and land evaluation sector study outputs *(Preferable)*.

4.5.3 Land tenure and landholding

Land tenure system of the project area needs to be identified in consultation with the communities and key informants. This will give the opportunity to highlight the current situation for recommendation of suitable land re-adjustment, land administration and cropping pattern development. Some of the land tenure practices in Ethiopia within the framework of country constitution are certified use-right entitlement, communal land, rental, share cropping, and leasing.

Landholding: the land holding size in the project area should be assessed and analyzed in different holding categories including number of households under each category. During the field survey and consultation, the average, minimum and maximum landholding sizes should be determined. Our experience depict that the arthematic average values are misleading the actual landholding conditions of the project area, rather its recommended to have the landholding size of the majority or owned by most of the beneficiaries. The landholding size need to be assessed for rainfed and irrigated agriculture production systems. This data will be important to analyze the existing crop budget and to be used for financial and economic analysis.

4.5.4 Description of soil resources

Soils conditions of the project area have to be addressed and discussed in the context of the irrigated agriculture. The required information should be collected from the soil sector investigation results. The following data need to be collected and compiled in tables and maps for better illustration:

- Type of major soils and area coverage (in table and map formats)
- Soil texture, soil structure, bulk density (in Tables)
- Soil moisture parameters like infiltration rate, permeability, field capacity, permanent wilting point, available water holding capacity (in Tables)
- Major chemical properties and soil fertility situation (availability of NPK, critical micro-nutrients, pH, toxicity like salinity, acidity)

Based on the data mentioned above the agronomist is expected to explain the soil conditions and fertility level in briefly and illustrate the suitability for various crop types. Further it is important to indicate that the detail information of the soil data can be referred from soil and land suitability feasibility report.

4.6 MAJOR FARMING SYSTEM

A farming system is a complex arrangement of soils, water sources, crops, livestock, labor, and other resources and characteristics within an environmental setting that a farm family manages in accordance with its preferences, capabilities and available technologies.

4.6.1 Purpose of the assessment

The main purposes are to understand the interaction of the cropping systems with land and water resource utilization; knowledge build-up on current farmers' experiences in crop management and to explain the typical agro-ecosystem of the Based on the obtained information; the agronomist can identify potential crops complement to the existing farming system; transfer the local knowledge into intended irrigated agriculture project; and to consider best conservation practices for recommendation

Example 1

If the project area is characterized by perennial horticultural complex farming system (where fruit trees, coffee, cereals, pulses, spices are growing in integrated manner) then the agronomist should keep in mind that perennial crops can be incorporated in irrigated farming considering a rich farmers experience, climate and soils suitability. Moreover, the constraints specific to this farming system will be consider in the analysis and recommendation for the new projects as required

Example 2

If the agronomist identifies and come to conclusion that the area is characterized by lowland cereals mixed farming system then he should keep in mind that warm climate loving crops with double cropping intensity is a possible cropping patterns for the project area, moreover he can identify some of common pests to be paid attention in pest control interventions. There is several information that the farming system gives to agronomist to focus on

Steps for farming system identification

Step 1: identify the agro-ecology and livelihood basis of the community (sedentary; agro-pastoral or pastoral)

Step 2: identify the major crops grown

Step 3: investigate most dominant cropping system (mono cropping/double cropping/multiple cropping)

Step 4: analyze the farming system (subsistence / commercial/irrigated/rainfed)

Step 5: identify the major limiting factors of the farming system

Step 6: identify the farming system based on major crops grown and cropping system of the project area.

Step 7: Identify other system components including livestock and illustrate how the different components interact

Example: If the project area is dominantly practicing barely or wheat production system then the area could be barely or wheat based highland cereals mixed farming system respectively. The word “mixed” uses to indicate the livestock husbandry component contribution in the system. On the contrary, in lowland area where maize and/or sorghum are dominant then the farming system named as lowland cereals mixed farming system.

Box 4

Contents of the farming system description: Major crops and livestock species, cropping seasons, technologies employed, interactions between major components of the farming system, major farming system produces, how livestock is managed and how it interact with crop production; other livelihood activities in the system that enhance or hider the local farming system.

4.7 EXISTING RAINFED AGRICULTURE

Purpose of the assessment: Most importantly the findings will help to identify potential crops for irrigated agriculture, to establish appropriate cropping patterns, to determine applicable cropping intensity, carry out long-term yield trend analysis and determine existing yield (Year 0) for yield projection in project planning. The following issues have to be addressed in assessment procedure.

4.7.1 Identify major crops grown

List the crops grown under rainfed condition in the project area, the data can be collected from community consultation and kebele record and reports. During crop identification, care need to be taken to include minor crops (small area coverage) with high farm return and economic value.

Step 1: Prepare list of crops grown in the project area

Step 2: Allow the farmers to prioritize in order of their importance

Step 3: Categorize the crops in their groups like cereals, pulses, oil seeds, vegetables, fruit trees, fiber crops, and forage crops.

Step 4: List the findings by cropping seasons if the area has two or more cropping seasons

4.7.2 Existing cropping pattern

Analyzing existing and most common cropping patterns in the project area is a spring board to propose appropriate cropping patterns. The farmers are practicing several cropping pattern options in each cropping season based on the availability of inputs, family need, market conditions and others family decision making factors, therefore the possibility having diversified cropping patterns in each cropping season is higher. Under such condition the agronomist has to be focus on representative and most common cropping patterns experienced in the command area. If the proposed command area has not been cultivated till the study period, then the agronomist should discuss on the practices undertaken on nearby cultivated land to get farmers' experiences in cropping patterns.

Purpose of the assessment:

- To identify most common cropping patterns which will be considered in the proposal
- To analyze the existing cropping land allocation,
- To establish cropping pattern for without project analysis for financial analysis study

In consultation with focus group discussion participants, the agronomist has to identify the most applied cropping pattern in the command area.

4.7.3 Experience of cropping intensity

Determine how frequent the farmers are cultivating their land in one cropping year. The assessment result provides information on cropping sequence that can be single season, double and triple cropping systems determining the integration of irrigated farming in the cropping system.

Cropping intensity of a given area can be calculated using the following equation:

$$CI = (A1 + A2)100/CA$$

CA = Total cultivated land;

A1 = Total area cultivated in the first season;

A2 = Total area cultivated in the second season

Example: in areas characterized by bi-modal rainfall patterns the farmers are traditionally growing in two seasons. If the total cultivated land is 85ha and the farmers cultivated the whole land in Meher season and if about 30 ha was left for fallowing during Belg season then the cropping intensity will be:

CI = (85 ha + 55ha)*100/85ha = 140*100/85 = 164%

4.7.4 Mapping of current cropping calendar

The cropping calendar of crops grown in the project area shall be collected in community consultation sessions or from kebele secondary data. Preferably, the information has to be collected from the community to obtain additional relevant site specific information. The tabulated cropping calendar gives basic information to determine the cropping calendar for proposed crops.

Table 4-10: Example for existing cropping calendar and recurrence of agricultural activities (mid-highland agro-ecology)

Crops	Land clearing	Ploughing		Planting	Weeding		harvesting	Threshing
		Calendar	Frequency		Calendar	Frequency		
Meher Season								
Teff	Jan	Feb-June	3-4	Early July	Aug-Sept	2-3	Nov-Dec	Nov-Dec
Millet	Jan	Feb-Apr	2	April-May	June-Sept	1-2	Nov-Dec	Dec
Barley	May	May-June	2	June-July	Aug-Sept	1	Oct-Nov	Oct-Nov
Wheat	May	May-Jun	2-3	June-July	Aug-Sept	1-2	Oct-Nov	Oct-Nov
Maize	Jan	Jan-Apr	2	Apr-May	June-July	2	Oct-Nov	
Faba bean	May	May-Jun	2	June-July	Aug	1-2	Oct-Nov	Oct-Nov
Belg Season								
Mung bean	Dec	Dec-Jan	2	Feb-Mar	Apr	1	May	May
Barley	Dec	Dec-Jan	2	Feb-Mar	Apr	1	May	May
Wheat	Dec	Dec	2-3	Feb	Apr	1-2	May	May
Teff	Dec	Dec	2-3	Feb	March	2-3	June	June-Jul
Chickpea	Dec	Dec	2-3	March	Apr	1-2	May-June	June

The agronomist can present the frequency of the agronomic activities in separate table to indicate the schedule in interval, which will help to recommend appropriate work schedule and to determine the length of cropping season. It is expected that the days between the activities should be shorten with intensive practices to get enough time for double or triple cropping system

Table 4-11: Frequency and schedule of current agronomic practices

Crops	Frequency	Ploughing			Frequency	Weeding				Harvesting
		1st	2nd	3rd		1st	2nd	3rd	4th	
Meher Season										
Teff	3	Feb 5-8	Apr 20-25	June 5	3	Early Aug	Late Aug	Mid Sept	-	-

4.7.5 Existing crop production and yield

Purpose: The main purpose of the analysis of current yield and total production parameters are to evaluate the performance of each crop under rainfed agriculture and input utilization; to analyze the potential of the crops to be part of the irrigated agriculture; to undertake yield trend analysis to find out the cause for yield changes; to establish basis for current project performance, future projection and financial analysis.

Data need to be collected: Three to five years crop area and yield per hectare by crop and season are required. Yields for different input level utilization such as "local seed without fertilizer", "Local seed with fertilizer", and Improved seed with fertilizer or full production package" have to be collected depending on the availability of the data.

Method of data collection: Yield estimates for each major crop can be obtained from FGD and key informants. For long-term yield analysis the data shall be collected from Kebele Development Office with the above mentioned timeframe.

The description and analysis part of this section have to answer the questions like why the crop yield significantly reduced or failed to meet the optimum yield considering the potential of the project area; and why the yield shows drastic increase from previous years. Based on the responses and other yield related issues the agronomist expected to discuss the yield fluctuation situation. Please, check the data collection format for crop yield and production in Appendix XVII. It is vital that the crop yield and production data presented in table 4.12 should be triangulated with the results of the household survey and FGD data for consistencies.

Example

Table 4-12: Three years crop area, yield and production data of Project Kebele

Crop	2009/10			2010/11			2011/12		
	Area, ha	Yield qt/ha	Prodn, qt	Area, ha	Yield qt/ha	Prodn, qt	Area, ha	Yield qt/ha	Prodn qt
Maize	635	30.0	19050	1000	41.8	41830	539	33.9	18263
Sorghum	900	15.0	13500	1540	27.5	42289	862	21.6	18644
Soybean	20	22.0	440	25	13.0	324	46	12.0	552
Haricot bean	150	15.0	2250	120	10.6	1272	67	8.2	552
Rice	6	46.7	280	10	18.7	187	6	20.0	120
Sesame	638	3.0	1928	800	4.5	3627	359	4.2	1525
Niger seed	232	10.0	2320	300	6.1	1836	256	6.2	1576
Finger millet	96	22.5	2160	145	2.4	344	81	8.6	696

For instance as presented in Table 4-12, the agronomist shall have adequate information from development agents, key informant and communities why the yields of soybean, haricot bean, niger seed, and maize decreased in subsequent years. Through discussion, the agronomist has to find out the major causing factors and possible intervention to combat the constraints, which will be considered in the proposed interventions and future crop production planning.

4.8 EXISTING IRRIGATED AGRICULTURE

Purpose: The purpose of assessing existing irrigated agriculture is to assess the experience in the area and promote best practices and recommend improved agricultural practices and technologies in the project area to increase production and productivity.

Description of irrigated agriculture in feasibility study should cover the experience from project kebele or surroundings to have exhausted information on performance and farm management of the irrigated agriculture. The assessment should not necessarily rely on the command area geographical boundaries, it has to outreach beyond the command area to collect relevant information.

Data required for description: types of irrigated crops, cropping calendar, cropping intensity, irrigation application methods; irrigation interval by crop, input utilization, average yields, users' involvement in water management.

Methods of data collection and sources: community consultation, stakeholder consultation including kebele development agents preferably irrigation DA, kebele reports and records.

The data collection formats and presentation are more or less similar with and/or can be modified as need rainfed agriculture description and can be adopted for description of the project area from irrigated agriculture perspectives.

4.9 DESCRIPTION OF EXISTING AGRICULTURAL PRACTICES

Purpose: The main purpose of collecting data on existing agricultural practices is to assess and analyze the current farming systems to be familiarized with the current farming practices and technologies being used for crop production.

In description and explanation of the farmers' experiences on major agricultural activities is expected to respond on the types of agricultural technologies applied, time schedule, labor requirements, and efficiency of the farming activities. The agronomist shall review existing agronomic practices to use as a database to develop recommendations of best practices to be applied for the irrigation scheme.

The most common agricultural practices in crop production system, which require brief information to be collected from local communities include: land clearing, ploughing, seedbed preparation, planting methods, planting time, thinning and pruning, transplanting, irrigation system, application of fertilizer and/or manure, weeding time, frequency and method of weeding, method of cultivation and frequency, type of major crop diseases, insect pests, vertebrate pests and their control practices, crop rotation and cover crops experiences, harvesting, threshing, cleaning, transporting, storage facilities, and marketing.

4.10 FARMERS' EXPERIENCE ON AGRICULTURAL INPUT UTILIZATION

Purposes of the assessment: to identify the technical and accessibility gaps of essential agricultural inputs such as improved seed, agro-chemicals including fertilizers and pesticides.

In general, despite the increasing trend of improved agricultural inputs utilization by smallholders, still significant size of farm population are either do not utilize or underutilize agricultural inputs in Ethiopia generally. It is also important to assess and identify farmers' experiences in using inputs both under rainfed and irrigated crops. In this context, the assessment of smallholders' experience in the project area found to be more critical to identify major gaps and propose appropriate proposals to enhance proper use of inputs.

Data required to be collected: Type of fertilizer used and rate of application, type of seeds sown and varieties, type of agro-chemicals and rate of application, labor allocation by activities per hectare and machineries in terms of machine hour or service of rental cost. In addition, fertilizer application timing and application techniques are important data to be collected and analyzed.

Make a comparison analysis of the actual experiences employed in the project area with recommended rates, method of application and outputs of the farms. Sample formats for collection of data for farmers' experience on input utilization can be referred from data collection formats recommended from different sources. Please see Appendix I to III. The input utilization trends have to be captured independently for rainfed and irrigated crops.

4.11 CROP PESTS OF THE PROJECT AREA

List of the insect pests, disease and weeds can be developed in consultation with the communities during focus group discussion and public meeting. Moreover the name of the pests also be available from secondary data from wereda and kebel agricultural offices.

Purpose of the assessment: To identify most harmful pests and level of vulnerability helping to in crop selection and cropping pattern development. On the other hand to strengthen the pest control interventions to safely protect the crop from pest attack.

Data required to be collected: name of the pests can be registered in local language later to translated with the help of reference or experts; level of damage or vulnerability and the name of the crops mainly affected (see Appendix III & IV)

4.12 DESCRIPTION OF LIVESTOCK PRODUCTION AND DATA REQUIREMENT

Livestock production briefing is required to analyze the constraints of the livestock husbandry, pin point-out the situation of forage resource availability/scarcity and to have knowledge on availability of drought power for irrigated farming. The data need to be collected are type of livestock, number of livestock, livestock population density (kebele livestock number /kebele area or pasture land), livestock production and by-product, these data can be collected from kebele records, community consultation and wereda office.

The data like lactation period in month range, milk production in lt/hd/day; butter extracted in kg/week, eggs in number/month or year and others should be collected from kebele development office and during community consultation. However, such specific and detail household based data can preferably be collected through household survey. It is also important to include in the assessment the current practice of crop-livestock integration in the project area, which will be useful to further develop recommendation for future improvements. (Refer Appendix I).

4.13 CONSTRAINTS AND OPPORTUNITIES OF AGRICULTURAL DEVELOPMENT

4.13.1 Agricultural development constraints

SWOT analysis could be a possible methodology to assess the agricultural constraints and opportunities. The constraints have to be categorized into agronomic, institutional and environmental to simplify the identification process and to suggest appropriate recommendations in planning section of the study. The agronomist can create additional category depending on the potential constraints.

Allow the FGD participants, key informants and development agents to identify and prioritize the major limiting factors of agricultural development in and around the project area.

Prioritization should be undertaken by the communities allowing them to do during focus group discussions.

- **Agronomic constraints**: nutrient depletion and land degradation; lack of skill on input utilization, lack of improved seeds, low crop yield, shortage of cultivable land, pest infestation, and poor irrigation water management.
- **Soils and land resources related**: soils acidity, poor water holding capacity, soil erosion, broken land feature, steep slope, extensive rock outcrop, land scarcity.
- **Institutional Constraints:** Short supply of agricultural inputs, lack of institutional capacity to support the farmers, weak capacity of research centers to address the irrigation agriculture constraints, weak institutional capacity of cooperatives, imperfect operation of agricultural marketing system, weakness of farmers' training centre in demonstration of improved technologies, and lack of managerial skills in community based organization.
- **Environmental:** Erratic rainfall pattern, flooding, frequent frost occurrence, strong wind causing crop damage, draught incidence and others, acidity, salinity and others.
- **Social related:** Population pressure causes land fragmentation, irrigation water resource use conflict, resistance to new technologies, gender equity in decision-making, lack of adequate knowledge on irrigation technology, and lack of commitment among the local leaders and committee members.

4.13.2 Investigation of agricultural development opportunities

The existing opportunities around the project area and within the expected market catchment area of the project have to be investigated and listed. In addition to the existing circumstances, the near future plans by the community, government and private sectors need to be considered to link the new project with future and tangible opportunities. Opportunities are differing from place to place based on the natural resource availability, social, economic and infrastructure conditions of the area. Therefore, the assessment should be specific to irrigated agriculture to identify reliable opportunities for anticipated project. The opportunities will guide the agronomist in cropping pattern development to exploit the development opportunities.

Some of the opportunities relevant to irrigated farming are: Suitable climate, Land and water resource suitability; farmers' experience in irrigated agriculture, availability and accessibility of agricultural support services, established marketing infrastructure, agro-processing center availability, conducive government development policies and strategies, unskilled and skilled labour availability, urban centers distribution, access to export market route, and road and communication infrastructure. Additionally government commitment and policy direction has to be assessed in this regard.

5 CROPS SELECTION CRITERIA AND CROPPING PATTERN

5.1 CROP SELECTION CRITERIA

In general crop selection criteria and procedures for a specific irrigation project depends mainly on physical, socio-economic and priorities indicated in the policy and strategic frameworks of the country. Once the crops are selected, it will be easy to work out the most appropriate cropping pattern for the proposed project area.

In deciding the major irrigated crops to be grown in the proposed irrigation project area, the following crop selection criteria are recommended to be taken into consideration. These are:

- **Agro-climatic condition**: Crops' adaptability and suitability to a given climate;
- **Irrigation method:** Water availability and quality, crop water requirement, crop type, soil type, socio-economic and institutional capacity;
- **Need of crop diversification**: Crop compatibility and characteristics, cropping pattern, length of growing period and market demand;
- **Availability of agricultural inputs**: Types of agricultural inputs including high yielding crop varieties and agro-chemicals such as fertilizers and pesticides;
- S**uitability and role of crops for crop rotation and resistance to crop pests**: Role of the crops for soil fertility enhancement to be proposed for the scheme, prevalence of crop pests and resistance of crop to crop pests, nutritional value of crops,
- **Accessibility and transportation facilities**: Perishability nature of the crop, labour availability both skilled and unskilled, storage and transportability, road and transport facilities;
- **Capacity of public support services**: Capacity of supporting institutions for effective and efficient delivery of extension services;
- **Employment opportunity and farmers' preference**: The crops to be selected can be crops that require engaging more labour and unskilled labour and experience of smallholders' farmers for food, fodder and fiber.
- **Nutrition Values**: currently nutrition value of crops become important selection criteria to address the nutrition deficiency and human health condition

So that it is vital to take into account the factors or basic crop selection criteria mentioned above in order to select the most appropriate and potential crops for small-scale irrigation farms.

These basic selection criteria would have high degree of importance in selection of appropriate crops for market- oriented irrigated agriculture. Most importantly for hillside irrigation projects criteria like crop appropriateness for conservation farming is an additional determining factor. On the other hand, in areas where agro-processing centers are available and contractual commitment is secured then "potential for agro-processing" criterion will dominate in addition to the basic criteria mentioned above. Considering the typical characteristics of the project area and objectives certain criteria become more important and this has to be taken into account in addition to the indicated basic criteria.

The criteria for selecting the potential crops should follow multidimensional approach to cover various issues. The criteria should not be complex to exercise rather need to be simple and focused to meet the desired project objectives.

Table 5-1: Proposed crop selection criteria for different irrigation system

Criteria	Surface irrigation	Hill side irrigation	Pressurized irrigation
Agro-climate	Y	Y	
Frost resistance (in frost vulnerable areas for drip irrigation)			Y
Potential for foliage damage due to large droplet or pressure (no delicate crops)			Y
Length of growing period	Y	Y	
Water demand & quality	Y		
Objectives of the project	Y	Y	Y
Suitability to soil conditions	Y	Y	Y
Appropriateness for conservation agriculture (for alley cropping)		Y	
Morphology of the root system		Y	
Compatibility to bed width of proposed soil bund or bench terrace		Y	
Availability of High Yielding Variety	Y	Y	Y
High market value	Y	Y	Y
Potential for agro-processing and other value chain activities	Y	Y	
Potential for soil fertility maintenance	Y	Y	
Farmers' preference	Y	Y	Y
Resistance to pest infestation	Y	Y	Y
Level of perishability	Y		
Government development policy, strategies and priority	Y	Y	Y
Water resource availability	Y		
Type of Irrigation system	Y	Y	
Nutritional value	Y		
Skilled labour requirement	Y		
Employment opportunity	Y		

The list of possible crop selection criteria presented in table 5-1 should be revised to pick most relevant criteria for a given project area. Therefore, try to focus on critical factors that could indirectly address some others less important criteria.

5.2 CROP SELECTION PROCEDURES

Step 1: prepare list of crops growing in the project area agro-ecology (crop basket)

Box 5

The crop basket not necessarily include only the list of crops currently growing in the project area rather based on the agro-climatic and soil conditions all possible crops should be incorporated in the crop list. There could be potential and suitable crops, which are not included in the existing cropping patterns of the project area however, they need to be considered in new development intervention.

Step 2: Screen the above listed crops (from step 1) in terms of their potential on yield responses to irrigated farming and market conditions. The most responsive crops to irrigation and local socio-cultural conditions should be identified to concentrate on limited but appropriate crops for further refined selection on predetermined criteria.

Box 6

The number of crops to be screened can be determined by considering the command area size and/or objectives of the project; for example: for command area up to 80 ha about 5 crops; for the command area 80-140 ha up 8 different crops and for the command area with140-200 ha up to 10 different crops

Step 3: Establish crop selection criteria

Set the selection criteria for specific project and the number of criteria should be manageable to evaluate the crops listed in Step 2. Make sure that the criteria are sufficient enough to select most appropriate crops for the desired objectives of the specific SSIP under consideration.

Step 4: Weight the selection criteria value to sum total of 1

Weighted sum model (WSM) *is the best-known and simplest* multi-criteria decision analysis *(MCDA) for evaluating a number of alternatives in terms of a number of decision criteria. It is very important to state here that it is applicable only when all the data are expressed in exactly the same unit.*

By weighting the crop selection criteria from their capacity to address the overall objective of the project and specific to crop characteristics, the agronomist will be able to give more weight for criteria that have higher importance for feasibility of the project. The criteria graded closer to one has highest contribution to the expected achievement on the contrary the criteria that have closer to zero has relatively less important to the objective of the project but important to integrate in the production system.

For example, criteria like high yielding crop, suitability to soils and agro-climate will have more weight in crop selection. On the contrary, criteria like consumption habit of the community, level of perishability, and water requirement might have relatively less importance depending on the advantage of the location, water resource availability and market oriented nature of most SSI Projects. The most important thing in Weighted Sum Model is that after the distribution of weighted values of each criterion we need to make sure that their sum total should not be greater than 1.

Step 5: Establish a Matrix Table and list the proposed crops a minimum of 8-12

In order to facilitate the evaluation procedure to be carried out in step 6, need to prepare a table, which has type of criteria or their codes on the first line while the type of crops will be listed on the first column to evaluate each crop by each criterion.

Step 6: Evaluate or grade each crop from 100% for satisfaction of each criterion based on the agronomist judgment (highlighted figures) [crop 1 evaluated by criteria 1 = 80% appropriate for the command area).

Table 5-2: crop evaluation based on selection criteria

Crop	Selection criteria						Weighted value total
	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6+	
	0.3	0.1	0.4	0.05	0.2	0.05	1
Crop1	80	75	90	65	55	75	
Crop 2	75	95	55	65	80	90	
Crop 3	50	45	85	75	65	75	
Crop 4	35	80	55	45	50	60	
Crop 5	65	75	70	50	35	0	
Crop 6	55	75	65	55	45	35	
Crop 7	65	53	45	80	70	55	
Crop 8	80	75	65	85	95	70	

Our evaluation result should answer the degree of satisfaction of crop characteristics to each criterion. For instance, if crop 1 is "maize" and criteria 1 is " suitability to agro-climate condition and criteria 2 is "high yielding crop" and criteria 3 is "farmers' preference" then the performance value of crop 1 or maize when it is evaluated in terms of criterion 1, 2 and 3 is 80, 75 and 90 out of 100 or (%) respectively. The knowledge/experience of the agronomist in crop characteristics, project area climate, soils and water resource is essential to make reasonable performance evaluation for selected crops.

Step7: Multiply weighted value of each criteria (recommended in step 4) by performance evaluation values given for each crop (in step 6) to get weighted performance value, which going to add up for each crop horizontally in step 8.

Table 5-3: crop evaluation based on selection criteria

Crop	Selection Criteria						Weighted Sum (Step 8)
	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6+	
Example Calculation for Crop 1	80*0.3 = 24	75*0.1 = 7.5	90*0.4 = 36	65*0.05 = 3.25	55*0.2 = 11	75*0.05 = 3.7	
Crop1	24	7.5	36	3.25	11	3.75	85.5 (1)
Crop 2	22.5	9.5	22	3.25	16	4.5	77.7 (3)
Crop 3	15	4.5	34	3.75	13	3.75	74 (4)
Crop 4	10.5	8	22	2.25	10	3	55.7 (7)
Crop 5	19.5	7.5	28	2.5	7	0	64.5 (5)
Crop 6	16.5	7.5	26	2.75	9	1.75	63.5 (6)
Crop 7	19.5	5.3	18	4	14	2.75	63.5(6)
Crop 8	24	7.5	26	4.25	19	3.5	84.2 (2)

Note: Figures in bracket are ranking results

Step 8: Add-up the results of Step7 for each crop and prioritize (see Table 5-3)

The weighted values computed in each line for respective crop need to be add and write the results in the column, then based on the sum total results values should be ranked to identify the most responsive crops

It is suggested that number of crops for cropping pattern establishment can be determined by the command area size; (for example: for command area up to 80 ha about 5 crops; for the command area 80-140 ha up 7 different crops and for the command area with140-200 ha up to 8 different crops) the type crops can be repeated in wet and dry season according to their demand in both seasons. The indicated ranges and number of crops can be changed depending on the peculiar condition of the projects.

Step 9: Select the top crops based on the decision taken for determining the number of crops require for cropping pattern development. In this case, the first 5 crops are taken for cropping pattern development these area [crop 1, crop 8, crop 2, crop 3, and crop 5] those scored 85.5, 84.2, 77.7, 74, and 64.5 respectively.

Step 10: Reanalyze the crop mix in case if very important crop is missed in selected crop list then make some adjustment as required.

5.2.1 Proposed weighted values of selection criteria for different agro-ecologies

This guideline is proposing the tentative weight values of indicated crop selection criteria considering the potential and resource suitability of the indicated agro-ecologies of the country. These values are subject to change considering the local conditions and the importance of the selection criteria in specific project.

Table 5-4: Proposed weighted values of crop selection criteria for different agro-ecologies

	Selection Criteria	Lowland	Mid-high land	Highland
1	Agro-climate	0.15	0.1	0.1
2	Length of Growing Period	0.15	0.2	0.15
3	Water use efficiency	0.05	0.03	0.02
4	Suitability to identified soils	0.2	0.2	0.2
5	Availability of HYV	0.1	0.1	0.12
6	High market value (export & local Markets)	0.05	0.05	0.05
7	Potential for agro-processing	0.01	0.02	0.03
8	Type of irrigation system	0.02	0.02	0.03
9	Potential for soil rehabilitation	0.05	0.04	0.02
10	Farmers' preference	0.03	0.03	0.03
11	Prevalence of pest infestation	0.03	0.02	0.01
12	Topography (slope gradient)	0.1	0.1	0.1
	Sum Total	**1**	**1**	**1**

5.2.2 Example for weighted sum model crop selection method

Example (for lowland area with 1300 masl, command area 90 ha)
Let us take six selection criteria

Step 1: maize, sorghum, soybean, haricot bean, tomato, cabbage, pepper, chick pea, teff, millet, mung bean, sesame, mango, guava, banana, pineapple, cotton, tobacco.

Step 2: Maize, haricot bean, tomato, pepper, sesame, teff, millet, and banana

Step 3: Selection criteria considered

- Suitable for lowland agro-climate
- Suitable for identified soils
- Length of growing period

- High yielding potential
- Farmers' preference
- High value crops

Step 4, 5 and 6

Table 5-5: weighted value for criteria and crop evaluation for satisfaction of criteria

CROPS	Agro-climate	LGP	Suitable for identified soils	High yielding potential	High market value	Farmers' preference	
Weighted values ➡	0.2	0.2	0.2	0.1	0.2	0.1	1
Maize	80	70	75	80	85	90	
haricot bean	80	90	75	75	80	85	
Tomato	60	75	65	80	80	60	
Pepper	60	50	60	80	75	70	
Teff	65	65	65	65	60	30	
Banana	80	40	55	70	60	55	
Millet	80	70	50	35	50	30	
Sesame	75	70	50	35	70	30	

Note: the evaluation is scored out of 100%

Step 7, 8 and 9

Table 5-6: Results of weighted value multiplied by evaluation score

CROPS	Agro-climate	LGP	Suitable for identified soils	Availability of HYV	High market value	Farmers' preference	Step 8	Step 9 Ranking
Maize	16	14	15	8	17	9	79	2
Haricot bean	16	18	15	7.5	16	8.5	81	1
Tomato	12	15	13	8	16	6	70	3
Pepper	12	10	12	8	15	7	64	4
Teff	13	13	13	6.5	12	3	60.5	5
Banana	16	8	11	7	12	5.5	59.5	6
Millet	16	14	10	3.5	10	3	56.5	7
Sesame	15	14	10	3.5	14	3	59.5	6

Note: Step 7 = for maize 0.2 x 80= 16

Step 10: Selected crops for the command area are haricot bean, maize, tomato, pepper, and teff.

5.2.3 Farmers' Involvement in crop selection process

The beneficiaries or smallholder farmers in Ethiopia context shall be undertaken as partner in the entire study process and more importantly they should have inevitable role in crop selection process. During the consultation process the farmers need to be consulted their crop preference and reasoning. In this consultation three inputs from the farmers are required. These are list of crops proposed by season (for full and supplementary irrigation); reasons for proposing these crops rather than others and ranking in order of their importance. The following format can be applied or it should be incorporated in FGD checklists.

Table 5-7: Community crop preference and ranking

Supplementary irrigation season		Full irrigation season	
Name of crop	**Rank**	**Name of crop**	**Rank**
Maize	1	Tomato	3
Potato	3	Cabbage	1
Teff	5	Mung bean	4
Pepper	2	Avocado	5
Wheat	4	Banana	2

5.3 CROPPING PATTERN ESTABLISHMENT

Cropping pattern is used to denote the spatial and temporal contribution of crops on a plot of land management used to produce them (Zandrastra 1981). Cropping pattern designing is the second important element that needs to be considered after the crop selection is finalized. Therefore, effective crop selection should be substantiated with appropriate cropping pattern proposal to optimize the resources and achieving optimum farm return under intensive smallholder management.

The major determining factors for establishing cropping pattern are physical factors such as climate and soil conditions; water availability, crop water requirement, input availability, extension and research capacity and availability of communication facilities, moreover other factors like the objective of the project, market price of agricultural produce and prevalence of crop pests could be influential in designing the cropping patterns.

The cropping pattern should be developed for dry season and wet season, even if the crops in wet set season are not requiring supplementary irrigation their cropping pattern have to be shown in the cropping patterns of the project. Because the agronomist has to justify the availability of free land for succeeding crops to be cultivated under full irrigation system, in addition the project should have complete information on required inputs and farm outputs considering the wet season crops.

5.4 FACTORS TO BE CONSIDERED FOR DEVELOPING CROPPING PATTERN

In the context of the small-scale irrigation project, the following factors should get more attention in development of suitable cropping patterns:

Availability of competent irrigated agriculture projects: the existence of irrigation projects with similar objectives and computing for the same customers or market catchments should be checked and assessed. Otherwise, the demand for particular commodity will be saturated and might cause significant price reduction or in the worst case the produce could be wasted. For example if two or three SSIPs are producing large volume of cabbage or pepper beyond the capacity of the surrounding local market then the above mentioned constraints will appear. Such condition is common in many vegetables growing areas. Considering the cropping patterns and plans of the competent projects is essential to establish reliable cropping pattern for other project. Relatively less land size should be allotted for these crops

Farming system mainly for agro-pastoral: in areas where the demand for forage resource is higher and the supply of forage produce is one of the objectives of the project, the agronomist shall allocate substantial portion of the command area for forage plants. This situation might be also applicable in highlands where there is critical shortage of animal feed.

Reliable outsourcing arrangement: obviously the contractual agreement signed by SSIP implementers should be fulfilled and the required land has to be secured considering the yield per hectare of the given crops, accordingly the land to be allocated for this crop is predetermined during cropping pattern establishment based on the demand of the partners' agreements.

Example if the SSIP is agreed to supply improved seed of wheat or onion to the regional seed agency directly or through UNION then out of the total command area proportional land need to be reserved for seed production.

Vulnerable to pest infestation: the probability of recurrence of diseases or insect pests in the project area is one of the determining factor for allocating lands for given crops. The allocated land size should be within the ranges where the farmers can manage the protection activities in terms of labor and costs. Therefore, the land to be allocated to this crop is limited with the costs for protection measures.

Profit margin range: profit margin is the most important decision making factors in cropping pattern development. Most likely, the crops with relatively high profit margin should have larger land size in the cropping pattern that secure the profitability of the project.

In some special cases, if the crop is selected for food security or environmental rehabilitation objectives, then the profit margin will not be considered. Generally, the crops with high profit margin should have large land plots by taking in to account the above determinate factors.

Example 1: most of vegetables have relatively high profit margin, which are advantageous in land size determination under full irrigation cropping season.

Example 2: Maize seed and onion seed production has the most attractive profit margin than all other irrigable crops and required to have large size of land in the command area, however the agronomist should be confident about the availability of adequate demand and readily available customers to absorb the produced seeds and it may be necessary to increase or decrease the plots of land allotted for seed production depending on seed demands.

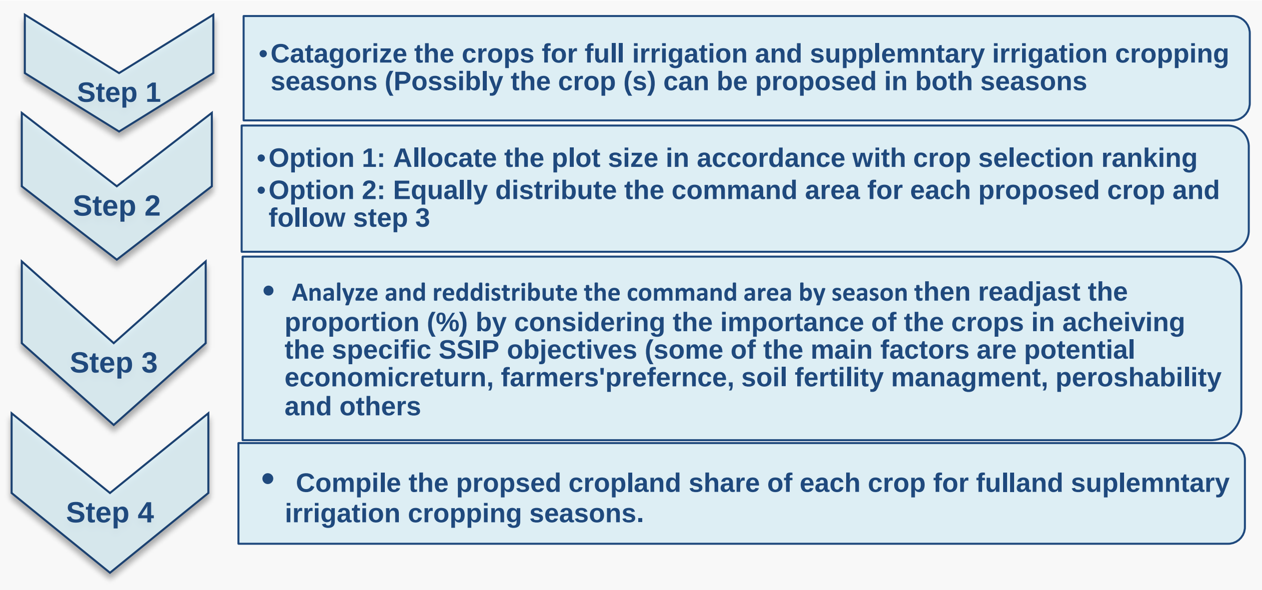


Figure 5-1: Procedures to be followed for establishing appropriate cropping patterns

5.5 PROPOSED CROPPING PATTERNS FOR DIFFERENT AGRO-ECOLOGIES

There are crops which are naturally adoptable only for certain agro-ecologies or the crop varieties can be developed through breeding adoptable to different agro-ecologies. Therefore, the crops those adopted for given agro-ecologies area used as a menu to develop suitable cropping patterns. Therefore, we have to mainly concentrate on climate, soils and crop genetic adaptation potential to determine the cropping patterns.

Accordingly, the agronomists have to properly asses and analyze the typical characteristics of the crops grown and agro-climatic conditions. In highlands, the crops are characterized by prolonged length of growing period than other areas, which need to be considered in selection and development of cropping patterns. It is advised to follow the following steps to determine the cropping pattern in line with the crop selection criteria established earlier.

Step 1: Refer the altitudinal range of the command area and monthly average rainfall from chapter II.

(Koji Kaka SSIP has 2874 m.a.s.l and average rainfall 1037mm) it is located in wet highland agro-ecology

Step 2: Suggested crops for the project are barley, wheat, faba bean, potato, cabbage, garlic (taken from crop selection section)

Step 3: Identify cash crop varieties to be included in the cropping pattern with their LGP from different sources.

For Koji kaka SSIP recommended varieties in which all varieties are checked having 110-140 days of LGP.

Cabbage: Copenhagen; **Barley**: HB 42, Setegn, Tila, HRH 485, Ardu 1260B, **Potato**: Zengena, Digemegn, Jalene; **Faba bean:** Lalo, Mosobo, Degage, Bulga, Holeta, **Wheat:** Gassay, HAR 1709, HAR 3730, Giluma **Garli**: Qoricho, Tseday, Bishoftu.

Step 4: Make sure that the LGP of the varieties are compatible for two seasons cropping system i.e. full and supplementary irrigation. Otherwise, the recommendations will not be applicable on the ground.

Step 5: The agronomist has to apply his professional knowledge and judgment based on the existing and future potential of the project area to determine the percentage or land to be allocated for each crop.

In particular, for perishable and vegetable crops, the agronomist should keep in mind that the capacity of the markets around the project area or other potential market centres have to be looked at to absorb the produced commodities from the SSIP. For example; if we allocate 25 ha of land for cabbage the estimated production will be 5000qt to 6250qt then the agronomist has to reconsider the capacity of the market centers with estimated production. If the cabbage harvest seems beyond the capacity of the markets then correction should be done by reducing the allocated hectare. Likewise, such kind of reconciliation step is important before finalizing the cropping pattern recommendations.

Table 5-8: Cropping pattern example for highland areas

S/n	Wet season					Dry Season				
	Crops	Area		Sowing date	Harvesting date	Crops	Area		Sowing date	Harvesting date
		ha	%				ha	%		
1	Barley	15	37.5	5-Jun	10-Oct	Potato	14	35	Dec. 1-15	Mar. 1-15
2	Wheat	10	25	5-Jul	17-Nov	Garlic	12	30	Dec. 1-15	Mar. 1-5
3	Cabbage	10	25	12-Jul	30-Oct	Cabbage	8	20	Nov. 25-30	Mar. 25-30
4	Faba Bean	5	12.5	15-Jun	23-Oct	Carrot	6	15	Nov 25-30	Mar. 15-20
Total		40	100				40	100		

Table 5-9: Cropping pattern example for Mid-highland areas

S/n	Wet season					Dry Season				
	Crops	Area		Sowing date	Harvesting date	Crops	Area		Sowing date	Harvesting date
		(ha)	(%)				(ha)	(%)		
1	Maize	15	50	15-May	27-Sep	Tomato	9	30	10-Jan	10-May
2	Tef	6	20	10-Jul	8-Oct	Onion	6	20	1-Jan	1-Apr
3	Haricot bean	1.5	5	10-Jun	9-Sep	Cabbage	3	10	1-Feb	5-May
4	Soybean	1.5	5	15-Jun	19-Sep	Maize	12	40	20-Dec	19-Apr
5	Pepper	6	20	15-Jul	13-Oct					
Total		30	100				30	100		

The cropping pattern for mid-highland areas are very diversified and large number of crop mixes can be proposed, due to suitability of the agro-climatic conditions for many food and cash crops. All development scenarios can be considered for development of appropriate cropping patterns for mid highlands.

The agronomist can recommend cash crops for both seasons and the export oriented scenario can also be proposed, or seed production can be alternative scenario in which the agronomist should select crop to fit the ultimate goals of these development scenarios. Once the agronomist identifies the development scenario then crop selection and cropping pattern development will be so easy. (Please refer Appendix V for development scenario briefing)

Table 5-10: Cropping pattern Example-1 for lowland agro-ecology

Crop type	Wet season				Dry season				
	Area (%)	Area (ha)	Sowing date	Harvesting date	Crop type	Area (%)	Area (ha)	Sowing date	Harvesting date
Maize	80	162	25-May	22-Oct	Maize	45	91	25-Nov	13-Apr
Banana					Banana	7	14	20-Jun	
Haricot bean	13	26	15-Jun	17-Sep	Haricot bean	30	61		
					Onion	10	20	10-Nov	9-Mar
					Tomato	8	16	15-Nov	4-Feb
Total	93	188				100	202		

Note: Example from Barada Lencha SSIP, East Haragrghe Oromiya regionwith an altitude of 1250masl

5.5.1 Cropping patterns for lowland areas with a potential of three round cultivation

In irrigated agriculture, there is a possibility to grow three times a year; mostly suitable for lowland areas. In designing three round cropping patterns where the agro-climate allows using the land and water resources efficiently, the agronomist should be aware about the schedules not to be overlapped and the sum total percentage should not be > 200% in any of the cropping period.

To check the patterns, draw a graph where all crops' planting and harvesting dates are indicated, then add the percentages vertically in busy months (October in Fig 5-9) where intensive cultivation is undertaken or with large cropping intensity. In this cropping pattern, the cropping intensity is 141.3% in October, which is less than 200% and the agronomist is safe to continue for further analysis.

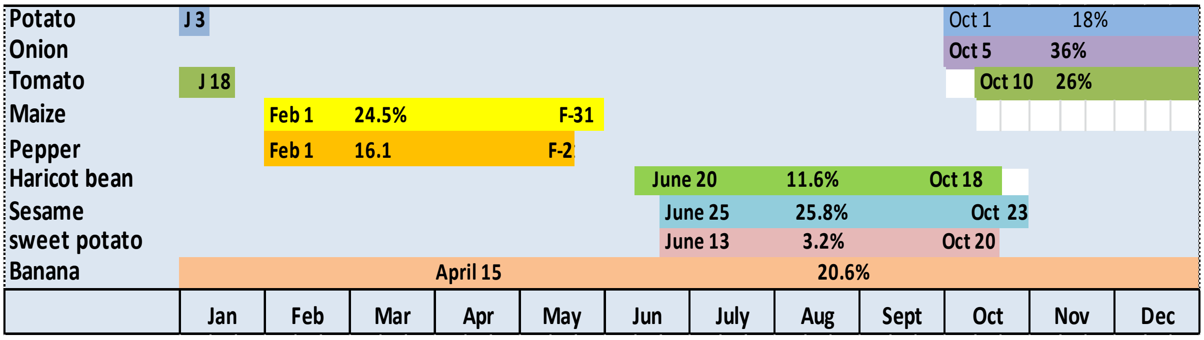


Figure 5-2: Land proportion in % and growing period of the proposed crops
Note: the numbers in black font are proposed sowing and harvesting date

If the annual sum total of the land allotted for production is more than 200% and the graph does not indicate sufficient land preparation period before planting date then our scheduling is not correct and subject to further adjustments.

More importantly, if the agronomist calculates the crop water requirement and schedules by CROPWAT 8 software it will reject the "inserted cropping pattern area data" automatically if it is greater than 200%. In addition, the software does not show whether you have sufficient time for land preparation or not therefore, we need to draw time schedule graph (Fig 5-9) to demonstrate the cropping calendar and at the same time to check the cropping intensity.

Table 5-11: Cropping pattern Example-2 for lowland agro-ecology

Crop	Area, ha	Area, %	Planting date	Harvesting date	LGP
1st Round Irrigation cropping pattern					
Potato	5.6	18.1	1-Oct	31-Dec	95
Onion	11	35.5	5-Oct	23-Feb	130
Tomato	8	25.8	10-Oct	18-Jan	110
Banana	6.5	20.6	15-Apr		365
Total	31.7	100			
2nd round Irrigation cropping pattern					
Maize	7.8	24.5	1-Feb	31-May	120
Pepper	5.1	16.1	1-Feb	21-May	110
Banana	-	-			
Total	12.9	40.6			
Supplementary Irrigation cropping pattern					
Maize Cobs	12.3	38.7	15-Mar	8-Aug	120
Haricot	3.7	11.6	20-Jun	18-Oct	120
Sesame	8.2	25.8	25-Jun	23-Oct	120
Sweet potato	1	3.2	13-Jun	20-Sep	95
Banana	-	-			
Total	24.6	79.4			

Note: Example from Dimtu SSIP located in Jimma zone of Oromiya region with an altitude of 1253 masl

5.6 CROPPING PATTERNS FOR HILLSIDE IRRIGATION

If the soil depth is shallow to moderate depth then crop with shallow root morphology should be proposed or included in the cropping patterns where vegetables and forage grasses could be good candidate for this condition like onions, cabbage, coach grass, elephant grass.

The cropping pattern should consider soil depth condition, human skill in land management, and crop type with shallow root system. If the soil depth is deep it can accommodate deep rooted perennial fruit crops then all types of irrigation system (surface and pressurized) and most of the crops can be proposed by taking into account additional crop selection criteria. High yielding and high value crops are preferable to drip and sprinkler irrigation systems because of relatively higher investment costs of the system. Therefore, the above-mentioned factors become determinant in the selection and cropping pattern development to acquire optimum project returns.

6 CROPPING INTENSITY, ROTATION AND CROP CALENDAR

6.1 CROP CALENDAR

Crop calendar of the proposed crops should indicate the seasonal schedule for major agricultural activities including land preparation, planting, weeding/ crop pest management and harvesting. The cropping calendar should be presented in dates and/or month-range. The activity schedule is necessary as input for computing crop water requirement and cropping calendar mapping such as planting and harvesting date should be precisely indicated in date and month.

Access to special equipment, draught animals or machines will increase the volume of work and time efficiency that could shorten the period for the accomplishment of the specified task. Smallholder managed semi-mechanized machinery also makes it possible to do certain tasks quickly– so as to catch critical dates in the cropping calendar.

The following considerations should be taken into account in determining the cropping calendar:

- The on-set and cessation dates of the rainfall: the information can be referred from chapter II "assessment of existing conditions" where the cropping calendar of crops grown in the project area is presented. The adjustment of cropping calendar mainly on land preparation, which is usually very pro-longed and extended, which can be shorten by recommending intensive tillage practice to save days for preceding crops to plant as early as possible. For example; in some areas, the land preparation takes 2-3 months, which require to reduce into one month to fit with the recommendable crop intensity without major side effects on crop and land health.
- Rainfall intensity can be used as indicator in reference with Chapter II Rainfall intensity analysis to identify the month where land preparation and planting could be scheduled with favorable soil moisture condition. Similarly the harvesting period or date shall be set on months with dry climate conditions

6.1.1 Indicative cropping calendar for different agro-ecologies

Table 6-1: Indicative cropping calendar for Highland Agro-ecology

Crop	Land preparation	Planting	Weeding	harvesting
Koji Kaka SSIP Oromiya (Altitude 2874 masl; Average rainfall 1040mm)				
Full irrigation	October	Early Nov	Nov - Dec	Jan-Feb
Supplementary irrigation	End of Feb	Feb-March	Feb - March	May-June
Hararu SSIP SNNPR (Altitude 2800 masl; Average rainfall 1400mm)				
Full irrigation	Oct- Early Sept	Mid – end Sept	Sept-Oct	Mid Jan -Mid Feb
Supplementary irrigation	April	Mid Apr -Mid Mar	April-May	Mid Jul – Big Aug
Beresa SIIP ARNS (Altitude 2797 masl; Average rainfall 980mm)				
Full irrigation	November	End Nov-Beg Dec	Dec - Feb	March
Supplementary irrigation	May to Early June	Early Jun-Mid July	Aug - Sept	End Sept - End Oct

Table 6-2: Indicative cropping calendar for Mid-highland Agro-ecology

Crop	Land preparation	Planting	Weeding	harvesting
Burabura SSIP ANRS: (Altitude 2085 masl; Average rainfall 1587mm) Wet Weynadega agro ecology				
Full irrigation	Dec-Jan	Jan-Early Feb	Feb-March	May-April
Supplementary irrigation	Mid April-May & June	Mid May to Mid July	May-June	mid Sept -Nov
Kebira Ilu SSIP ONRS: (Altitude 2330 masl; Average rainfall 780mm) Dry Weynadega agro ecology				
Full irrigation	December	Early November	Nov-Oct	Feb-March

Crop	Land preparation	Planting	Weeding	harvesting
Supplementary irrigation	March	Early-mid April	April-May	Sept-Oct
Megecha SSIP SNNPR: (Altitude 1813 masl; Average rainfall 1227mm) Moist Weynadega agro ecology				
Full irrigation	November	Nov-Dec	Jan-Feb	March
Supplementary irrigation	May	Jun-July	June-Aug	Oct-Nov
Aleltu SSIP ONRS: (Altitude 2300 masl; Average rainfall 1329mm) Moist Weynadega agro ecology				
Full irrigation	Mid Oct	Early November	Nov-Dec	March-April
Supplementary irrigation	Early May and June	May-June	Jul-Aug	October

Table 6-3: Indicative cropping calendar for Lowland Agro-ecology

Crop	Land preparation	Planting	Weeding	harvesting
Barada Lencha SSIP ONRS (Altitude 1250 masl; Average rainfall 706mm) Dry Kolla agro ecology				
Full irrigation	Oct &Nov	Mid to Late November	Dec-Jan	March – Mid April
Supplementary irrigation	May	Mid June	July-Aug	Sept-Oct
Guaroeshet SSIP ANRS (Altitude 1132 masl; Rainfall 921mm) Moist Kolla agro ecology				
Full irrigation	December	Late Dec	Jan-Feb	March to Apr
Supplementary irrigation	June & July	July – Early Aug	Jul- Aug	Oct-Early Nov
Dimtu SSIP ONRS (Altitude 1253 masl; rainfall 1513mm) Moist Kolla agro ecology				
Full irrigation				
Round 1	Mid-Late Dec	1-10Oct	Oct-Nov	Dec 31-end Feb
Round 2	Mid-Late Jan	Feb 1st	Feb-Mar	21-31 May
Supplementary irrigation	June	Late June		Late Sept-Oct
Bereda Lencha SSIP ONRS (Altitude 1210 masl; Rainfall 706mm) Dry Kolla agro ecology				
Full irrigation	Late Oct-Nov	Mid-End of Nov	Nov-Jan	Feb – Early Apr
Supplementary irrigation	May	Early to Mid June	July-Aug	Late Sept-Oct
Miflah SSIP TNRS (Altitude 1030 masl; Rainfall 675mm) Dry Kolla agro ecology				
Full irrigation	Oct-Nov	Late Nov-Mid Dec	Dec-Feb	April
Supplementary irrigation	May	Early June	July - Sept	October
Raya Valley SSIPs in TNRS (Altitude 1400 masl; Rainfall 673mm) Dry Kolla agro ecology				
Full irrigation	Aug	Late Sept	Oct-Dec	Feb-March
Supplementary irrigation	March	Late April-Mid May	June-July	Early Sept
Full irrigation	Sept & Oct	Oct & Nov-Dec	Nov-Jan	Late March - Apr
Supplementary irrigation	May	May –early June	May-July	Late Sept

Table 6-4: Example for crop calendar presentation (low land areas)

Crop	Dry Season				Wet season			
	Land preparation	Sowing	Weeding	Harvesting	Land prep	Sowing	Weeding	Harvesting
Maize seed					October	10-Nov		
Maize grain	Mar-Apr	17-Apr	May-June	3-Aug	Oct-Nov	15-Dec	Jan-Feb	3-May
Wheat					April-May	05-Jun	June -Aug	17-Oct
Haricot bean	May	5-Apr	May	23-Jul				
Carrot					Dec	3-Jan	Feb	12-Apr
Onion					Sept	15-Oct	Nov-Jan	26-Feb
Cabbage	June-July	10-Jul	Aug-Sept	17-Oct	Dec	10-Jan	Feb-Mar	29-Apr
Tomato	Sept - Oct	10-Oct	Oct-Dec	16-Feb				
Banana	March	22-May	every two months	16-Apr				

6.2 CROPPING INTENSITY

Cropping intensity for anticipated irrigated agriculture project required to compute based on the proposed cropping patterns. The data required to estimate the cropping intensity to be employed during implementation is seasonal area coverage in each cropping season. The following formula is used to compute cropping intensity. Once the cropping pattern is estimated, then the agronomist might require reconsider the recommended cropping patterns when the CI is significantly lower than the expectation or potential of the project area or the rivers. If the selected crops have shorter length of growing pattern and properly design of the cropping calendar by optimizing crop characteristics, farmers' efficiency and climate factors, then the crop intensity can be higher more than 200%.

$$\text{Cropping intensity (CI)} = \frac{(CA1+CA2+CA3)X\ 100}{CA} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{[1]}$$

CA_1: Cultivated Area in first cropping season
CA_2: Cultivated Area in second cropping season
CA_3: Cultivated Area in third cropping season (rarely farmers practicing for third round cultivation)

Example: Data from Table 6-4 Dimtu SSIP

CA_1: 31.7 ha; CA_2: 12.9 ha; CA_3: 24.6 ha

$$\frac{(CA1 + CA2 + CA3) \times 100}{CA} = \frac{(31.7 + 12.9 + 24.6) \times 100}{31.7} = 218\%$$

Note: Area for perennial crops should be counted once in one of the seasons, as stated in FAO publication the crop intensity determination consider the crop cycle of constituent crops in given year.

6.3 CROP ROTATION

Adoption of various mix of crops with in a systematic crop rotation is essential for maintaining stable yield levels through enriching soil fertility, improving soil stability, and breaking pest life cycle and thereby reduce crop damage, due to crop pests. The principal methods to build effective patterns are cultivating alternatively crops with different families, crops with different root morphology or effective root depth, and intercept the cropping patterns with leguminous group.

The crop rotation under smallholder managed farms should reflect the experiences of the project area and target of the projects. As recommended in many references the crop rotation with 2-3 years are desirable to attain the optimum yield and to practice the above indicated benefits of crop rotation under irrigated agriculture. FAO, website “agro-ecological land resource assessment for agricultural development planning (Technical Appendix IV)” suggested that about one-third of the command area should be covered with leguminous plants in order to enhance soil fertility and reduce crop pest infestation at the same time.

In order to plan effective crop rotation the agronomist has to undertake the following procedures:

Step 1: Identify the crops in the cropping pattern with particular emphasis on the following:

- Rotate deep and shallow rooted cropping systems;
- Include the rotation cycle leguminous and non-leguminous crops;
- Avoid crops from same crop families in order to avoid buildup of crop pests

Step 2: Note their land area size allotted for each crop
Step 3: Prepare tables with “Type of seasons” like wet season and dry season for at least five years (Year 1-5 Column). In rows different options of crop sequences or blocks will be demonstrated (5-6 blocks/crop sequences depending on the number of crops in the proposed cropping pattern).

The agronomist is expected to present these options in feasibility report. The recommendations on each row of the table below are alternative options for the farmers being followed during project implementation. For instance, in Burabure SSIP (see Table 6-6) the farmers those started their cultivation with maize in wet season can follow the first row (CS1) crop sequence; and the farmer chose to start with haricot bean he will apply the sequence on row 3 or (CS3), it proceeds with this pattern for other options. It is important that the economic return from different crop during crop ration would be able to maintain seasonal feasibility of investment.

Step 4: In each cell indicate the type of crop assigned to grow in that particular season and year

Table 6-5: Crop rotation presentation

Option in different rotation cycle	Year 1		Year 2		Year 3		Year 4		Year 5	
	Wet season	Dry Season	Wet season	Dry Season	Wet season	Dry Season	Wet season	Dry Season	Wet season	Dry Season
Crop rotation option 1	C_1WS	C_1DS	C_1WS	C_1DS	C_2WS	C_2DS	C_2WS	C_2DS	C_1WS	C_1DS
Crop rotation option 2	C_2WS	C_2DS	C_3WS	C_3DS	C_1WS	C_4DS	C_4WS	C_1DS	C_2WS	C_2DS

Note: CWS = crop for wet season; CDS = crop for dry season

<u>Example</u> for crop rotation establishment

Table 6-6: Proposed crop rotation for Burabure SSIP, Amhara NRS (Two-Year Cycle)

Crop	Year 1		Year 2		Year 3		Year 4		Year 5	
	Wet season	Dry Season	Wet season	Dry Season	Wet season	Dry Season	Wet season	Dry Season	Wet season	Dry Season
CS 1	Maize	Tomato	Maize	Tomato	Soybean	Onion	Soybean	Onion	Maize	Cabbage
CS 2	Pepper	Onion	Pepper	Onion	Teff	Cabbage	Teff	Cabbage	Haricot bean	Tomato
CS3	Haricot bean	Tomato	Haricot bean	Tomato	Pepper	Maize	Pepper	Maize	Soybean	Onion
CS 4	Teff	Tomato	Teff	Tomato	Maize	Cabbage	Maize	Cabbage	Pepper	Maize
CS 5	Soybean	Maize	soybean	Maize	Haricot	Tomato	Haricot	Cabbage	Teff	Maize

Note: detail crop rotation by land size or ha can be demonstrated for operation phase

Table 6-7: Four-Year Crop Rotation Cycle

Crop	Year 1		Year 2		Year 3		Year 4	
	Wet season	Dry Season	Wet season	Dry Season	Wet season	Dry Season	Wet season	Dry Season
CS 1	Maize	Onions	Groundnuts	Potatoes	Cabbages	Green maize	Beans	Wheat
CS 2	Beans	Wheat	Maize	Onions	Groundnuts	Potatoes	Cabbages	Green maize
CS3	Cabbages	Green maize	Beans	Wheat	Maize	Onions	Groundnuts	Potatoes
CS 4	Groundnuts	Potatoes	Cabbages	Green maize	Beans	Wheat	Maize	Onions

7 CROP WATER REQUIREMENT

Having a thorough analysis of agro-climatic parameters of the project area, established cropping intensity (chapter five), investigation of soil-plant-water relationship for each crop, the next core element to be considered in irrigation development planning and management is estimation of reference crop evapotranspiration, crop water requirement and project irrigation water requirement. Crop water requirement (CWR) is the water required by the crop for its survival, growth, development and to produce economic parts.

The water required could be supplied either naturally by precipitation, or by irrigation or in combination of the two options. The crop water requirement comprises the water lost as evaporation from the crop field, water transpired and metabolically used by crop plants, water lost during application which is economically unavoidable, but can be reduced to some extent and the water used for special operations such as for land preparation and for leaching to bring the salinity level of the soil to salt tolerance level of the crop

7.1 ESTIMATING REFERENCE CROP EVAPOTRANSPIRATION (ETO)

The influence of climate on crop water need is given by the reference crop evapotranspiration (ET_O). The ET_O is usually expressed in millimeter per unit of time (mm/day, mm/month, or mm/season) and is defined as the rate of evaporation from a large area, covered by green grass, 8 to 15 cm tall, which grows actively, completely shades the ground and which is not short of water. ET_O can be determined using various methods and these include: (i) direct methods, (ii) pan evaporimeter method and (iii) empirical methods. However, the most appropriate method of estimating ET_o is the one which generates more reliable results in determining the crop water requirement. In this connection, the direct methods, which include the water balance or hydrologic methods such as Lysimeter, field experimentation, soil water depletion or soil moisture studies and the water balance method. These methods are more reliable in generating better results, but require adequate equipment and precise measurements. However, costly, laborious and time consuming, due to they are not widely applied for estimating reference crop water requirement.

Methodologies have been developed to predict the amounts of water needed to obtain optimal crop yields based on climatological data, crop coefficients and to some extent by taking into account the influence of other factors on CWR. Different researchers in the world have been involved and developed various empirical formulae for computing CWR. The panel of experts recommended the adoption of the Penman-Monteith method as a standard in estimating ET_0 and is considered as the more accurate method to calculate ET_0 for periods of 30- day period or as short as 10 days, but not accurate as the direct methods.

Actual crop evapotranspiration involves the use of a crop factor called; crop coefficient (Kc) while computing it from reference crop (ET_O) estimated by different empirical formulae or evaporation rates from evaporimeters. The ET_C varies under different soil water and atmospheric conditions and at different stages of crop growth, geographical locations and periods of the year.

The crop Evapotranspiration is formulated mathematically as:

$$ET_C = ET_O \times K_C \qquad (2)$$

Where: ET_C = Crop Evapotranspiration

ET_O = Reference Crop Evapotranspiration

K_C = Crop coefficient

Overall, the calculation procedures of crop water requirements should follow the following steps:

(1) **Reference crop evapotranspiration (ET_O)**: Collect and evaluate available climatic and crop data; based on meteorological data available and accuracy required, select prediction method to calculate ET_0. Compute ET_O for each 30-or 10-day using mean climatic data;

(2) **Crop coefficient (kc)**: Select cropping pattern and determine time of planting, rate of crop development, length of crop development stages and growing period. Then select kc for a given crop and stages of crop development under prevailing climatic conditions;

(3) **Crop evapotranspiration (ET_C)**: Calculate ET_C for each 30- or 10- day period using the formula:

It is important to note that evapotranspiration is influenced by various factors such as climate, growing season, crop characteristics, soil characteristics and cultural practices. ET_0 can be determined using various methods and these include: (i) direct methods, (ii) pan evaporimeter method and (iii) empirical methods. However, considering the accurateness and the need to standardized the method, it is recommended herewith to use the the Penman-Monteith Computer Program based Procedures for computing crop water requirement. The details of the method in determining ET_0 are briefly discussed and presented as follows.

7.2 COMPUTER PROGRAM BASED PROCEDURES FOR COMPUTING CROP WATER REQUIREMENT

The reference crop evapotranspiration (ET_O) is usually calculated by using Crop Wat software program 8.0 that uses the FAO Penman-Monteith method. The detail procedures to compute ET_o are as follows.

Step 1: Select the most representative meteorology center for the project area or identify climate data source (make sure that the agro-ecological conditions of the meteorological center or selected site in other data sources have to be compatible with the project area agro-ecology and altitude).

Step 2: Make available long-term average (not < 20 consecutive years) climate data including minimum and maximum temperature, relative humidity, wind speed and sunshine hours. Make sure that the measurement units are compatible with CROPWAT 8.0software data units. The first priority data source is representative meteorology center or National Meteorology Agency; then can be moved to satellite based climate dataset like CFSR then New LocClim V10.1 or its latest version can be used if the first two sources are inaccessible.

If the agronomist prefer to use other data sources like New LocClim V 10.1, due to inconvenience to the available data or unavailability of representative station then the data of the selected town or meteorology site should be exported to CROPWAT 8.0 climate module data table or data in table format can be saved in working file then should be taken and inserted manually on climate module format.

Step 3: the data availed in "step 2" should be inserted in climate module/table after displaying the climate module by clicking Climate/ETo icon on the right side of CROPWAT 8.0 window. In addition to the climate data, the climate module requires information about the meteorology site: country, station name, altitude, latitude and longitude.

Step 4: Insert the rainfall, soils and crop data in respective modules to run the irrigation and crop water requirement calculation.

Step 5: The CROPWAT 8.0 software will calculate the crop water requirement and scheme irrigation requirement and irrigation schedule for the proposed crops.

The ET loss is taken as crop water use or crop water consumptive use. The ETo computation will be demonstrated with recommendable methods FAO Penman-Monteith method, which can be made with CROPWAT 8.0 software.

7.2.1 Calculation procedures of ET0 using the Penman-Monteith Equation

Background

For areas where measured data of temperature, humidity, wind and sunshine hours or radiation are available, the Penman-Monteith method is suggested for computing. The Penman-Monteith equation consists of two terms:

- the energy (radiation) term and
- The aerodynamic (wind and humidity) term

The empirical formula for the FAO Penman-Monteith combination equation is mathematically formulated as:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \qquad (3)$$

Where
ET_o reference evapotranspiration [mm day^{-1}],
R_n net radiation at the crop surface [MJ m^{-2} day^{-1}],
G soil heat flux density [MJ m^{-2} day^{-1}],
T mean daily air temperature at 2 m height [°C],
u_2 wind speed at 2 m height [m s^{-1}],
e_s saturation vapour pressure [kPa],
e_a actual vapour pressure [kPa],
$e_s - e_a$ saturation vapour pressure deficit [kPa],
D slope vapour pressure curve [kPa °C^{-1}],
g psychrometric constant [kPa °C^{-1}].

The above noted background on basic equation description is for general knowledge to grasp about the data requirement and other calculation procedures if the agronomist decided to calculate the ETo manually or by empirical equation. This guideline suggests computing the ET_o estimation by CROPWAT 8 software:

7.2.2 Input data required for ETo computation

The climate data to be used for reference evapo-transpiration computation for FAO Penman Monteith method are:

- Long-term average maximum and minimum temperature in (^{o}C)
- Long-term average relative humidity in % or Vapor pressure in Kpa
- Wind speed in kilometers per day or meters per sec
- Sunshine in hours sunshine,(optional in % day length, fraction of day length),
- Radiation to be calculated by default by the software MJ/m^{2}/day.

The above indicated climate parameters' values can be converted from one unit measurement to other instantly by the software during data entry as required.

With CROPWAT 8 software the ETo can be calculated from temperature data only when only temperature data are available.

7.2.3 Source of data

As described in Chapter II, the agronomist able to collect the climate data from meteorology centers, reliable websites, FAO data base like New LocClim V 10.1. The data from this source can be exported to CROPWAT software for analysis. On the other hand, the data from meteorology centers and other datasets like CFSR should be entered manually.

The agronomists should bear in mind that the long-term data from local meteorology centers and re-corrected climate data should be given priority to use for ET_o analysis. Moreover, the latter sources can be used as required where there is deficiency.

7.2.4 ETo computing procedures

Computing reference evapotranspiration is the primary step to calculate the crop water requirements of the proposed crops in which it can be undertaken by different software. However, the CROPWAT 8.0 software is recommendable and comprehensive method suggested to calculate CWR for the feasibility study of irrigation projects. The agronomist can collect the climate data and ETo values from the hydrologist or they have to estimate in consultation to provide consistent data

Example demonstration of ETo computation for Bereda Lencha SSIP

Location: Oromiya National regional State, East Haraghe zone, Gola Oda Wereda, Bereda Lench kebele. Geographical location: The project is located at 8.73 latitude; 41.71 longitudes and altitude: 1300 m.a.s.l.

The closest and representative meteorological station: Burka meteorological station, which is located in lowland agro-ecology

Select the data source and evaluate the completeness of the climate data: As indicated in section 8-1 step1, the climate data source should be identified based on the meteorological site characteristics similarity with the project area agro-climatic conditions. Accordingly, ***Burqa Meteorological station*** is selected as a climate data source. It is a lowland agro-ecology found near to the project area.

Once the agronomist ensured the availability of climate data then he shall arrange and insert the monthly average data in climate module of CROPWAT 8.0 software. The Evapotranspiration can be calculated in two ways based on the availability of climate data. The first option is when all the required climate data are available (Fig 7-1) while the second option is when the meteorology centers provide only temperature data (Fig 7-2). Some examples are presented below.

Option 1: the Evapotranspiration calculated by feeding all the above-indicated data including Temperature, Humidity, Wind speed and Sunshine hours as demonstrated in figure below:

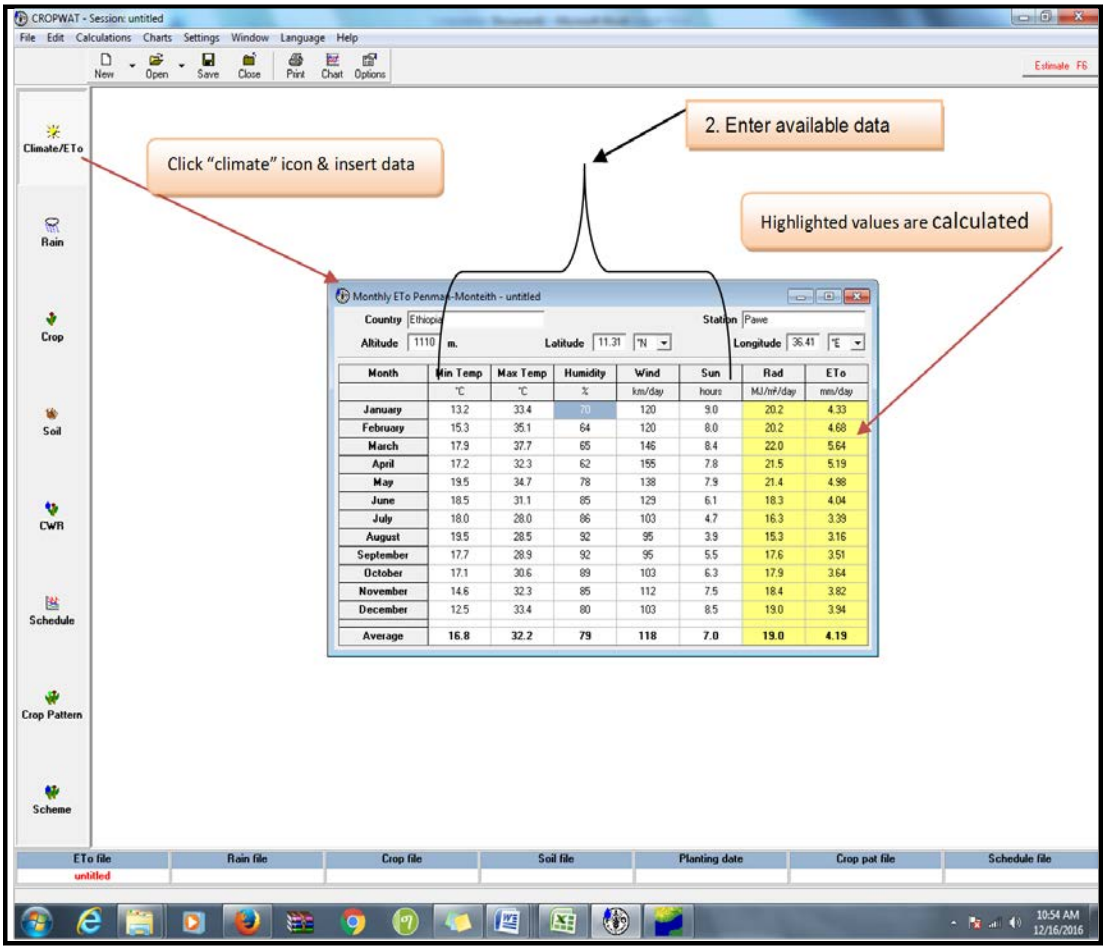


Figure 7-1: CROPWAT 8.0 window and climate module for ETo estimation

Option 2: If the meteorological station has only temperature data the CROPWAT 8.0 software can estimate other data such as humidity, wind speed, sunshine hours and radiation.

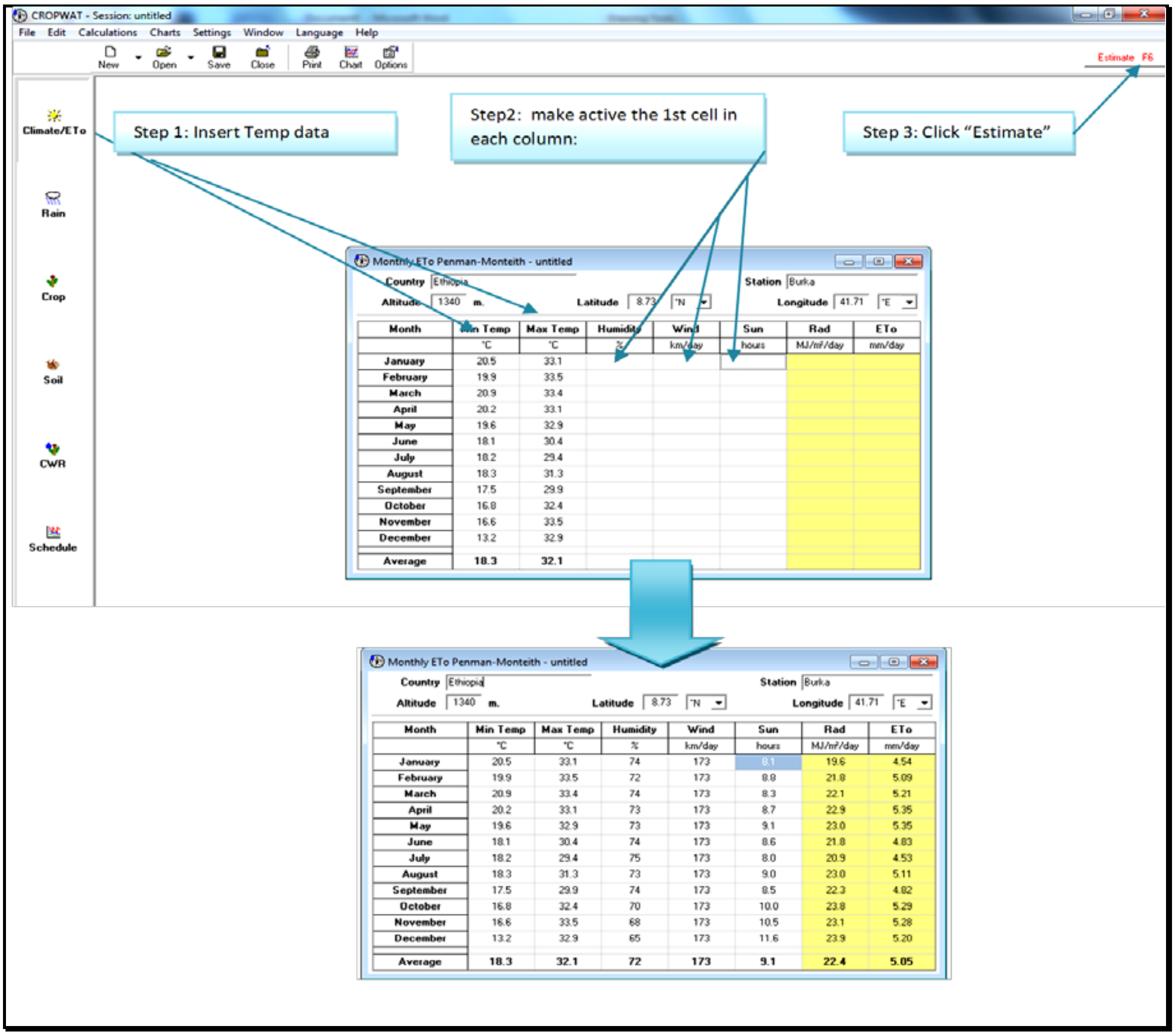


Figure 7-2: Evapotranspiration estimation from temperature data (Bereda lencha SSIP)

The CROPWAT 8 software also gives better estimated ETo values for areas with only min and max temperature data by extrapolating the missing climatic data from global database based on the location (Latitude and longitude) and altitude of the site which are specified in climate module.

7.3 EFFECTIVE RAINFALL DETERMINATION

This can be expressed as: Precipitation = ET + Runoff + deep percolation + Change in total water content. Therefore, mathematically the effective rainfall is expressed as the difference between the total rainfall and that portions of rainfall, which are lost through surface runoff, evaporation and deep percolation (Pe = P – R – ET – DP) and only the water retained in the root zone can be used by the crop plants. As principal water supply for plant growth the effective rainfall should be estimated to calculate irrigation water requirements

7.3.1 Methods for estimation of effective rainfall by CropWat 8.0 software:

Fixed percentage:

Effective rainfall is a fixed percentage of actual rainfall, being calculated according to:

$$Peff = Fixed\ percentage \times P \quad \text{[4]}$$

The fixed percentage is to be given by the user to account for the losses, due to runoff and deep percolation.

In general, the efficiency of rainfall will decrease with increasing rainfall. For most rainfall values below 100 mm/month, the efficiency will be approximately 80%. Unless and otherwise, more detailed information is available for local conditions, it is suggested to select the Option “fixed percentage” and give 80% as requested value, which is the probability of exceedance.

Dependable rainfall (FAO/AGLW formula)
Based on analysis carried out for different arid and sub-humid climates, an empirical formula was developed in the Water Service of FAO to estimate dependable rainfall, the combined effect of dependable rainfall (80% probability of exceedance) and estimated losses, due to Runoff (RO) and Deep Percolation (DP).

This formula may be used for design purposes where 80% probability of exceedance is required. The effective rainfall can be calculated using the following formula: :

Monthly step:

$$Peff = (0.6 \times P) - 10;\ for\ Pmomth < 70mm/month \quad \ldots\ldots \quad [5]$$

If the recorded rainfall amount is less than 70 mm/month, then the effective rainfall (P_e) is calculated as:
P_e = (Px0.7)-10 = (70 x 0.7) – 10 = 39 mm.

$$Peff = 0.8 \times P - 24;\ for\ Pmonth > 70mm \quad \ldots\ldots \quad [6]$$

Decadal rainfall data:

$$Peff = 0.6 \times Pdec - 10/3\ for\ Pdec \le (70/3)mm \quad \ldots\ldots \quad [7]$$

$$Peff = 0.8 \times Pdec - 24/3\ for\ Pdec > (70/3)mm \quad \ldots\ldots \quad [8]$$

USDA Soil Conservation Service:
Formula developed by USCS, where effective rainfall can be calculated using the following formulae:

Monthly step:

$$Peff = \frac{Pmonth\ (125 - 0.2 \times Pmonth)}{125\ for\ Pmonth \le 250mm} \quad \ldots\ldots \quad [9]$$

$$Peff = 125 + 0.1 \times Pmonth\ for\ Pmonth > 250mm \quad \ldots\ldots \quad [10]$$

Rainfall not considered in irrigation calculations (Effective rainfall = 0):
The rainfall data is ignored during the calculations of irrigation requirements. For example; in crop water requirement computation for spate irrigation where the contribution of rainfall in that project area is zero then this option shall be considered. Because the proper spate irrigation in arid areas is usually practicing using the runoff transported from highland area, it is not generated from project area rainfall pattern or complemented by scanty rainfall from project area. If there is a rainfall in the project area even if it is scanty then this formula will not be applicable.

In most cases, in Ethiopia the dependable rainfall (FAO/AGLWA formula) option has been preferred by planners because most of the scheme designs have considered the 80% dependable probability for runoff estimation. Among the effective rainfall estimation options incorporated in CROPWAT 8, the second option will be considered in the following presentation or illustration of effective rainfall calculation.

7.3.2 Procedures to calculate the effective rainfall with CROPWAT 8.0 software

Step 1: Open the CROPWAT window and click the Rainfall module
Step 2: choose and click on one of the five calculation options
Step 3: Insert the monthly actual rainfall data obtained from Climate data source manually
Step 4: instantly the software calculate the effective rainfall
Step 5: save in save as mode or copy the "table with headers" by using right click button and paste on Excel format.

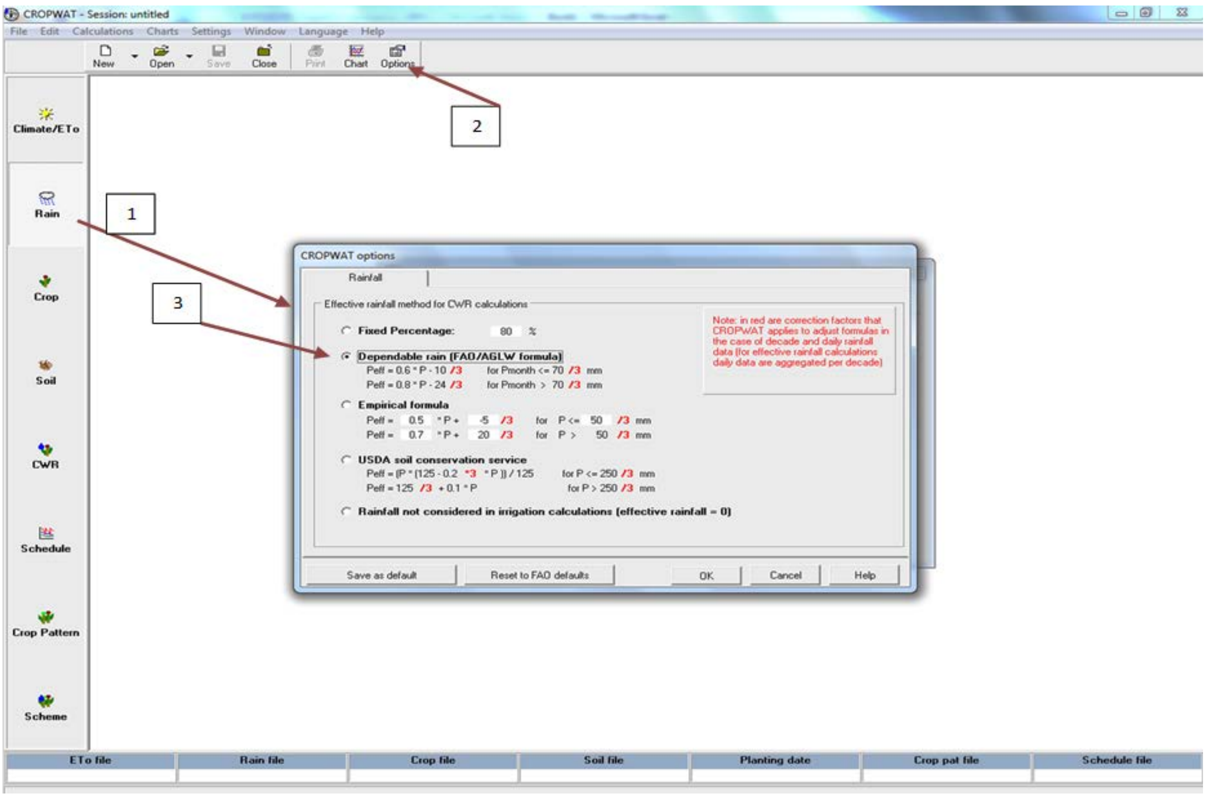


Figure 7-3: CROPWAT 8.0 window with effective rainfall estimation options display

Example 1 Effective rainfall calculation for Bereda Lencha SSI Project:

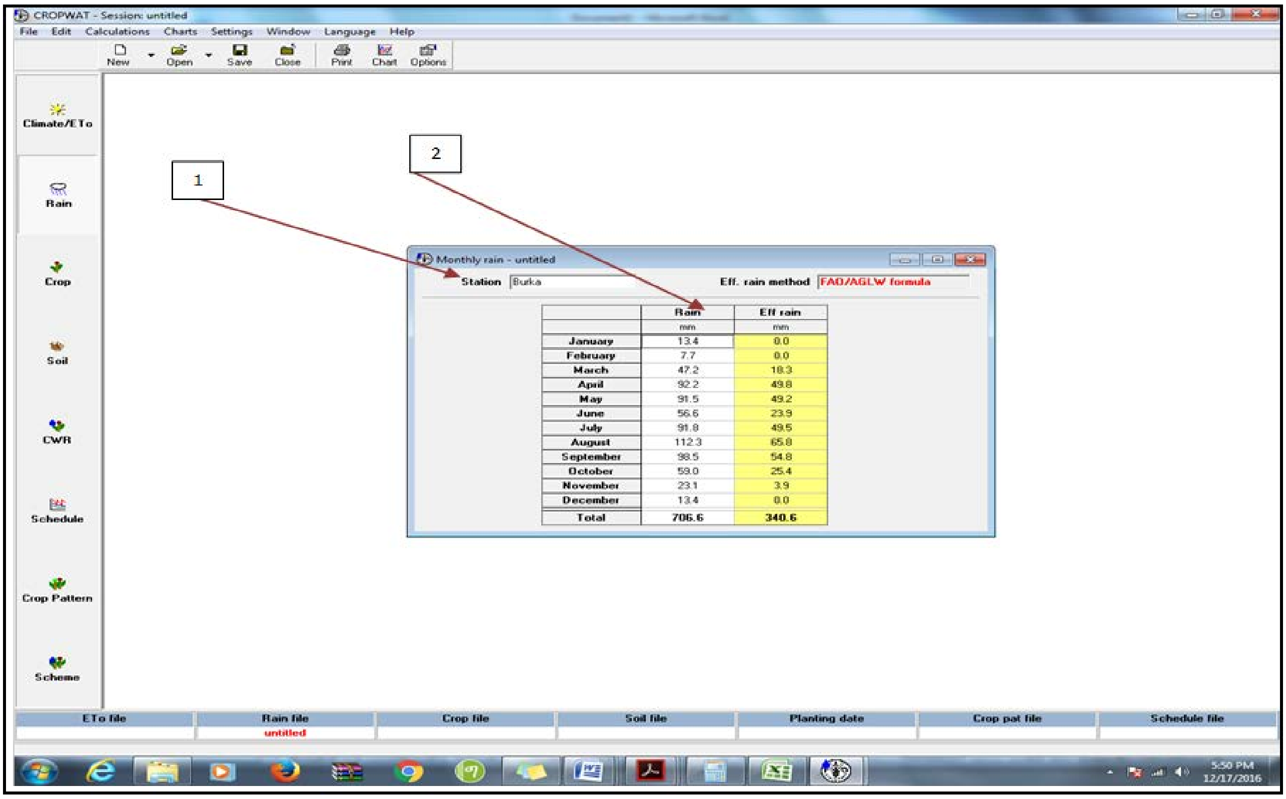


Figure 7-4: Effective rainfall estimation by FAO AGLW formula

7.4 REQUIRED CROP DATA FOR CROP WATER REQUIREMENT ESTIMATION

As a general rule, when the crop growth stages increase the water needs of a crop gradually increase and reached at the maximum during flowering and grain filling stages for most crops, whereas towards the maturity period of the crop the water demand is gradually decreasing and ET is low. During early periods of plant growth, while much of the soil surface is exposed to sun and wind, the moisture loss by evaporation predominates. At later stages of crop maturity, much of the soil surface is shaded and protected from wind. Then transpiration water requirements predominate. Crops with longer duration and with large leaf area need more water than crops with short duration and with smaller leaf area, which need less water. Deep- rooted crops will have the capacity to extract water from deep soil layers and can withstand drought effects.

After calculating the ETo, the next step is to enter the crop data into CROPWAT to enable the program to calculate the crop water requirements for proposed crops. Please, follow the steps to manage the crop data entry.

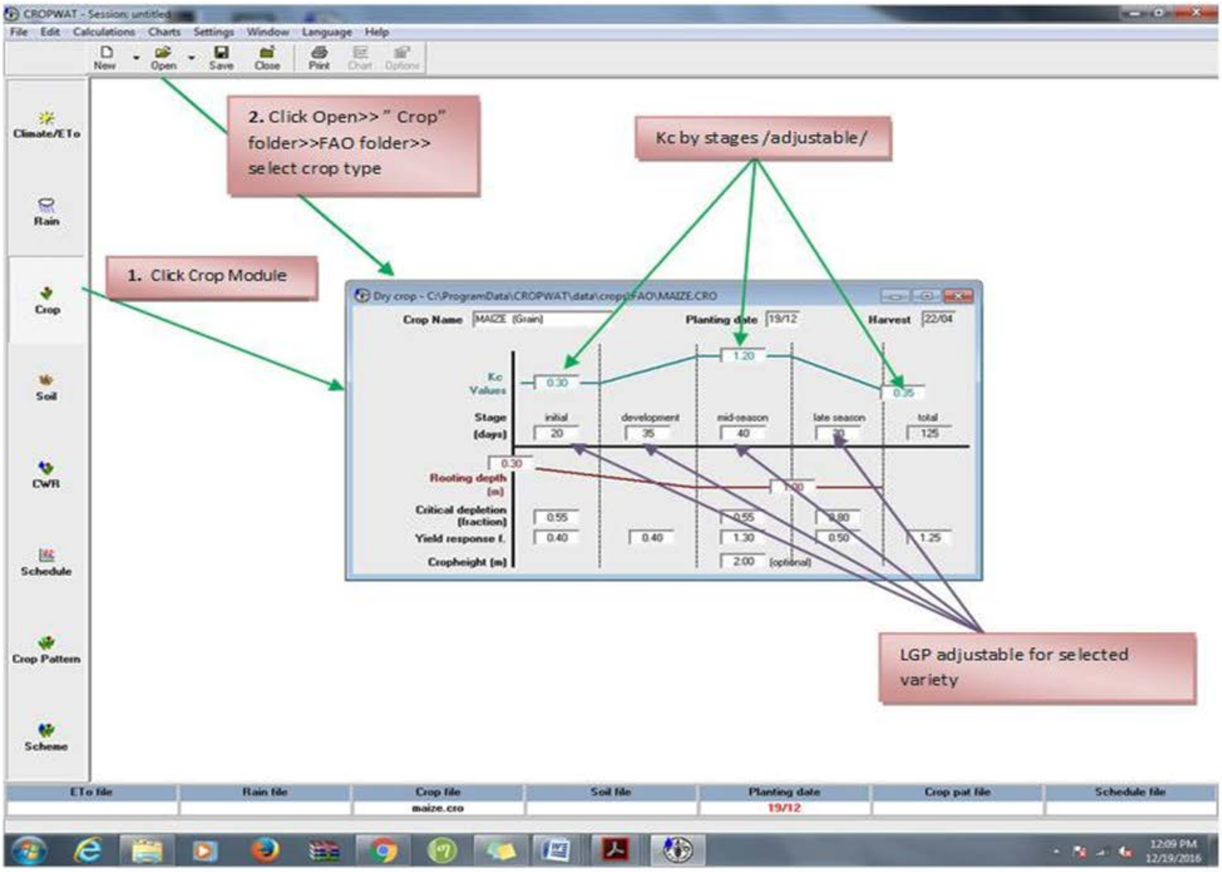


Figure 7-5: CROPWAT 8.0 Windows and Crop Module

7.4.1 Planting and harvesting date

Planting and harvesting dates are important input for estimating the crop water requirements. In case of computer program based computation, the harvesting date will be determined by the software from the given planting date and length of growing period.

Box 8

The agronomist is required to set and enter the planting date for each proposed crop and take a note for each crop to transfer the data in cropping pattern module later

Source of data: the agronomist can refer the planting date from the cropping calendar determined in previous section "cropping pattern" or cropping calendar tables.

7.4.2 Crop coefficient (Kc):

ETc is determined by the crop coefficient approach whereby the effect of the various weather conditions are incorporated into ETo and the crop characteristics into the Kc coefficient:

$$ETc = Kc \times ETo \quad \ldots\ldots [11]$$

The Kc coefficient incorporates crop characteristics and averaged effects of evaporation from the soil. For normal irrigation planning and management purposes, for the development of basic irrigation schedules, and for most hydrologic water balance studies, average crop coefficients are relevant and more convenient than dual Kc values for transpiration and evaporation from soils separately. ***There is usually close similarity in the coefficients among the members of the same crop group, as the plant height, leaf area, ground coverage and water management***

are normally similar (FAO ID Paper 56). Here it gives an indication to use the Kc values of crops in the same group having similar plant morphology characteristics.

All crops are not included in the lists of Kc value or in crop data of the FAO CropWat program therefore the Kc values can be collected from research institution where the Kc determination research has been undertaken. In Ethiopia Kc values of limited crops like teff and haricot bean are determined by Ethiopian Institute of Agricultural Research. These research outputs should be used for crop water requirement calculation in any of the methods and some of the available Kc values are presented in this guideline. See Kc values in Appendix XII and Appendix XIII.

7.4.3 Length of growth stages

It is one of the crop data can be retrieved from the Crop Wat program while opening the “crop file” from Crop-FAO folder. In most cases, the length of growing period retrieved by default is not compatible to the crop varieties usually grown in different agro-ecologies and released varieties from research institute. Under this condition the Length of growing stages displayed on Crop Module should be adjusted according to the recommended variety growing stage.

The growing period can be divided into four distinct growth stages: initial, crop development, mid-season and late season. See illustration figure 7-6 the general sequence and proportion of the stages

a. Initial stage

The initial stage runs from planting date to approximately 10% ground cover. The length of the initial period is highly dependent on the crop, the crop variety, the planting date and the climate. The end of the initial period is determined as the time when approximately 10% of the ground surface is covered by green vegetation.

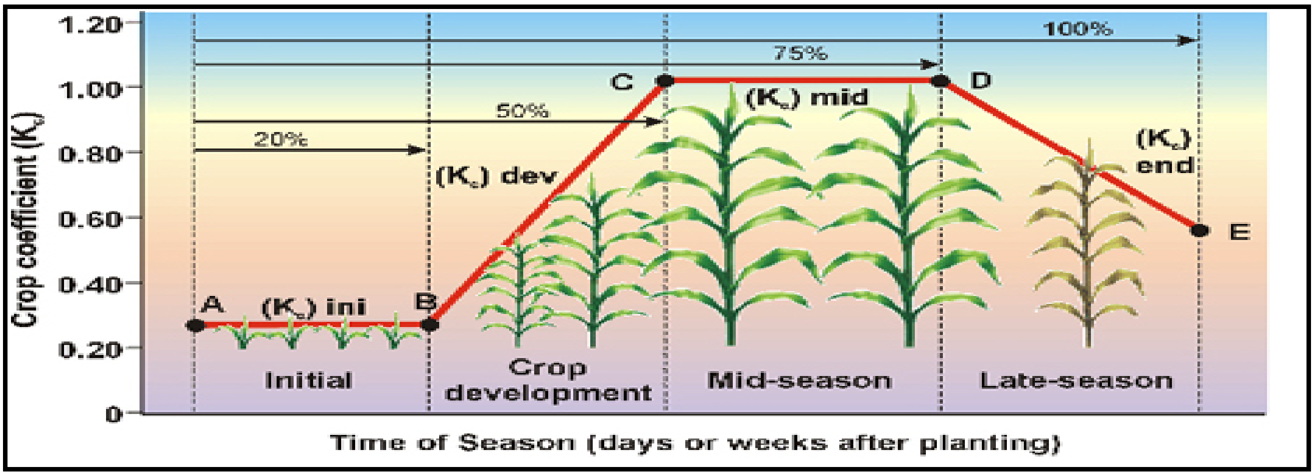


Figure 7-6: Growing stages and Kc distribution

b. Crop development stage

The crop development stage runs from 10% ground cover to effective full cover. Effective full cover for many crops occurs at the initiation of flowering. For row crops where rows commonly interlock leaves such as beans, sugar beets, potatoes and maize, effective cover can be defined as the time when some leaves of plants in adjacent rows begin to intermingle so that soil shading becomes nearly complete, or when plants reach nearly full size if no intermingling occurs. *Crop development stage ranges from 10% ground cover to 70-80% ground cover by vegetation.*

c. Mid-season stage

The mid-season stage runs from effective full cover to the start of maturity. The start of maturity is often indicated by the beginning of the aging, yellowing or senescence of leaves, leaf drop, or the browning of fruit to the degree that the crop evapotranspiration is reduced relative to the reference ETo. The mid-season stage is the longest stage for perennials and for many annuals, but it may be relatively short for vegetable crops that are harvested fresh for their green vegetation. At the mid-season stage the Kc reaches its maximum value.

d. Late season stage

The late season stage runs from the start of maturity to harvest or full senescence. The calculation for Kc and ETc is presumed to end when the crop is harvested, dries out naturally, reaches full senescence, or experiences leaf drop. (Torsten Arnold, 2006).

Table 7-1: Example: Adjustment for length of growing stage for maize BH 540 variety

Crop	LGP days determination by development stages					
	Initial	Development	Mid-season	Late season	Total	
Maize	20	35	40	30	125	LGP data from CropWat 8.0
Maize BH 540	25	40	45	34	145	Variety LGP

Table 7-2: Indicative values of the total growing period

Crop	Total Growing Period (days)	Crop	Total Growing Period (days)
Alfalfa	100 – 365	Melon	120 – 160
Banana	300 - 365	Millet	105 – 140
Barley/Oats/Wheat	120 – 150	Onion green	70 – 95
Bean green	75 – 90	Onion dry	150 – 210
Bean dry	95 – 110	Peanut/Groundnut	130 – 140
Cabbage	120 – 140	Pea	90 – 100
Carrot	100 – 150	Pepper	120 – 210
Citrus	240 – 365	Potato	105 – 145
Cotton	180 – 195	Sorghum	120 – 130
Cucumber	105 – 130	Soybean	135 – 150
Flax	150 – 220	Spinach	60 – 100
Grain/small	150 – 165	Sugar beet	160 – 230
Lentil	150 – 170	Sugarcane	270 – 365
Lettuce	75 – 140	Sunflower	125 – 130
Maize sweet	80 – 110	Tomato	135 – 180
Maize grain	125 – 180		

e. Crop rooting depth

For crop water requirement computation the crop module require data at early and late stages of growth. The module of the CROPWAT 8.0 software provides the rooting depth data as default and if the agronomists have different figures or the local research centers provide specific rooting depth for given variety then it's better to rely on local data rather than using the tabulated values. The agronomist can also refer the root depth from Appendix XIV attached in this guideline.

f. Allowable soil moisture depletion levels

Allowable soil moisture depletion (P) values are considered in crop water requirement that varies by crop types. The P value as other values is available from Appendix XIV in this guideline. The agronomist working with CropWat 8 software, the P values are displayed with other crop data on crop module and possible to adjust as required.

g. Yield response factors (Ky).

A simple, linear crop-water production function was introduced in the FAO Irrigation and Drainage Paper N_33 to predict the reduction of actual crop yield Y_{actual} under water stress. The ky values for most crops are derived on the assumption that the relationship between relative yield (Y_{actual} / Y_{max}) and relative evapotranspiration (ETc_{real} / ETc_{pot}) is linear and is valid for water deficits of up to about 50 percent or 1 – ETc_{real} / ETc_{pot} = 0.5

Values for Ky for individual growth periods and for the complete growing season have been included in the FAO Irrigation and Drainage Paper N_33. Water stress during specific growth stages Water deficit of a given magnitude, expressed in the ratio actual evapotranspiration (ETc real) and maximum (potential)

Ky is a factor to estimate yield reductions due to water stress, the Ky value can be referred from FAO ID 33 or use the default figures in CropWat program.

While running the crop module of the CropWat 8 for crop water requirement computation the agronomist should give considerable attention and checking data appropriateness of the figures inserted for sowing date and length of growing stage distribution. After the completion of the data entry the information of each crop should be saved. The print format of the crop data can be retrieved or copied by clicking the print icon and save the ASCII file in……

Make available the crop in crop module ⇨ Click print ⇨ select ASCII file ⇨ click preview icon and save where you need.

DRY CROP DATA

(File: C:\Program Data\CROPWAT\data\crops\Petu SSIP\Haricot-dry.CRO)

Crop Name: Haricot bean dry Planting date: 20/12 Harvest: 08/04

Stage	Initial	develop	mid	late	total
Length	20	30	40	20	110
Kc values	0.40	→	1.15	0.35	
Rooting depth (m)	0.30	→	0.90	0.90	
Critical depletion	0.45	→	0.45	0.60	
Yield response f	0.20	0.60	1.00	0.20	1.15
Crop height (m)		0.40			

Cropwat 8.0 Beta 20/12/16 12:10:03 PM

Figure 7-7: Crop data retrieved from CropWat 8.0 Program

Finally the crop water requirements of the proposed crops will be estimated and presented in crop water requirement format the detail information can be seen by clicking the CWR icon on the left side of the CropWat window.

The CWR information as presented in Fig 7-8 can be only copied and past by "right clicking" for reporting and presentation of the crop water requirement information of individual crops.

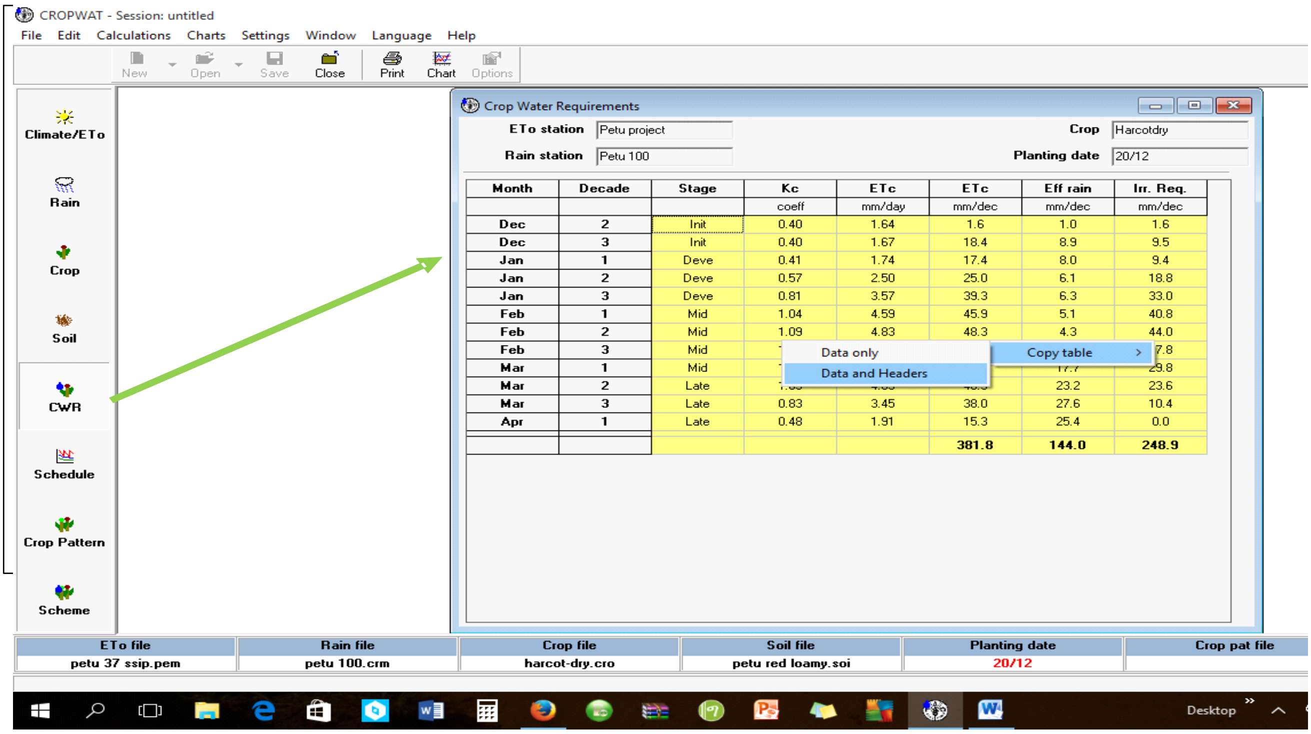


Figure 7-8: Crop water requirement of individual crop as output of crop module

7.5 SOIL DATA INPUT

The soil data is important in crop water requirement calculation for rice production only in other cases the soil data require for irrigation scheduling in which the CropWat program estimating the available water holding capacity in the root zones of selected crops. The soil module is selected by clicking on the "Soil" icon in the module bar located on the left of the main CROPWAT window. The Soil module is essentially requiring the following soil data, which should be referred from soil survey results of the project:

Total Available Water: It is the difference in water content of soil water content at field capacity and soil water content at wilting in root zone, and it should be expressed in mm/m for crop program computation.

The total available water data should be collected from soil experts after the required soil analysis results. In most of the previous studies the experts have been relied on reference /literature/ recommendations which might lead to ineffective water utilization because of water requirement exaggeration. Therefore, the agronomist and soil expert should pay attention to the TAW and other soil water parameters to be realistic.

Maximum infiltration rate: It is an important soil physical characteristic determining the water holding capacity of the soils. The data also should be sourced from the project area soil analysis results. Here the agronomist should be curious and discuss with soil expert when the result seems not appropriate for given soil type and texture, otherwise the data could mislead the output of the ***irrigation requirement of the scheme.*** Infiltration rate is expressing in mm/day, and if the data given in m/sec it should be converted to mm/day (use http://www.convertunits.com). Usually the reports are providing in mm/day.

Maximum rooting depth: Maximum rooting depth in most cases be determined by the genetic characteristics of the plant. In some cases, the root depth can be restricted by limiting layers. it is one of the determinant crop factors that can be referred from Appendix XIV for different irrigable crops.

Initial soil moisture depletion: It indicates the dryness of the soil at the start of the irrigation. This expressed as a depletion percentage from total available moisture. The computer program will calculate the initial available soil moisture by considering the moisture depletion percentage and given total available soil moisture (TAM). In most cases, it is recommended to use 50% initial soil moisture deletion.

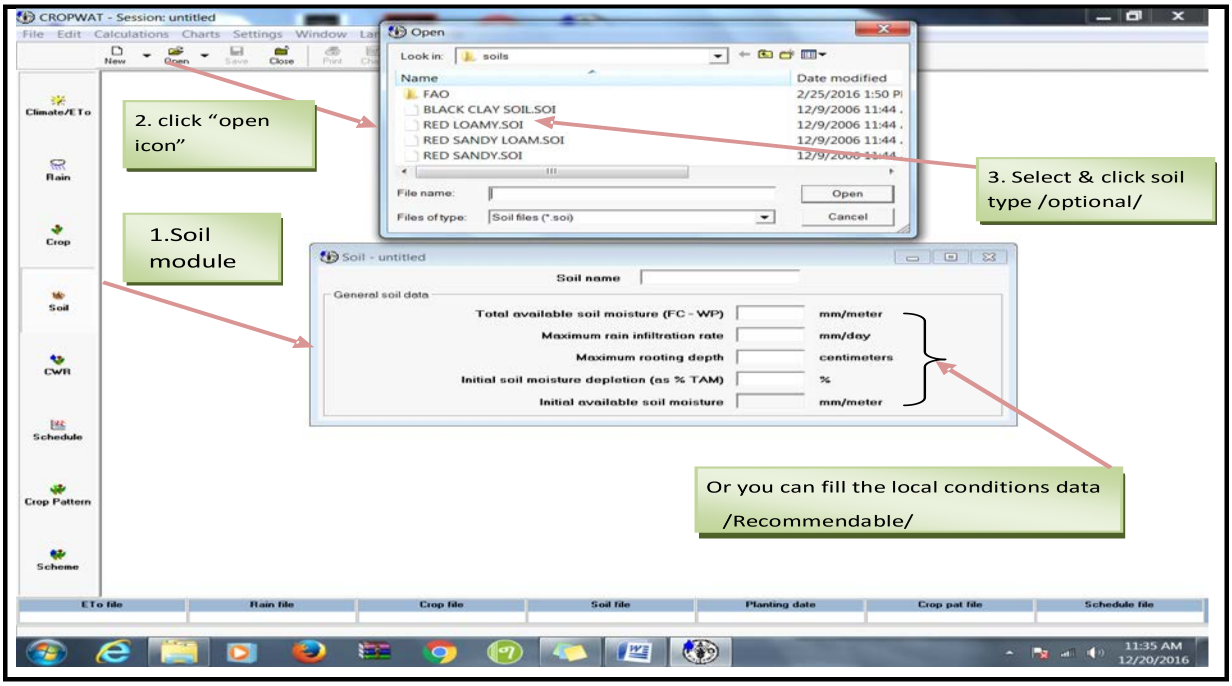


Figure 7-9: Soil data entry process in CropWat 8.0 software

Once the soil data is in place then the computer program will calculate the daily water balance to determine the irrigation schedules of each crop.

7.6 CROPPING PATTERN INPUT FOR CROP AND IRRIGATION WATER REQUIREMENTS

Cropping pattern is the basic input for irrigation water requirement computation, which needs to be completed after processing the individual crop water requirement determination. The agronomist should transfer the cropping pattern percentage from *cropping pattern section of the report* as presented in crop pattern chapter.

The user has to be aware that cropping pattern module will reject data entry when the total land area with spatial distribution become more than 200%, this indicate that at that particular date the land which you planned to cultivate is not free to accommodate additional crop. Therefore, the agronomist has to readjust the cropping calendar of the proposed crops. The discussion undertaken in cropping calendar section suggested to map the cropping calendar is important at this stage to avoid such overlapping scheduling errors. Once the cropping calendar is approved or checked in previous section, readjustment of the cropping calendar is not required.

To run the cropping pattern module in CropWat window follow these steps:

1. Click the cropping pattern icon at the left side of the CropWat window and display the cropping pattern module (step 1 Fig 7-10)
2. Give file name for cropping pattern file (use the name of the project)
3. Retrieve the crop data from saved crop date file (step 2 Fig 7-10)
4. Insert the planting data of activated crop (make sure this data should be similar with the data given in crop data file) better to have notes on planting dates of all crops. While you enter planting data the module will give the harvesting data based on the previous LGP data (step 3 Fig 7-10)
5. Enter the cropping pattern data and make sure the caution in above paragraph
6. Save the data with project name

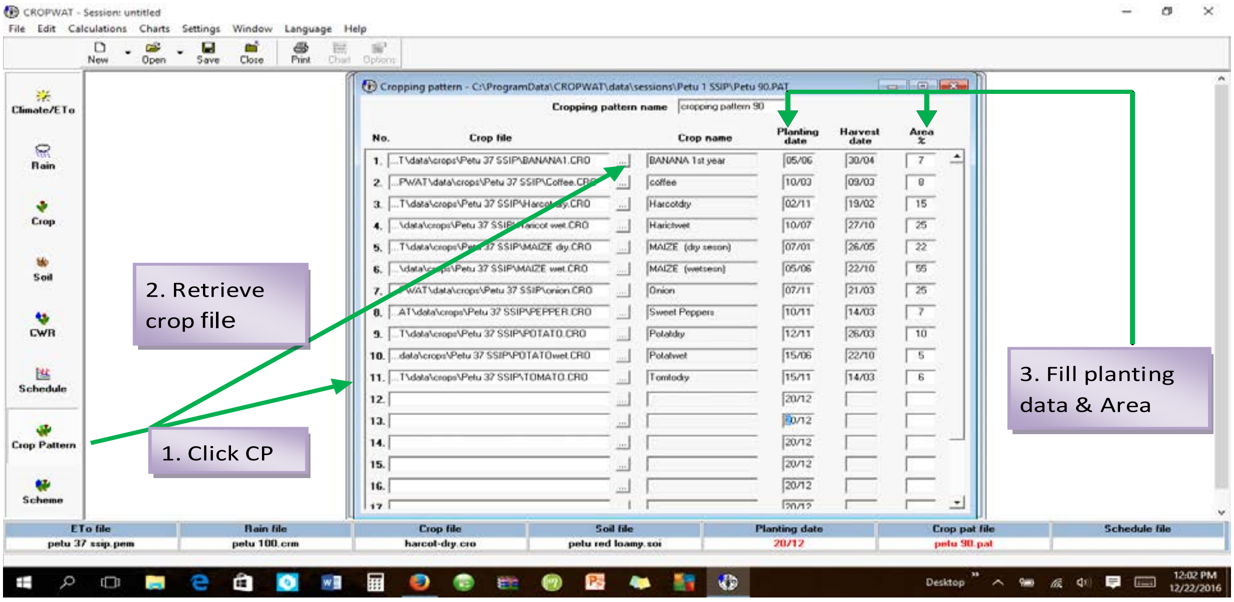


Figure 7-10: Cropping pattern data entry procedures

7.7 CALCULATING NET IRRIGATION REQUIREMENTS

Net irrigation water requirement is the quantity of water necessary for crop growth. It depends on the cropping pattern and the climate. Information on irrigation efficiency is necessary to be able to transfer NIWR into gross irrigation water requirement that consider the water losses.

Irrigation water requirement for a given period is estimated by performing a water balance study for the selected volume of the root zone area and plant canopy. The principal variables include crop water requirement, carry-over moisture at the beginning of the growing season, moisture recharge from ground and effective rainfall. The net irrigation requirement is calculated as follows:

NIR = ETc - (Pe+Wb + Ge) in mm……………………………………………………… [12]

NIR = Net irrigation requirement

Wb = Soil moisture at the beginning of the growing period

Ge = Recharge water from the nearby ground reserve

In most cases, Wb and Ge are neglected and

NIR will be = $NIR = ETc - Pe$ ………………………………………………………………. [13]

7.7.1 Net Irrigation Requirement in the Case of Salt Affected Soils

a. Surface and sprinkler irrigation system

It will be determined

$$IRn = ETcrop - R + LR$$

Where: IRn = Net irrigation requirement

ETcrop = Crop evapotranspiration

R = Water received by plant from sources other than irrigation (for example rainfall)

LR= amount of water required for leaching of salts

b. In drip irrigation system will be determined

$IRn = (ETcrop\ x\ Kr) - R + LR$ …………………………………………………………….. [14]

Where:

IRn = net irrigation requirement

ETcrop = crop evapotranspiration

Kr = ground cover reduction factor

R = water received by plant from sources other than irrigation (for example rainfall)

LR= amount of water required for leaching of salts

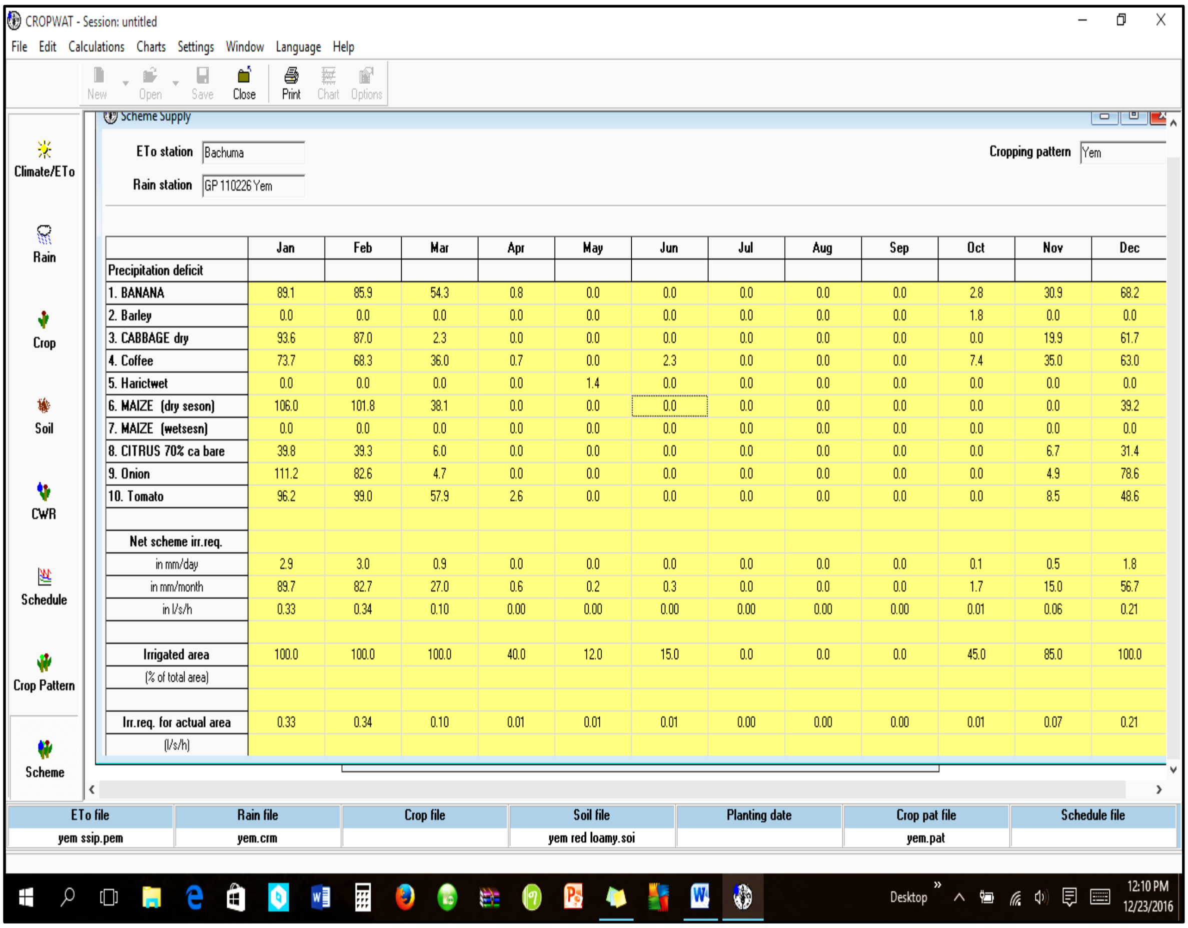
7.7.2 CropWat 8.0 software based calculation of Net Irrigation Requirement

In CropWat 8.0 computer program, the Net irrigation requirement is being computed from combined crop water requirement data of the crops which are irrigated in the same months and the results are summarized in Scheme water supply output as illustrated in Figure 7-11.

The crop data for each crop in the cropping pattern have to be inserted and saved as indicated in previous section. Based on the available climate and crop data the scheme module of the CropWat program will calculate the following outputs:

- Irrigation requirement of all crops by months
- Net irrigation requirement in mm/day, mm/month, and l/s/h
- Irrigated land area coverage in %
- Irrigation requirement for actual area in l/s/h

Please see the scheme supply cropwat output below (Fig 7-11)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation deficit												
1. BANANA	89.1	85.9	54.3	0.8	0.0	0.0	0.0	0.0	0.0	2.8	30.9	68.2
2. Barley	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0
3. CABBAGE dry	93.6	87.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.9	61.7
4. Coffee	73.7	68.3	36.0	0.7	0.0	2.3	0.0	0.0	0.0	7.4	35.0	63.0
5. Harictwet	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6. MAIZE (dry seson)	106.0	101.8	38.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.2
7. MAIZE (wetsesn)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8. CITRUS 70% ca bare	39.8	39.3	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	31.4
9. Onion	111.2	82.6	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	78.6
10. Tomato	96.2	99.0	57.9	2.6	0.0	0.0	0.0	0.0	0.0	0.0	8.5	48.6
Net scheme irr.req.												
in mm/day	2.9	3.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	1.8
in mm/month	89.7	82.7	27.0	0.6	0.2	0.3	0.0	0.0	0.0	1.7	15.0	56.7
in l/s/h	0.33	0.34	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.21
Irrigated area	100.0	100.0	100.0	40.0	12.0	15.0	0.0	0.0	0.0	45.0	85.0	100.0
(% of total area)												
Irr.req. for actual area	0.33	0.34	0.10	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.07	0.21
(l/s/h)												

ETo file	Rain file	Crop file	Soil file	Planting date	Crop pat file	Schedule file
yem ssip.pem	yem.crm		yem red loamy.soi		yem.pat	

Figure 7-11: Monthly crop water and Net irrigation requirements outputs

Further the agronomists will determine the gross water requirement of the scheme considering the project irrigation efficiency and net irrigation requirement.

7.8 DETERMINATION OF IRRIGATION EFFICIENCY

7.8.1 Setting the irrigation efficiency

Irrigation efficiency refers to the amount of water removed from the water source that is sused by the crop. This value is determined by irrigation system management, water distribution characteristics, crop water use rate, weather and soil conditions. The amount of loss depends on the efficiency of the irrigation system. There are three basic irrigation efficiency concepts.

These are:

$$Conveyance\ efficency\ (Ec)\frac{water\ received\ at\ inlet\ to\ block\ of\ fields}{Water\ released\ from\ the\ headwork} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ [15]$$

$$Distribution\ efficiency\ (Ed) = \frac{Water\ received\ at\ field\ inlet}{Water\ received\ at\ inlet\ to\ block\ of\ fieds} \quad \ldots\ldots\ldots\ldots\ [16]$$

$$Application\ efficiency\ (Ea) = \frac{Water\ stored\ in\ the\ root\ zone}{Water\ received\ at\ field\ inlet}$$

$$Project\ effiœincy\ (Ep) = Ec\ \times Ed\ \times Ea) \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ [17]$$

In consultation with the irrigation engineer about the designed structures and their efficiency, the agronomist and the engineers should jointly set the conveyance, distribution and field efficiencies.

Table 7-3; Conveyance, field canal and field application efficiencies (Adapted from: FAO, 1992)

1	**Conveyance efficiency (Ec)**	**Efficiency**
1.1	Continuous supply with no substantial change in flow	0.9
1.2	Rotation supply in projects of 70-300 ha, with effective water management	0.65 – 0.70
2	**Field canal efficiency (E_d)**	
2.1	Blocks larger than 20 ha	
	Unlined	0.8
	lined or piped	0.9
2.1	Blocks up to 20 ha :	
	Unlined	0.7
	lined or piped	0.8
3	**Field application efficiency (Ea)**	
3.1	Surface methods	
	light soils	0.55
	medium soils	0.7
	heavy soils	0.6
	Graded border	0.6-0.70
	Basin and level border	0.60-0.80
	Contour ditch	0.50-0.55
3.2	Sprinkler :	
	hot dry climate	0.6
	moderate climate	0.70-0.60
	humid and cool	0.8

Source: FAO-SFAR Irrigation Manual 2006

Example for project efficiency: Based on Yem SSIP database located in SNNPR, Bench Maji zone in Bachuma wereda (the conveyance and distribution structures are lined with furrow irrigation application method)

Given:

Conveyance efficiency Ec = 95%;

Distribution efficiency Ed = 85% and

Field application efficiency Ea = 60%

Project efficiency refer (equation 10.9.2 a)

= 0.95 x 0.85 x 0.60

= 0.48 or 48%

7.9 GROSS IRRIGATION WATER REQUIREMENT

It is the net irrigation requirement plus water distribution and application losses in the irrigation system. This can be determined at the outlet head or canal head regulator for calculating the design discharge capacity of the main off taking canal. The losses generally depend upon lined network or unlined network, the surface area and the ground percolation.

The agronomist expected to calculate the gross irrigation requirement considering the project irrigation efficiency.

7.9.1 Gross irrigation water requirement (GIR) estimation

The gross irrigation requirement is computed based on the net irrigation requirements and proposed project and field application efficiency depends on the purpose of the computation.

If the focus of the analysis is to get the gross requirement at project level then the formula will be:

$$GIR = NIR/Ep \quad \text{[18]}$$

If the gross irrigation requirement at field level is required then the field application efficiency will be considered for computation:

$$GIR = NIR/Ea \quad \text{[19]}$$

This formula mainly applied at operation and implementation level to compute various parameters at field level.

Table 7-4: Gross Irrigation Requirement computation based on Cropwat 8.0 scheme supply outputs

Precipitation deficit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1. BANANA 1st year	88.9	85.7	54	0.8	0	0	0	0	0	2.7	30.7	68
2. Barley	0	0	0	0	0	0	0	0	0	1.8	0	0
3. CABBAGE	92.6	86.4	2.4	0	0	0	0	0	0	0	19.9	61.3
4. Coffee	73.9	68.5	36.1	0.8	0	2.3	0	0	0	7.4	35	63.1
5. Haricot bean	0	0	0	0	1.4	0	0	0	0	0	0	0
6. MAIZE (dry season)	105.5	101.4	37.7	0	0	0	0	0	0	0	0	39
7. MAIZE (wet season)	0	0	0	0	0	0	0	0	0	0	0	0
8. MANGO	88.6	81	43.8	1.8	0	0	0	0	0	14.8	48.1	76.9
9. Onion	110.4	82.5	4.9	0	0	0	0	0	0	0	4.8	78
10. Tomato	96.3	99.1	58	2.8	0	0	0	0	0	0	8.5	48.6
Net scheme irr.req.												
in mm/day	3	3.1	1	0	0	0	0	0	0	0.1	0.6	2
in mm/month	94.2	86.7	30.8	0.8	0.2	0.3	0	0	0	3.2	19.1	61
in l/s/h	0.35	0.36	0.11	0	0	0	0	0	0	0.01	0.07	0.23
Irrigated actual area %	100	100	100	50	12	15	0	0	0	55	85	100
Irr.req. for actual area in l/s/h	0.35	0.36	0.11	0.01	0.01	0.01	0	0	0	0.02	0.09	0.23
Pro. efficiency (Ep)	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
GIR (irr act % / Ep) for 24hr	0.73	0.75	0.23	0.02	0.02	0.02	0	0	0	0.04	0.19	0.48

The net irrigation requirement calculated for each month should be divided by the proposed project efficiency to get the Gross Irrigation Requirement.

7.9.2 Procedures to calculate gross irrigation requirement

1. Consider the Net Irrigation requirement

Transferring the CropWat software scheme supply output by copying to excel format follow this procedure: right click & ⇒ copy table ⇒ Data and headers and paste in excel file.

2. Determine the project irrigation efficiency (see 8.8.1)
3. Divide the net irrigation requirement by project efficiency (on excel table)
4. Determine the monthly gross irrigation requirements

GIR for January = NIR/Ep = $\frac{0.35 l/s/ha}{0.48}$ = **0.73l/s/h**

8 IRRIGATION SCHEDULING

Irrigation scheduling is a planning, measuring and decision making process focused on the primary questions of how much water to apply and when and where to apply it. In practice, it is the application of irrigation water at the time of actual need of the crop depending on the availability of water over the growing period of the crop with just sufficient water to wet the effective root zone soil. These determinations may be undertaken by observation of crop water stress, weather based crop water use estimate, soil water content determination or some combinations of these. For this feasibility study guideline, brief explanation will be given on software based scheduling and with empirical formula determinations.

The on-farm irrigation water management involves the manipulation of such factors as the timing and amounts of irrigation water to be applied to the crop, the flow rates to be used, and the methods of controlling the water. The principal aim is to obtain maximum crop yield by making the most efficient and economic use of the available water. Factors such as irrigation method, irrigation system geometry (width, length, depth and spacing), slope, type of soil and topography, crop type, tillage practices, flow rates, irrigation timing and duration and availability of irrigation water need to be considered for modification of on- farm irrigation water management. The soil type and its depth and climatic conditions such as temperature, wind, humidity, and rainfall have a significant effect on the main practical aspects of irrigation, which are the determining factors to estimate how much water should be applied and when it should be applied to a given crop.

8.1 IRRIGATION SCHEDULING DEVELOPMENT

This concerns the development of schedules for the distribution of the seasonal or total irrigation requirement during the growing period of the crop. In practice it represents usually a compromise between providing the optimum application of water that matched to satisfy the varying crop water requirements over the growing season and a simplified schedule, which confirms to what can actually be managed by the farmers. In general, two types of schedules are being commonly practiced. These are: *fixed* and *flexible* schedules. A fixed schedule implies a fixed quantity of water at each application /water duty/ and at a fixed frequency, or time interval. Such schedules are usually developed to cater for the peak water demands of the crop. This system does not reflect the varying water requirements of the crop and is wasteful of water in the early and late stages of crop growth and development. The excessive water applied during the early and late stages of crop growth can cause problems of waterlogging, salinity and leaching of soil nutrients.

The flexible schedules are more common that overcomes the problems related to fixed schedules, is to keep the water duty constant but varying the irrigation interval. In this way the delivery of water to the root zone is varied in accordance with the changing water requirement of the crop and thus, over- watering at the early and late stages of crop growth is avoided. This method is, particularly well suited to deep- rooted crops such as maize, cotton and sunflowers growing in clay or fine textured soils, which have better water holding capacity. Therefore, in Ethiopian condition, flexible schedule, which vary the irrigation interval of water application to reflect the changing water requirements of the crop, but keeping the water duty constant, is perhaps the most efficient system that can be used. However, it might be difficult for farmers to apply smaller quantities of water below 40- 50 mm without having proper field water control structures and effective rainfall should be taken into consideration.

8.2 CROPWAT PROGRAM BASED DETERMINATION OF IRRIGATION SCHEDULING

Irrigation software packages are becoming more common and accessible that can be used by the agronomists to determine the irrigation schedules, in which CropWat software is considered in this guideline.

The water balance method is used for calculation of irrigation schedules in CropWat 8.0, which means that the incoming and outgoing water flows from the soil profile are monitored. For irrigation scheduling, the program requires data on crop evapotranspiration, rainfall, crop data and soil data.

The schedule module provides many options to be set by the users that can be displayed by clicking the “Option” icon before the start of irrigation schedule determination.

Steps to be followed for determining irrigation scheduling

- After computing the crop water requirement of the first crop choose the schedule module (make active)
- Click “option” icon on main menu tool bar
- Select the appropriate type of irrigation timing (presented in table 8-1 for your information)
- Select the appropriate type of irrigation application
- Adjust the irrigation efficiency as required which 70% given by default
- The setting will remain the same for all crops

Table 8-1: Irrigation timing and application alternatives for irrigation scheduling

Irrigation timing options	Irrigation application options
Irrigate at user defined interval	User defined application depth
Irrigation at critical depletion	Refill soil to field capacity
Irrigation below or above critical depletion	Refill soil below /above field capacity
Irrigate at fixed interval per stage	Fixed application depth
Irrigate at fixed depletion	
Irrigate at given ET_c reduction per stage	
Irrigate at given yield reduction	
No irrigation (rainfed)	

Source: FAO, CROPWAT 8.0 software

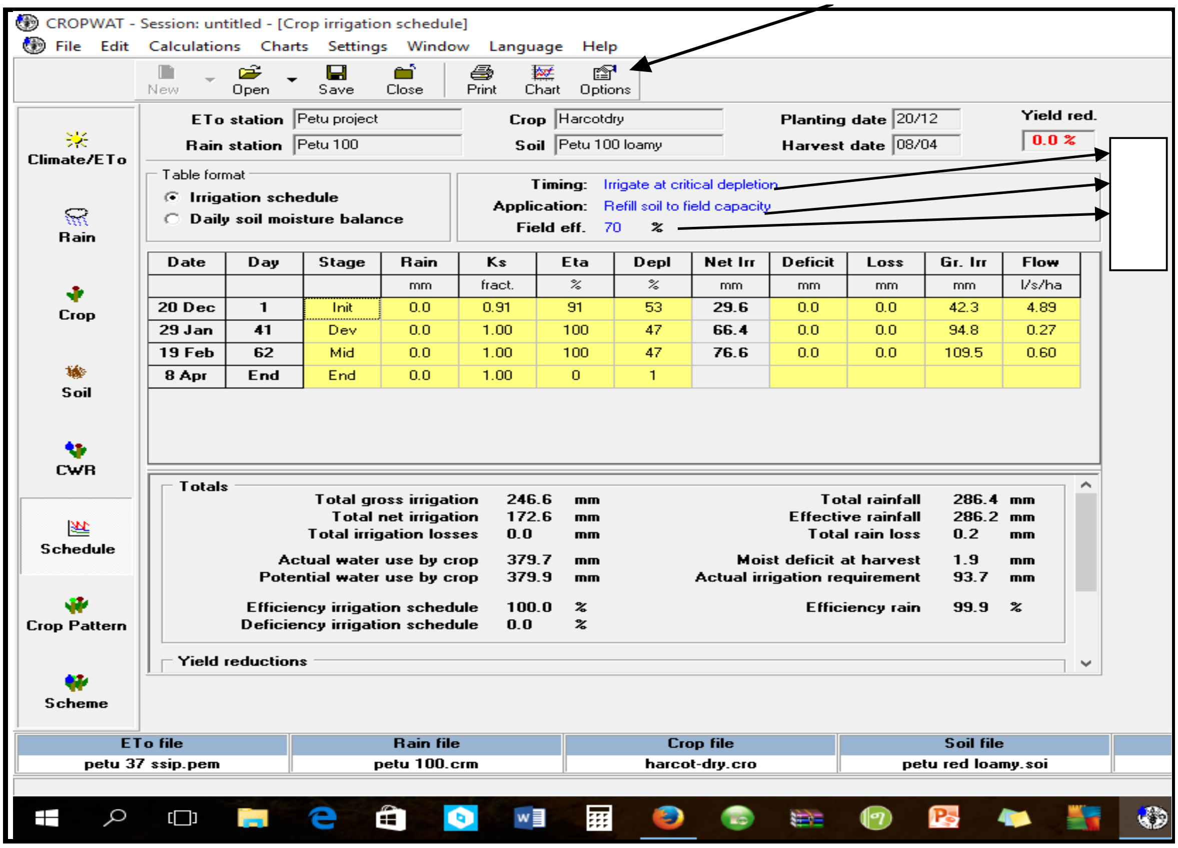


Figure 8-1: Irrigation schedule estimation sample

8.2.1 *Empirical formula based determination of Irrigation interval*

The irrigation schedule or days interval between two consecutive applications may be determined with simple formula when the agronomist decided to do manually due to different reasons, however, the cropwat software instantly calculate the depth and schedule based on daily soil moisture balance, therefore the experts not require to compute once they run the cropwat software. The irrigation interval (i) values should be rounded to zero or 5 lower case to be safe from the time fraction cumulative effects.

$$i = \frac{D \times Sa \times P}{ETc\,(peak)} \text{, in days} \qquad [20]$$

Where: i = Irrigation interval

D = Rooting depth, m

Sa= Total available soil moisture mm/m

P = fraction of available soil water (%)

ETc = Crop water requirement (peak rate)

Source of data:

D = tabulated reference (Appendix XIV) or local experience for given crop

Sa = soil laboratory results for the project area or from references based on soil texture

ETc = calculated peak rate of crop water requirements

P = given in (Appendix XIV)

8.3 CROPS GROWTH STAGES SENSITIVE TO WATER SHORTAGE

Out of the four growth stages, the mid-season stage is most sensitive to water shortage. This is mainly because it is the period of the highest crop water needs to perform the main physiological processes. If no irrigation is given at this particular growth stage, there will pronounced negative effect on the crop yield.

The least sensitive to water shortage is the late season stage. This stage of growth includes ripening and harvesting. Water shortages in these stages have especially if the crop is harvested dry only a slight effect on the yield. In the feasibility report, the critical growing stages for proposed crops should be noted and some of the critical stages for selected crops are presented in table 8-2.

Table 8-2: Critical growth stages to water deficit

Crop	Critical growth stages /periods
Maize	Flowering > grain filling > vegetative period; flowering is very sensitive if no prior water deficit
Wheat	Flowering > yield formation > vegetative period
Groundnut	Flowering > yield formation, particularly during pod setting
Potato	Period of stolonization and tuber initiation > yield formation > early vegetative and ripening
Onion	Bulb enlargement, during rapid bulb growth > vegetative period /and for seed production at flowering/
Pepper	Throughout but particularly just prior and at start of flowering
Tomato	Flowering > yield formation > vegetative period, particularly during just and after transplanting
Banana	Throughout but particularly during first part of vegetative period, flowering and yield formation
Cabbage	During head enlargement and ripening
Alfalfa	Just after cutting (and for seed production at flowering)
Citrus	Grapefruit, lemon and orange flowering and fruit setting > fruit enlargement for lemon heavy flowering may be induced by withholding irrigation just before flowering
Cotton	Flowering and boll formation
Grape	Vegetative period, particularly during shoot elongation and flowering > fruit filling
Pineapple	During period of vegetative growth
Rice	During period of head development and flowering > vegetative period and ripening
Sugarcane	Vegetative period, particularly during period of tillering and stem elongation > yield formation
Watermelon	Flowering, fruit filling > vegetative period, particularly during vine development
Bean	Flowering & pod filling, vegetative period not sensitive when followed by ample water supply
Pea	Flowering and yield formation > vegetative, ripening for dry peas
Safflower	Flowering and pod filling > vegetative
Sorghum	Flowering > yield formation > vegetative period less sensitive when followed by ample water supply
Soybean	Flowering and yield formation, particularly during pod development
Sunflower	Flowering and yield formation, particularly during bud development
Tobacco	Period of rapid growth, yield formation and ripening

Source: Adopted from the Guideline on Irrigation Agronomy, MoA, 2011

9 ESTIMATION OF AGRICULTURAL INPUTS REQUIREMENTS

Agricultural inputs are essential components of improved agricultural production system for enhancing agricultural productivity through maintaining most of the plant growth requirements. In most part of the country, input utilization in smallholder farms constrained with technical, economic and social problems such as lack of purchasing power, inefficient credit system, and lack of information on input market.

Agricultural inputs estimation is part of the agricultural development planning that determine the rates of input applications, types of inputs and quantity considered to meet the proposed optimum crop yields. During feasibility study, the agronomist should specify and quantify the essential agricultural inputs such as fertilizer, improved seeds, agro-chemicals, farm labor and machinery as required. Determination of these inputs will be a basis for input supply during implementation period and for financial analysis of the project at feasibility level of study.

This section of the guideline is focused on identification and quantifying of the agricultural inputs for the purpose of feasibility study and as reference for implementation period.

9.1 PLANTING MATERIAL REQUIREMENTS

Improved planting materials including the seeds and seedlings for proposed crops should be identified suitable for the project area. Moreover, the identified improved seed/seedling have to be quantified based on their land area coverage shown in the cropping patterns.

The agronomist should calculate the seed requirements of the proposed crops based on the seasonal allocation cropland and seed rate. The cropland shares of the given crop are taken as basis for calculation and multiply by recommended seed rate to get the seasonal seed requirements. Sum up the seasonal requirement results to compute the annual seed requirement of the given crop.

9.1.1 Issues to be considered in identification of the appropriate crop varieties

- Length of growing period of potential varieties should be compatible with recommended cropping pattern in which in most cases short-cycle seeds are preferable
- Suitability to the project area ecology or compatible to altitude ranges;
- Level of acceptance of given varieties in the project area, for instance there could be some varieties which have rejected due to different reasons. Therefore this information has to be gathered during community consultation
- Susceptibility to insect pests and diseases
- Availability of the improved seeds

9.1.2 Data required for computation of seasonal seed requirements

- Type of crop varieties recommended for the project
- Seasonal cropland size distribution, in ha
- Seed rate of the proposed varieties, kg/ha or numbers/ha

While calculating the seed requirements of the project the planner has to pay attention for unit of measurement, which usually the seed rate should be expressed in kg/ha. The vegetable seeds, which have light weight by nature, the seed rate usually expressed in gram per hectare (g/ha). In this case, the agronomist is expected to convert the seed rate to kg/ha as indicated in Table 9.1

and qt/ha for seasonal and annual requirement quantities. Thus, all seed requirement units for the recommended crops should be compatible and the result will be presented in qt/ha.

Table 9-1: Example for seed requirement calculation

Crop	Area	Rate	Unit	Seed /seedling requirement, qt
Dry season seed requirement				
Maize	91	30	kg/ha	30kg/ha X 91ha = 27.3 100
Haricot bean	61	90	kg/ha	54.9
Onion	20	3.5	kg/ha	0.7
Tomato	16	0.25	kg/ha	0.04
Banana	4	1800	seedling/ha	7200
Mango	10	270	seedling/ha	2700
Sub -Total	202	-------	------	
Wet season seed requirement				
Maize	162	30	kg/ha	48.6
Haricot bean	26	90	kg/ha	23.4
Sub -Total	**188**	**-------**	**------**	
Annual Total Seed (qt)		**-------**	**------**	**154.94**
Annual Total Seedlings				**9900**

The agronomist in the feasibility report expected to present the crop varieties recommended for the project and some basic characteristics like altitude range, planting rate and other additional information on the specific crop variety has to be discussed in this section briefly to provide adequate information and indicating the suitability of the variety for the given agro-ecological features.

9.2 SEASONAL AND ANNUAL FERTILIZER REQUIREMENTS

It believed that application of appropriate and required quantity of fertilizer has remarkable contribution to enhance the plant water use efficiency and ultimately increase the productivity of the crops. Therefore, determining the type of fertilizer and its requirement would be critical task for the agronomist.

Fertilizer recommendations are based on the results of the soil test analysiss and on the nutrient requirement of the crop to be grown. Recommendations on time and method of fertilizer application are also included. In the context of the SSIP feasibility study, the recommendations for the proposed crops have to be relying on the soil nutrient status analysis results undertaken by the soil expert. If the essential elements are found in excess amount then the agronomist requires recommending at least for the first two years.

Currently the country introduced new types of blended fertilizers which are recommended for respective soil nutrient deficient areas. This can be refereed from MoA –ATA soil mapping document or Atlas. The agronomist can identify the type of fertilizer appropriate for the project area from the proposed kebele based maps presented on regional soil nutrient status and fertilizer recommendation atlas. At this moment the Atlas for Tigray and Amhara regions are published and available for the users.

Organic fertilizers also should be recommended mainly for perennial tree fruits as required. The application rate for compost is around 4.0 t/ha for instance study indicates that the smallholder farmers are applying within the range of 1.3t/ha – 4.3 t/ha in different district of Tigray region (Hailu Araya 20210). The cost for unit of compost can be collected from the farmers because currently in different parts of the country selling of animal manure and crop residual compost become common practice and income generating activity. If the data is not available estimate the labor required for preparation of defined volume of compost and convert in terms of money assuming that ingredients are supplied from local sources.

9.2.1 Data required for determining and calculating fertilizer requirements

The following information is important for determining and calculating the fertilizer requirements at project level. The localized data on fertilizer type and approved rates which have been confirmed by research or practiced in and around the project areas are the most preferable to compute and determine the fertilizer. Therefore the agronomist has to primarily assess the research outputs on fertilizer rates to get appropriate information for recommendation. Data required:

- Cropland area to be covered
- Recommended types of fertilizer: in reference with the soil nutrient status atlas of the region the agronomist can determine the type of fertilizer recommended for the project kebele(s).

Fertilizer rates for each proposed crop: application rate should be determined from national and regional relevant references like MoA crop variety registration booklet, EIAR proceedings, and agronomy guidelines. The existing experience in application of fertilizer under extension packages could be good reference for recommendation after discussion with farmers and development agents.

9.2.2 Estimation of seasonal and annual fertilizer requirements

Based on the available information on the above mentioned issues, the agronomist should calculate the seasonal and annual fertilizer requirements that can be further utilized by economist for financial and economic analysis. Moreover, the information can be used for facilitating the fertilizer demand assessment and purchasing procedure during implementation period. Therefore, use the Excel template to calculate the seasonal and annual requirements of recommended fertilizers in Appendix XX. In areas where Lime treatment is required the quantity need to be estimated.

Table 9-2: Example for seasonal and annual fertilizer requirements

Crop	Dry season		Wet season		Lime, qt	Annual requirement			Lime, qt
	DAP, qt	Urea, qt	DAP, qt	Urea, qt		DAP, qt	Urea, qt	Total	
Maize grain			109	73	800	109	73	182	800
Pepper	68	46				68	46	114	
Groundnut	53	0	36	0	400	89	0	89	400
Onion	63	42				63	42	105	
Haricot bean	33	0				33	0	33	
Sesame			64	32	700	64	32	96	700
Total	**217**	**88**	**209**	**105**	**1900**	**426**	**193**	**619**	1900

9.3 ESTIMATING SEASONAL AND ANNUAL AGRO-CHEMICALS REQUIREMENTS

Agro-chemicals are the main inputs for crop yield increment, appropriate type of chemicals and quantity should be determined in the course, of feasibility study. Local and regional experiences in utilization of agro-chemicals mainly the pesticides have to be taken into consideration to identify environmentally friendly and effective agro-chemicals in order to reduce pesticide impacts on the environment and the people.

9.3.1 Data/information required for identification and estimation of agro-chemicals

In order to identify appropriate pesticides or other agro-chemicals for plant protection and soil condition improvement like liming, the agronomist has to undertake discussion with the farmers and experts on pest infestation history, extent of vulnerability of the project area to different common pests, type of controlling method have been applied and rate of application. This discussion and required information should be summarized in the existing agricultural situation assessment , which are good input for estimating and identification of pests and controlling measures to be considered in this section. Some of these are:

Step 1: Identify crops susceptible for pest infestation from the proposed crops: in most areas, almost all crops are potentially susceptible for different diseases, insects and weed infestation.

Step 2: Identify and list the most common diseases, insects and weeds in the project area by crop (take information from chapter “existing condition assessment”)

Step 3: Identify the controlling measures have been experienced in and around the project area and simultaneously collect data on rate of applications. (take information from chapter “existing condition assessment”)

Step 4: Summarize the information acquired from the community, development agents and different references and summarize the crop protection recommendations in the sample formats attached in Appendix VI. See the following example for clarity

Table 9-3: Sample Format for crop pests and recommended agro-chemicals

Crop	Pests	Type of chemicals	Rate of application	Other measures
Haricot bean	Bollworm	Cypermithrin 150 AI/ha	500 ml/ha	Intercrop with maize
	Weevils	Phostoxin,		Good sanitation
	Bacterial blight, anthracnose, rust			Use clean seed; crop rotation, resistant variety
Maize	Stalk borer	Cypermethrine 1%, Diazinon 10%	one pinch per plant in leaf funnel	Crop rotation
	Aphids	Rogger 40% EC	1 lt/ha with 200lt water	
		Endosulohan 35% EC	1-2 lt/ha	
	African bollworm	Endosulphan 35%	2 lt/ha	Deep plough and expose the eggs and pupa
Cabbage	Aphids	Rogger 40% EC	1 lt/ha with 200lt water	
		Endosulohan 35% EC	1-2 lt/ha	
	Cutworm	Endosulphan 35%	2 lt/ha with 200lt of water	

Crop	Pests	Type of chemicals	Rate of application	Other measures
Onion	Purple blotch	Mancozeb	3-5 kg/ha	Crop rotation, use clean seed
	Downy mildew	Captafol (80%)		
	Rust	Captafol (80%)		Tolerant varieties
	Thrips	Cypermithrin	500 ml/ha	
		Decamethrine	12.5 g AI/ha	AI (Active ingredient)

9.3.2 Estimation of seasonal and annual agro-chemicals

Estimation of agro-chemicals, particularly the pesticides would have to follow different approach compared to estimation of seed and fertilizer requirements. The later inputs are expected to apply on the whole cropland without any restriction and the calculation shall consider the entire cultivable land for calculation. In case of pesticides, the agro-chemicals are not necessarily applied for the whole cropland, which shall be depending on the size of infested cropland area and infestation intensity. In general, up to 5% infestation of the cultivated land is considered as an economic threshold in order to use pesticides for controlling. The cropland, which is infested above 5% infestation intensity is subject for pest control measurement.

The estimation of agro-chemicals is requiring a special professional effort to determine the area to be taken for calculation in order to secure adequate chemicals reserve to use as required. The agro-chemical requirement computation needs a slight modification in approach to avoid exaggerated figures which could not be practically applied during the implementation period.

Unique characteristics of this input requirement calculation compare to others are:

- Agro-chemicals requirements should not be calculated for the whole cropland (the agronomist can assume that 20-30% could be potentially affected)
- The frequency of pest occurrence is unpredictable
- Storage capacity and toxicity nature to human and animals of agro-chemicals
- High investment requirement for purchasing

Due to the above indicated peculiar conditions of agro-chemical utilization, the calculation should be estimated by excel format in soft copy available with this guideline. The final agro-chemicals requirements need to be summarized and incorporated in the feasibility study report. Please refer the example presented below.

Table 9-4: Examples for seasonal and annual pesticides requirement presentation

Crop		Dry season		Wet Season		Annual requirement
	Unit	Area (ha)	Pesticide lt	Area (ha)	Pesticide lt	Pesticide, lt
Maize seed	Kg	8.15	4.89			4.89
Maize grain	Kg	12.18	3.65	33.23	19.94	23.59
Wheat	lt			12	7.20	7.20
Carrot	Lt	12.18	3.65			3.65
Onion	Lt	16.24	9.74			9.74
Cabbage	Lt	16.24	9.74	10	6.00	15.74
Tomato	Lt	4.06	2.44			2.44
Haricot bean	Lt			14	8.40	8.40
Total		69.05	34.12	81.23	34.34	68.46

9.3.3 Labour requirement

Based on the data collected during the community consultation and key informants, the labour required for each activity of crop production should be estimated considering the improved farm managements recommended by the study. The labor requirements for the same crop in different agro-ecology could vary due to the hardship of the area to engage at full capacity. Most likely the capacity of the laborer is higher to work 8 hours in highland areas, whereas, in more arid areas the work day become shorten to 6hours. The estimated labor requirement should bring into consideration the traditional working hours of the project area. The labor or draught power requirements are expressed in person- days (MD) and Oxen days (OD). Person- days is the required number of days (1 day = 8hrs or 6hrs) to accomplish the tasks by one person. Similarly the oxen day is the number of days (1 day = 8hrs or 6hrs) required to complete the work with pair of oxen.

Table 9-5: Sample labor requirements for different crops, PD and OD

Activities	Unit	Maize	Sorghum	Sesame	H/bean	Pepper	Onion	Elephant grass
Nursery management						40	60	
Sowing	Person-days	0.5	0.5	2	0.5	12	14	16
Fertilizing	Person-days	0.5	0.5	0.5	0.5	3	0.5	
Spraying	Person-days	0.2	0.2	0.2	0.2	0.2	2	3
Thinning	Person-days	3	3		1.5	3	3	
Weeding 1	Person-days	12	12	8	10	12	10	
Weeding 2	Person-days	8	8	8	5	12	10	
Harvesting	Person-days	12	12	12	8	12	20	10
Bagging and handling	Person-days	2	2	2	2	2	2	
Loading and unloading	Person-days	2	2	2	2	2	2	2
Guarding	Person-days	10	10	6	8	10	10	
Irrigation	Person-days	12	12	6	12	12	48	
Sub-total		62.2	64.2	46.7	49.7	124.2	181.5	36
Land preparation	Oxen-days	16	12	12	8	12	20	12
	Person-days	16	12	12	8	12	20	12

10 YIELD AND PRODUCTION PROJECTION

Agricultural production estimate and projection are some of the important outputs of the agronomy feasibility study that explains the potential of the project to meet the anticipated objectives. Moreover, the crop yield estimates will be used as a major input for financial and economic analysis that determines the feasibility of the small-scale irrigation project. The yield incremental rate per year could vary depending on the genetic potential yield increment of the proposed crops and farm management efficiency.

10.1 STEPS FOR YIELD BUILD-UP

- **Step 1:** Set appropriate yield build up assumptions, which are the basis for determining the time series yield increment during the project life-span.
- **Step 2**: Fix the year "0" or existing crop yield for the proposed crops growing .
- **Step 3:** Determine or schedule the production year when each of the proposed crop can achieve the optimum yield or reaching at full development stage. The crops will attain the optimum yield at different production years depends on the existing yield performance and potential of the crops.
- **Step 4:** Identify the production year when perennial crops are starting production and optimum yield to be attained (applicable for perennial crops)
- **Step 5**: Propose relevant yield build-up method for each crop for the life-span of the project
- **Step 6:** Calculate the yield at each cropping year for 5-7 years by considering the yield increment potential of the crops under improved farm management that gradually increases due to human skill efficiency and input utilization accuracy.

10.2 YIELD BUILD-UP ASSUMPTION

The following assumptions or considerations required to develop appropriate annual yield increment based on the local conditions of the project area and objectives of the project.

- Existing crop productivity performance of the proposed crop without project intervention
- Yield achieved through improved practices in the project area. If the project area has experience irrigated agriculture then the maximum yield obtained in this project need to be considered
- Farmers' exposure and capacity to practice improved irrigated farming and use of improved agricultural inputs
- Comprehensive technical support from wereda and kebele agricultural office experts
- The effectiveness of agricultural input supply system and availability of effective credit facility
- Farmers' commitment to practice the proposed improved farm managements

10.3 YIELD BUILD-UP METHODS

The yield build-up or projection can be undertaken indifferent ways which should be decided by the agronomist. These are:

1. Constant yield increment: by taking a fixed yield increment percentage to be calculated from the year 0 or Year 1. To determine the constant yield increment margin, calculate the yield difference between Year 0 and optimum yield at full development stage then divide for the year that takes to reach at project full development stage or the year that takes to achieve the optimum yield. The yield increment shall be done for each proposed crop.

$$Yield\ increment\ qt/ha = \frac{\text{Optimum yield (qt/ha) – Yield at Year 0 (qt/ha)}}{\text{Year takes to achieve optimum yield (Year)}} \ldots\ldots\ldots\ldots\ [21]$$

2. Incremental yield margin: the increment of the crop yield gradually increasing to attain the optimum yield and continuing with constant yield for the remaining cropping years. The yield margin increment can be determined by the agronomist from his experience considering the assumption taken in previous section (section 10.2)

10.4 YIELD BUILD-UP EXAMPLES AND FORMAT

In the project area where there is good irrigation farming system experience, active beneficiary involvement and high level of improved technology application, the optimum yield could be achieved at shorter period. In the context of the small-scale irrigation with intensive extension support the optimum yield for annual crops can be attained at 3-4 years. In case of tree fruit perennial crops the year could be extended to 7-8 years. Please refer Appendix VII to apply the sample format for presentation

Table 10-1: Yield build-up with progressive yield increment qt/ha

Crop	Projection Year								Existing yield, t/ha
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8+	
Maize grain	30	45	55	65	65	65	65	65	20
Maize seed	25	30	35	40	40	40	40	40	-
Haricot bean	12	18	24	25	25	25	25	25	7
Onion	160	200	250	270	270	270	270	270	-
Green Pepper	60	90	130	160	160	160	160	160	-
Cabbage	170	190	220	230	230	230	230	230	150
Papaya	90	110	150	200	200	200	200	200	-
Banana	120	140	180	200	200	200	200	200	-

"-" the crops do not have data for existing crop yield performance

Table 10-2: Crop yield-build with constant yield increment (qt/ha)

Crop	Projection Year						Existing yield, qt/ha
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 5-25	
Maize grain	40	48	56	64	64	64	35
Groundnut	15	23	31	39	39	39	5
Haricot bean	13	17	21	25	25	25	10
Pepper	10	13	16	19	19	19	
Onion	160	197	234	271	271	271	110
Sesame	8	11	14	17	17	17	4.5

10.5 CROP PRODUCTION ESTIMATION AND PROJECTION

Based on the yield build-up and seasonal cropland area coverage of the proposed crops, the seasonal and annual crop production will be calculated and presented to show the production trends over the project lifespan. Please refer Appendix VII and Appendix XX to apply the sample format for presentation

Annual production = Annual cropland of a given crop (ha) X Yield at respective year (qt/ha)

If the crop is cultivated in dry and wet seasons the land area of the two seasons should be added up and multiply with yield per hectare indicated in yield build up.

11 CROP BUDGET ESTIMATE

Having estimated productivity per unit of land and yield build up over the project life (chapter 11) the agronomist has to calculate crop budget in collaboration with the economist. The price data for proposed inputs should be collected from the socio-economicstudy. In calculating crop budgets, it is assumed that land and climate conditions are favorable as stipulated. Crop budget can be calculated for a hectare on annual basis over the project life.

11.1 CROP BUDGET FOR WITH AND WITH-OUT PROJECT

Crop budget computation for the project should be undertaken in consultation with economist. The crop budget includes all farm level operational costs and farm returns. All agricultural inputs need to be estimated per hectare for the projected project life.

The agronomist should develop crop budget for each proposed crops where the type of operation, materials, prices are indicated and quantified. The same approaches should be applicable for both "with" and "without" project budget estimation. Refer the templates attached in Appendix VIII for both budgets.

The crop budget shows the financial cost for producing on one hectare of land; and the gross and net returns obtained from the production of the respective crops. Net return per hectares should be calculated by deducting total cost of production from gross return.
Data required for calculation:

- Labor requirement for each operation per hectare: labour data in man-days for each labour based activity has to be set in consultation with the communities and knowledgeable farmers in the project area. The agronomist ask this question for each activity to get the labor requirement: How many farm labour /people/ can finish the given activity carried out on one hectare of land in one day? One day mean working hours prominent in the project area that could be 4 hrs, 6hrs, and 8hrs depends on the harsh climate conditions.
- Farm machinery hour cost if the project planned to use tractor drawn machineries: this data required if the agricultural machineries are accessible and beneficiaries are interested in using it, then the agronomist should include rate and cost of the service in the crop budget. The simplest way is that considering the per hectare service cost for a given activity that can be obtained from DA and farmers experienced in renting.
- Oxen-power requirement per hectare: oxen-power in days should also be estimated based on their efficiency. This estimate has to be compatible to the man-power used for land preparation excluding land clearing activity. In different parts of the country the oxen efficiency varying due to climate condition where the efficiency is reducing towards lowland areas. Accordingly there are areas where the farmers plough ¼, 1/6, and 1/8 of a hectare in one day. Then calculate the days require to practice oxen-drawn activity to complete the tasks on one hectare. To get reliable data consult the farmers during field visit
- Rate of inputs application per hectare: input rate utilization can be referred from "project area description chapter" for "without" project analysis. For "with-project" analysis refer from input requirement estimation chapter.
- Unit cost of inputs including the human and oxen-power: the input costs for each activity can be collected from financial and economic analysis study data source.
- Current price of the crop products: the output price can also be referred from financial and economic analysis study data source.

- Lump sum cost can be used for inputs or services which have difficulties to get per unit costs

Use Appendix VIII crop budget estimation Template

Table 11-1: Option 1: Crop budget estimation (example for maize)

Input	Unit	Qty	Unit Rate (Birr)	Total season cost (Birr)	Years				
		ha			1	2	3	4	5_25
Labour									
Canal clearing	PD	4	35	140	140	140	140	140	140
land clearing	PD	8	35	280	280	280	280	280	280
1st plough	PD	4	35	140	140	140	140	140	140
2nd plough	PD	4	35	140	140	140	140	140	140
Cultivation	PD	2	35	70	70	70	70	70	70
Furrowing	PD	2	30	60	60	60	60	60	60
Sowing	PD	4	30	120	120	120	120	120	120
Fertilizing Basal app	PD	4	30	120	120	120	120	120	120
Fertilizing Top dressing	PD	4	30	120	120	120	120	120	120
Irrigation	PD	32	35	1120	1120	1120	1120	1120	1120
Spraying	PD	1	35	35	35	35	35	35	35
Thinning	PD	2	30	60	60	60	60	60	60
Weeding 1	PD	8	35	280	280	280	280	280	280
Weeding 2	PD	8	35	280	280	280	280	280	280
Weeding 3	PD	6	35	210	210	210	210	210	210
Harvesting	PD	12	17	204	204	204	204	204	204
Bagging and loading	PD	3	35	105	105	105	105	105	105
Sub-total		**86**		**2704**	**2704**	**2704**	**2704**	**2704**	**2704**
Land preparation									
	OD	4	120		**480**	**480**	**480**	**480**	**480**
Other Inputs									
Seeds	kg	30	15		450	450	450	450	450
Fertilizers									
NPS	kg	100	15		1500	1500	1500	1500	1500
Urea	kg	100	13.5		1350	1350	1350	1350	1350
Pesticides	lt				750	750	750	750	750
Herbicides	lt				350	350	350	350	350
Packing materials	ETB				450	50	700	100	800
Land tax	ETB				50	50	50	50	50
Sub-total	**ETB**				**4,450**	**4,050**	**4,700**	**4,100**	**4,800**
Total cost	**ETB**				**7,634**	**7,234**	**7,884**	**7,284**	**7,984**
Miscellaneous (5%)	**ETB**				382	362	394	364	399
Grand Total cost	**ETB**				**8,016**	**7,596**	**8,278**	**7,648**	**8,383**
Yields	qt				45	50	70	80	80
Price	**Birr/qt**				**500**	**500**	**500**	**500**	**500**
Gross income	**ETB**				**22500**	**25000**	**35000**	**40000**	**40000**
Farm return	**ETB**				14,484	17,404	26,722	32,352	31,617

PD = Person days; OD = Oxen days

12 IMPROVED AGRONOMIC PRACTICES FOR THE PROPOSED CROPS

Major crop production practices with their specific recommendations for each of the proposed crop are required to discuss briefly to provide information for future implementation. In this chapter, each of the agronomic tasks is treated to indicate the content of the descriptions and points to be covered. The agronomist shall be curious on the consistency of the information with previous planning chapters.

In addition to the recommended input rates and requirements, the feasibility study requires to present briefly improved agricultural practices for the proposed crops. The following basic agricultural activities have to be addressed for each of the proposed crops. This guideline is indicating important issues to be included in the study report, which could use as reference during implementation period. In this chapter, the agronomist should briefly indicate crop description and its use, soil and climatic requirements, recommended irrigation application and improved agronomic practices, which in detail discussed below.

The agronomic data and information to be used for this chapter are available in different crop production guidelines, which are prepared in the context of Ethiopian agro-ecology and farming system conditions. The research findings and recommendations released from national and regional research centers proceedings; Ministry of Agriculture and Natural Resource crop variety registration proceedings; grass root informants and other relevant sources are some of the suggested information sources for relevant agronomic descriptions.

The following agricultural practices (but not limited to) can be recommended and each briefly discussed as guidance for the users.

Land clearing: It is a prior agricultural practices carried out after the harvest of preceding crops by burning or slashing the crop residues and stalks. This agricultural practice should be recommended to carry out just after harvesting to clear the farm plots immediately and arrange adequate time and space for crop rotation and to meet the proposed cropping intensity.

Important issues need to be included: consideration to be taken to maintain the soil fertility and soil physical conditions, farm tools/machineries to be utilized, labor requirement in man-days/ha, schedules for practicing.

Land preparation: It is a pre-planting primary tillage usually made by draught power, hoe cultivation and rarely by tractors of low-high horse power. Based on the experience of the farmers in the project area and level of efficiency in time and power drawn, the agronomist has to recommend appropriate land preparation mechanisms.

In areas, where hoe cultivation is predominant, the oxen plough is a possible land preparation system, however in areas where tse-tse fly is a constraint then low-power tractors could be proposed. The later proposal requires checking of their availability and farmers attitudes to the technology; if there is no other better alternative in the area the agronomist can propose technology dissemination programs on use of mini-tractor or walking tractor, which are appropriate for smallholder farmers. Moreover, renting of usual tractors or wheel tractor could be recommended in areas where rental service is available.

In addition to the above mention recommendations, the agronomist has to discuss or recommend the frequency of land cultivation and schedules for each proposed crop to fit to the proposed cropping intensity.

Nursery management: Predominantly seedbed preparation is an initial agronomic practice for some of the vegetables and fruit trees those require intensive management at their early growth. The agronomist should recommend that seedling nursery managements shall be undertaken in separate places out of the main irrigable field but near to water source to use the irrigable land efficiently in space and time.

Planting: The agronomist should specify the planting schedule for each proposed crop and seed/seedling rates, method of planting that might be *direct sowing or transplanting; planting spacing, depth of planting, recommended plant population per hectare and equipment to be used* (as required), the planting mechanism could be manual row planting; oxen-drawn planter, walking tractor fixed planter seed, and wheel tractor accessories. The appropriate and easily accessible planting method and equipment shall be recommended in the guideline. The information has to be consistent with previous planning chapters.

Transplanting: It is an optional planting method mostly for horticultural crops and fruit trees which maintain the recommended plant population with minimum losses at early stage. The agronomist should note about *date of transplanting, watering, cares need to be undertaking during transportation and transplanting.*

Fertilizer application: Basal and top dressing applications are most common in irrigated farming which expected from the agronomist to specify *the quantity and schedule of recommended fertilizers* for proposed crops. If split application is required the date (in days after planting date) should be indicated in this section.
If organic fertilizers are recommended in previous section, then the recommended rate, method of preparation, source of organic fertilizer should part of this section.

Irrigation: This irrigation agronomic practice is thoroughly discussed in previous chapter. However, the agronomist can summarize major findings and recommendations like *seasonal irrigation requirement, average irrigation interval in days, critical growth stage for moisture stress effect, and the requirement of* special *irrigation* like pre-planting irrigation or irrigation for soil treatment like leaching. Recommended average man-power need for irrigating per ha is important to include in this section.

Weeding: The information like how frequent weeding should be undertaken, method of weeding (hand weeding or with herbicide) and time of weeding in days after each weeding task are require to indicate in this section. Cultivation by oxen, manual or machinery to reduce weed population and pulverize soil can be elaborated in addition to above indicated activities. The best time for the removal of weeds is before they produce flowers and seeds

Disease and insect pest control: - Cultural, biological and chemical spraying methods and timing have to be explained considering economic threshold. Integrated pest control is preferable and could be recommended with appropriate and specific methods for this particular project. IPM recommendation for specific project should take in to account the availability of inputs or ingredients, farmers' experience and efficiency.

Harvesting: Method of harvesting (picking, cutting, up-rooting), type of harvesting machinery recommended and transporting mechanisms to storage facility are issues to be covered.

Threshing and winnowing: Method of threshing, places and materials to be used have to be explained.

Storage: Types of storage facilities used, storage capacity, storage disease and pests including cares to be taken have to be explained.

Other post-harvest handling: The product handling methods for crops those require additional technologies to keep the products safe for further utilization need to be recommended. This intervention is mostly important for vegetables and fruits to extend their live storage capacity. Cold room is one of the post-harvest handling technology which used for mass harvest of perishable vegetables, fruits and cut flower

Marketing: The marketing issues will be discussed in detail in socio-economy sector, however in order to give comprehensive information for users, the agronomist recommend some of the potential marketing centers for each of the proposed crop. Moreover potential partners in marketing system like UNION, Farmers' service associations, irrigation water users' association, traders, higher institutions and others could be proposed for future consideration.

13 DETERMINATION OF IRRIGATED AGRICULTURAL DEVELOPMENT INTERVENTIONS

13.1 GENERAL

The development interventions are important tools helping in realizing the intended irrigated agriculture intervention that has multifaceted benefits to the beneficiaries and communities situated in the project area and surrounding.

The auxiliary interventions could be technical, social, institutional and agronomic interventions which are relevant to on-farm crop production system. They would have critical impacts on the output of the project. All stakeholders most importantly the communities need to participate in identification of these supplementary interventions during community consultation.

The auxiliary interventions includes various activities those contribute to sustainability of the project or livelihood of the beneficiaries; among long list of the development interventions the following are meant to be appropriate for smallholder irrigation projects

Purpose: The main purpose of this section is identifying additional or supportive development interventions which are relevant to the project area irrigated agriculture constraints and opportunities required for overall sustainability of the project and benefits of the communities.

13.2 SELECTIONS OF SUPPORTING DEVELOPMENT INTERVENTIONS

Appropriate selection of supportive interventions is basic procedures to identify and propose relevant activities where the communities and stakeholders entirely involved during study period. There are two basic areas where the idea for supportive interventions could be emerged:

1. Investigated crop production constraints and opportunities

In reference with chapter 5 of this guideline, the determinant constraints of the crop production, which are categorized in agronomic, social, land resource, institutional issue groups are providing initial project/intervention requirement ideas to be suggested in this study document. Please, consider the following procedures to draw essential interventions from the identified crop production constraints.

Step 1: reanalyze the constraints and possible remedy recommendations those could be designed in sub-project formats

Step 2: reanalyze the findings investigated in exiting agricultural support service assessment chapter (chapter 6) and change the gaps into sub-project or intervention

Step 3: Combine the above indicated findings as required to integrate different development activities

Step 4: change the intervention ideas into project profile format that briefly indicates the rational, objective, includes

2. Consultation outputs and Expertise experiences

The intervention idea could be brought from the stakeholder suggestions, which can be collected during consultation session with expertise and administration staff. Moreover, the rich information background of the agronomist is important source to recommend appropriate supportive intervention.

13.3 BRIEF DESCRIPTION OF RECOMMENDED SUPPORTING IRRIGATION DEVELOPMENT INTERVENTIONS

13.3.1 Farmers' capacity building

Regular farm visit: it is a regular activity of the extension development agent expected to visit all irrigation users in each cropping season. In addition to the regular farm visits the development agents need to undertake demand or problem based visits as required to support the farmers. In order to carry out farm visit on time, the development agents should have transportation facilities and materials as appropriate. At least the agronomist can propose purchase of bicycle and gradually provide motorcycle depends on size of the project and topography of the project area.

On-farm technology demonstration: it should be suggested as a capacity building tool to improve the knowledge of the farmers for proper farm management and optimum crop yield achievement. It is the most appropriate technology dissemination mechanism using locally available technology and skilled farmers. Model farmers are expected to involve actively in technology demonstration activity where new crop technology promoted on farmers' plots.

Every 20 hectare of irrigable land would have at least one demonstration plot with the size of 0.15ha – 0.25 ha depends on the type of crops and technology being demonstrated.

Experience sharing visits: experience sharing tour in different parts of the country where the farmers can obtain good agronomic and on-farm water management skills. Group of farmers including model farmers, women and youth farmers should be member of the visitors' group. The agronomist has to indicate in the description part that in-house experience sharing forum or sessions is required to disseminate their knowledge after experience sharing visits.

In description of the suggested training interventions the following sub-titles should be included:

- Rational and objectives of the intervention
- Type of training like on-farm technology demonstration, experience sharing visits, and regular training
- Training topics need to be addressed in each type of training
- Number of trainees per session and annual basis which require to estimate annual costs and determine annual budget
- Estimate costs per session and annual total cost

13.3.2 Promotion of organic fertilizer utilization

If organic fertilizer like compost is recommended in small-scale irrigation project, brief description on preparation of compost can be included as an intervention. The compost preparation guideline is Attached in this guideline, however the agronomist can elaborate and enrich the given compost preparation guideline as required.

13.3.3 Market assessment and business network development

Market outlet assessment and network development should be a routine activity of the beneficiaries through established community organization or individual farmers. The agronomist in this report shall suggest the following activities to be undertaken by concerned bodies including beneficiary organization:

- Undertaking the market assessment and network establishment with close technical supports of the wereda and zonal agricultural offices or other relevant institution by establishing permanent institutional linkage through farmers' association or irrigation water users' association.
- The periodical assessments should cover large market potential catchments depend on the availability of infrastructure and transportation facilities. The agronomist able to indicate the potential market centers and marketing network that possibly include export opportunities. If the project is situated within export trade route like Ethio-Djibuti, Ethio-Sudan through Metema, Ethio-Sudan through Gambella or Assosa, Ethio-Kenya through Moyale routes, then the agronomist has to indicate possible export market extensions depend on the type of produces.
- The market assessment and contractual agreement with potential partners should be carried out annually and each year the assessment results and agreements have to be revised depends on the production type and volume. Suggest in consultation with economist the need of institutional platform.
- To accomplish the market and business partner assessments short, medium and long term planning is a prerequisite activity to build manageable and efficient business network.

Major actors: list major stakeholder to be part of this intervention like irrigation users' cooperatives, wereda and zone marketing department, business partners and others

Objective of the intervention: ***(set the objectives of the intervention)*** identify potential market outlets for each agricultural product and develop marketing network.

Expected output: ***(indicate the potential benefits and outputs of this intervention depend on the project features and outputs***) the marketing wing of the irrigation users' cooperatives will have clear plan for the management of the marketing system and to interact with identified potential business partners. Contractual agreement could be undertaken with identified traders, governmental institutions, NGOs and agro-processors.

13.3.4 Promote effective cropland utilization and allocation

It is a crucial intervention to optimize water resource utilization proposed during feasibility and detail design phases. In almost all implemented small-scale irrigation projects, the farmers are not cultivating the type crops with respective land area coverage which were proposed during feasibility studies. As the result, mis-utilization of water and land are the main limiting factors of irrigation projects, therefore the agronomist has to include this supportive intervention to secure the resource utilization as proposed or minimal deviations.

The peak project supply quantity should be taken as guiding limitation for proper water management at scheme and block level, this implies that cultivation of high water demanding crops which were not proposed in the project will affect the whole irrigation water regime and downstream users. Therefore systematic cropland allocation at household and project levels is an important planning activity for the sustainable development of the project. To attain seasonal and annual optimum resource utilization, the households in each Water Users Association need to consider the overall crop based land allocation not to exceed beyond the proposed cultivated area for each crop.

Remark: The agronomist has to design or recommend mechanisms how the cropland allocation can be practically exercised according to the proposed seasonal cropping

In order to come-up with acceptable cultivable land area, before the beginning of the cropping season, cropland utilization plans of the households need to be collected and analyzed against the overall project cropping patterns.

Objective: optimum utilization of land and water resources in accordance with the recommendation.

Major actors: project beneficiaries, water users association, development agents, wereda agricultural or pastoral development office

Expected output: planned cultivated land allocation system development and implementation towards optimum utilization of available resources.

13.3.5 Farmer-research-extension group establishment

The establishment of Farmers-research group helps to carry out more relevant and problem oriented research for the project area. Farmers will involve in all research process including problem identification, evaluation and recommendations in collaboration with researchers. The intervention creates conducive opportunity to address area specific agricultural problems and respective reliable recommendations.

The model farmers in the project area and other knowledgeable farmers will be selected for the formation of the indicated research group. Based on the diversity of soil type and cropping system the pilot trial sites will be determined and revised periodically.

Based on the background of this intervention, the agronomist need to propose:

- The research centers to be involved in this triangulated research and technology verification and dissemination network
- Requirement of model farmers involvement
- Appropriate research ideas to be addressed with respect to project site agricultural development constraints and opportunities. The following research ideas can be considered:
    - Set fertilizer rate by irrigable area soil type and crop
    - Identify potential integrated pest management practice
    - Crop variety adaptation trials
    - Weed control management
    - Post-harvest technology development or adaptation
    - Effective irrigation water management and utilization
    - Developing effective and site specific irrigation schedule

Main actors: wereda/kebele agriculturalists, potential and knowledgeable farmers, researchers, kebele development committee.

Objective: Promote research based technologies to enhance crop productivity.

Expected output: *(indicate the potential benefits and outputs of this intervention depend on the project features and outputs*).

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APPENDICES

APPENDIX I: Focus Group Discussion Checklists for Irrigation Agronomy Study

Location: Region _______________ Zone ________________ Wereda _________________
Kebele ___________________ sub-village name _______________________
Date _____________________ Time _____________________
Name of the Project: ____

List of focus group members

	Full Name	Occupation

GPS Points ___________________________

I. Physical and environmental background

1. Agro-ecological zone: a) dega b) weyna dega c) kola d) combinations
2. Occurrence of frost a) frequently b) rarely c) frost free area (frost hazard duration in months)

II. Land resource and preparation experiences

3. Level of soil fertility a) most of the land is very fertile b) moderately fertile c) degraded
4. Land preparation technologies
   a. Land clearing mechanisms ____
   b. Land ploughing mechanisms ____
   c. Cultivation ____
   d. Furrowing (if any) ____

III. Farming system and types of crops grown

5. Cropping seasons ____
6. Dominant farming system a) Enset based cereals farming system b) Cereals based mixed farming c) Only crop production
7. Types of crops grown under rainfed and irrigated agriculture
   a. Major crops grown during meher season
      i. Food crops ____
      ii. Cash crops ____
   b. Major crops grown during Belg season
      i. Food crops ____
      ii. Cash crops ____
   c. Major crops grown under irrigation
      i. Food crops ____
      ii. Cash crops ____
8. Average land holding
   a. Rainfed farm max __________ ha Min ___________ ha average _________ ha
   b. Irrigated farm max __________ ha Min ___________ ha average _________ ha
9. Cropping patterns in different landholdings

Max landholding ____ ha				Average landholding ____ ha				Min landholding ____ ha			
Irrigated		Rainfed		Irrigated		Rainfed		Irrigated		Rainfed	
Crop	Farm plot, ha	Crop	Farm plot, ha	Crop	Farm plot, ha	Crop	Farm plot, ha	Crop	Farm plot, ha	Crop	Farm plot, ha

After filling the table convert the size of the farm plots into percentage to describe the cropping patterns

10. Cropping Calendar (labor for 0.25 ha)

Meher /Long rainy season /season (range in month)

Crop	Land clearing	Ploughing	sowing	weeding	harvesting

Belg /short rainy season (ranges in Month)

Crop	Land clearing	Ploughing 1	sowing	weeding	harvesting

Irrigation (range in Month)

Crop	Land clearing	Ploughing 1	sowing	weeding	harvesting

IV. Input Utilization

11. Agricultural input utilization

Types of Inputs and use

Crop	Type variety	Seed rate of application	Fertilizer		Pest control
		Kg/ha	DAP	Urea	Name of chemicals

Comments on appropriateness of the input application or utilization

____

____

____

12. Farm labor utilization
    a. Is there labor shortage in most of the households? Yes No
    b. Average number of farm laborer available in the household ____ person or range ____ to ____
    c. If the households hire extra labour
        i. Number of hired laborer at peak season _________ person;
        ii. Range of payment per day at peak season _____ birr;
        iii. Source of extra labour ____
    d. Labor inputs for each crop by activity **Man days/0.25ha**

Crops	Land clearing	Ploughing	discing	sowing	Furrowing	weeding	Fertilizer application	Irrigating	harvesting

13. Yield estimates and price of major crops

Crop	Yield under rainfed qt/ha	Yield under irrigation qt/ha	Current Output price

14. Farmers' suggestions

14.2 Suggested cropping pattern (crop mix) (farmers' experience)

14.2.1 Proposed crops for supplementary irrigation (during rainy season)

a. Option 1: Example Wheat, Maize, Teff, Garlic and Onion
b. Option 2
____
c. Option 3
____

14.2.2 Proposed crops for full irrigation (during dry season)

a. Option 1: Example Onion, Tomato, Garlic, and Wheat seed
b. Option 2
____
c. Option 3
____

V. Major constraints and recommendation

15. What are the major constraints of agriculture?
    a. Agronomic and soils
    ____
    ____
    ____
    b. Environmental problems
    ____
    ____
    ____

c. Institutional constraints
___
___
___

d. Financial constraints
___
___
___

e. Irrigation management constraints ___
___
___
___

f. Beneficiaries capacity constraints
___
___
___

16. What are the potential recommendations to mitigate the problems
___
___
___

VI. Livestock production

17. Types of livestock production
    a. Livestock holding per household cattle ___ ox-___ calves ___ heifer ___ ___ milking cows ___
    b. Shoats holding per HH sheep ___ Goats ___
    c. Number of bull/ heifer kept for fattening ___ frequency of output ___ per year
    d. Milk and by-products production
        i. Milk production per cow per day ___ lt lactation period ___ month
        ii. Butter production ___ kg/month
        iii. Cheese production ___ kg/month

18. Forage resources
    a. Types of forage (in local language)
        i. Tree and bush species ___
        ii. Grass species and others ___
    b. Forage resource availability ___
        i. Critical animal feed shortage period from ___ to ___ (month)
        ii. Alternative solution for feed shortage ___
        ___

19. Major constraints of livestock production development
___
___
___

20. Recommendations to mitigate the problems
___
___
___

THANK YOU

Appendix I- a: Checklist for Key Informant Interview

Name of Key informant: ___________________________________
Social group: (elder, youth, women, local leader, irrigation user, professional expert..)
____
Wereda ___________ **Kebele** _____________ **Sub-village:**__________________

Interview schedule:
Time: starting _________________ End of interview ________________________

Key questions for discussion:

1. ____

2. ____

3. ____

4. ____

Response for questions (short and precise notes)

Issue 1:
____
____
____

Issue 2:
____
____
____

Issue 3:
____
____
____

Issue 4:
____
____
____

Response for other issues:

____
____
____
____
____
____
____
____
____
____
____
____

Tentative list of discussion issue:

- Constraints of irrigation development in project area and/or similar area
- Potential crops for irrigated agriculture
- Experiences on irrigation efficiency and interval
- Land suitability of the command area for irrigation development
- Potential agricultural input and output market opportunities and
- Others

APPENDIX II: Kebele level Irrigation development questionnaire

Region ___________________________________

Zone ___________________________________

Wereda ____________________ Kebele______________

1. Land use of the project:
   a. Total kebele land area _______ ha; Cultivable land _______ ha ; (*Irrigated land* ______ *ha; Rainfed land* _______ *ha)* ; grassland _____ ha Forest/woodland ____ ha; wasteland _____ ha
2. Agro-climate condition of the area
   a. main rainfall duration: _____________ to ______________
   b. short rainfall duration _______________ to _____________
   c. Dry season months _______________ to ______________
3. What are the main farming systems practicing in your kebele? Please answer more than one answers and rank accordingly
   a. Enset based highland cereals mixed farming system
   b. Chat-coffee based mixed farming system
   c. Highland cereals mixed farming system
   d. Lowland cereals mixed farming
   e. Smallholder commercial irrigated farming (vegetable; fruit; cereals)
   f. Other ………………………..
4. Which one is the major source of household income?
   a. Irrigated agriculture
   b. Rainfed agriculture outputs
   c. Both have equal contribution
5. Suggest types of crop which are more promising for rainfed agriculture? (in order of importance) ____
6. Suggest types of crop which are most promising for irrigated agriculture? (in order of importance) ____
7. Estimate existing average cropland holding per household in you kebele
   a. Rain fed Field cropland _______ ha/HH (open field)
   b. Irrigated plot _________ ha/HH
   c. Homestead farmland ______ ha/HH
8. Cultivated land area coverage and production in different seasons

8.1 List of major crops, area and production for the last three years **(Meher season)**

	Year 3		Year 2		Year 1		
Rainfed	Area, ha	Production, qt	Area, ha	Production, qt	Area, ha	Production, qt	Current Price, birr
Teff							
Wheat							
Maize							
Barley							
Sorghum							
PULSE							
Lentils							
Chick pea							
Soya bean							
Haricot bean							
OIL SEED							
Sesame							
Linseed							
Groundnut							

	Year 3		Year 2		Year 1		
Rainfed	Area, ha	Production, qt	Area, ha	Production, qt	Area, ha	Production, qt	Current Price, birr
Vegetable							
Pepper							
Tomatoes							
Beet root							
Carrot							
Onion							
Cabbage							
Potato							
Garlic							
Shallot							
Sweet potato							
Perennial crops							
Enset							
Banana							
Papaya							
Citrus							
Mango							
Avocado							
Chat							
Coffee							

8.2 List of major crops, area and production for the last three years (Belg season)

	Crops	Year 3		Year 2		Year 1	
I	Rainfed	Area, ha	Production, qt	Area, ha	Production, qt	Area, ha	Production, qt
	Teff						
	Wheat						
	Maize						
	Barley						
	PULSE						
	Lentils						
	Chick pea						
	Soya bean						
	Haricot bean						
	Vegetable						
	Pepper						
	Onion						
	Shallot						
	Cabbage						
	Root crops						
	Sweet potatoes						
	Potato						

8.3 Area and Production of Major crops grown under irrigation (can be traditional)

	Crops	Year 3		Year 2		Year 1	
		Area, ha	Production, qt	Area, ha	Production, qt	Area, ha	Production, qt
	Cereals/pulse/oil						
1	Maize						
2	Wheat						
3							
	Vegetables						
1	Green pepper						
2	Tomatoes						
3	Beet root						
5	Onion						
6	Cabbage						
7	Sweet potato						
8	Potato						
9	Shallot						
	Perennial crops						
1	Banana						
2	Papaya						
3	Citrus						
4	Mango						
5	Avocado						
6	Chat						
7	Coffee						

9. Most common crop rotation experienced in your kebele

9.1 Crop Rotation Patterns for rainfed cropping system

	Production system	Crops in Year 1		Crops in Year 2		Crops in Year 3	
		Meher	Belg	Meher	Belg	Meher	Belg
I	Rainfed						
	Option 1						
	Option 2						
	Option 3						

9.2 Crop Rotation Patterns for rainfed cropping system

	Production system	Crops in Year 1	Crops in Year 2	Crops in Year 3
II	**Irrigated**			
	Option 1			
	Option 2			
	Option 3			

10. Cropping season for rainfed and irrigated agriculture
    a. Meher cropping season from _______________ to _____________
    b. Belg cropping season from _______________ to ______________
    c. Irrigation farming from ______________ to ______________
11. Cropping calendar of rainfed and irrigated agriculture

11.1 Cropping calendar for rainfed crop production (month range) **(main season)**

Crops	Land preparation	sowing/Planting	Weeding	Harvesting	Threshing and storage
.					

11.2 Cropping calendar for **rainfed** (month range) **(Belg season)**

	Crops	Land preparation	sowing/Planting	Weeding	Harvesting	Threshing and storage

11.3 Cropping calendar for irrigated crops (month range) **(Irrigation)**

	Crops	Land preparation	Sowing/ Transplanting	Weeding	Harvesting	Threshing	Seedling raise

12. What type(s) of cropping system(s) is/are dominant in project kebele?
    a. Inter-cropping Crops: ____
    b. Mono cropping Crops ____
    c. Multiple cropping Crops____

(Multiple cropping: growing more than two crops on the plot or at the backyard for example enset, coffee, shallot, haricot bean, taro, sugarcane, spices growing at backyard)

13. How many times does the community utilize their **land** for crop production?
    a. Use for only one season ___________ % of the total households
    b. Use for two seasons _________ % of the total households
    c. Use for three cropping seasons including irrigation ________ % of the total households
14. Agricultural input utilization at kebele level

14.1 Level of improved seed utilization for the last three years

	Type of seeds	Year 3		Year 2		Year 1		Major supplier
		quantity, qt	area, ha	quantity, qt	area, ha	quantity, qt	area, ha	
1	Maize							
2	Wheat							
3	Field pea							
4	Haricot bean							
	Oil seeds							
1	Sesame							
2	Groundnut							
3								
	Vegetables							
1	Tomato							
2	Onion							
3	Cabbage							
4	Carrot							
5	Potato							
	Fruit perennials							
1	Citrus							
2	Mango							
3	Avocado							

14.2 Level of fertilizer utilization for the last three years (quantity supplied and area covered)

	Fertilizer	Year 3		Year 2		Year 1		Price, birr/qt	Crops type applied for
		Quantity ,qt	area, ha	Quantity ,qt	area, ha	Quantity qt	area, ha		
1	DAP								
2	Urea								
3	Manure								

14.3 Herbicide and pesticide utilization for the last three years

		Year 3	Year 2	Year 1	Crops mainly applied	Price /unit
		quantity, lt/kg	quantity, lt/kg	quantity, lt/kg		
1	Herbicide					
2	Pesticides					

15. Which are the peak farm labor demand months for crop production system?

Use in Ethiopian calendar, code = Meskerem=1 to Nehase=12

____

16. Irrigation potential

16.1 What type(s) of irrigation scheme(s) is/are available in the kebele? (more than 1 answer)
a. Modern small-scale b. Modern medium scale c. traditional small-scale
e. large scale irrigation scheme f. None

16.2 What types of water abstraction experiencing in project site?
a. river diversion b. flood diversion c. spring development d. pump supported e. None

17. Could you comment on the contribution of irrigation sector in achieving food security and livelihood improvement in your kebele

____
____
____

18. Existing Irrigation systems and area coverage

	Irrigation technologies	Total Area	Crops cultivated	Gere/Got
1	Motorized Water pump			
2	Manual Pump (treadle, pedal, use of watering cane or container)			
3	River diversion			
4	Spring development			

19. Crop marketing
Marketing route of major cash crops

____
____
____

20. Major constraints of crop production

a. Social problems

____
____
____

b. Economic and marketing problems

____
____
____

c. Agronomic problems

____
____

i. Pest and disease

Type of pests	Affected crops	Types of disease	Affected crops

Weed

Type of weeds	Affected crops	Controlling measures

21. Recommendations for crop development under irrigation farming

APPENDIX III: Wereda Agricultural Development Office checklist

1. Current and Future role of wereda agricultural development office in implementation of the SSIP
   Current involvements and gaps
   ____
   ____
   ____
   ____
   ____
   Future possible support
   ____
   ____
   ____
   ____
   ____

2. Number of technical staff in the wereda
   a. Irrigation agronomist ________________________
   b. Irrigation expert/technicians __________________
   c. Plant protection ____________________________
   d. Cooperative promotion expert ________________

3. Existing extension service provisions for irrigation projects
   Is there special arrangement for irrigation for agricultural extension service or it has usual structure like any other kebeles?
   ____
   ____
   ____
   ____
   ____

   What are the opportunities of the SSIP or relative comparative advantage for sustainability and higher returns
   ____
   ____
   ____
   ____
   ____

4. What are the most profitable commercial irrigated crops in the wereda, neighboring areas
   a. Domestic consumption ____
   b. For Agro-processing ____
   c. For Export market ____

5. What is the experience of the farmers/investors/commercial farmers on cultivation of tropical fruit, high value horticultural crops, high value fodder in the region and areas with similar agro-ecology?
   Type of tropical fruit crops growing in the wereda and
   ____
   ____
   ____
   Type of horticultural crops growing in the wereda and potential for smallholder commercial farming
   ____
   ____

6. What are potential agricultural, irrigation application and post-harvest technologies for SSIP
   Potential agricultural technologies need to be adopted in SSIP
   ____
   ____
   ____
   ____

7. What types of potential post-harvest technologies available around the project area for the improvements of SSIP production

8. Input and credit accessibility for SSIP

8.1 Identified gaps in input supply system

8.2 Institutions involved/responsible for input marketing:

8.3 Role of agricultural office in input supply/efficiency:

8.4 Involvement of private sector in input supply/efficiency

9. What do you suggest the cultivation of forage plants under irrigation to support the livestock development in the project area? What types of species are suitable for it?

Contribution of irrigated agriculture development for livestock production development

10. What need to be done to improve the extension service, research output utilization, and cooperatives role for the betterment of SSIP

11. Major constraints of agricultural development in the wereda

____

____

____

12. Wereda cultivated land area and production
    12-1 List of major crops, area and production for the last three years **(Meher season)**

	Year 3		Year 2		Year 1		
Rainfed	Area, ha	Production, qt	Area, ha	Production, qt	Area, ha	Production, qt	Current Price, birr
Teff							
Wheat							
Maize							
Barley							
Sorghum							
PULSE							
Lentils							
Chick pea							
Soya bean							
Haricot bean							
OIL SEED							
Sesame							
Linseed							
Groundnut							
Vegetable							
Pepper							
Tomatoes							
Beet root							
Carrot							
Onion							
Cabbage							
Potato							
Garlic							
Shallot							
Sweet potato							
Perennial crops							
Enset							
Banana							
Papaya							
Citrus							
Mango							
Avocado							
Chat							
Coffee							

12-2 List of major crops, area and production for the last three years (Belg season)

	Crops	Year 3		Year 2		Year 1	
I	Rainfed	Area, ha	Production, qt	Area, ha	Production, qt	Area, ha	Production, qt
	Teff						
	Wheat						
	Maize						
	PULSE						
	Lentils						
	Chick pea						
	Soya bean						
	Haricot bean						
	Vegetable						
	Pepper						
	Onion						
	Shallot						
	Cabbage						
	Root crops						
	Sweet potatoes						
	Potato						

12-3 Area and Production of Major crops grown under irrigation (can be traditional)

	Crops	Year 3		Year 2		Year 1	
		Area, ha	Production, qt	Area, ha	Production, qt	Area, ha	Production, qt
	Cereals/pulse/oil						
	Maize						
	Vegetables						
	Green pepper						
	Tomatoes						
	Beet root						
	Onion						
	Cabbage						
	Sweet potato						
	Perennial crops						
	Banana						
	Papaya						
	Citrus						
	Mango						
	Avocado						
	Chat						
	Coffee						

APPENDIX IV: Reporting formats for study findings

Format 1: Data format for area and yield at different level of input utilization

Crop	local seed without fertilizer			Local seed with fertilizer			With Full package		
	Area, ha	Yield qt/ha	Total production, qt	Area, ha	Yield qt/ha	Total production, qt	Area, ha	Yield qt/ha	Total production, qt
Crop1									
Crop 2									
Crop 3									
Crop N									

Note: total production can be collected or estimated

Format 2: Data collection format for crop area and yield of last three consecutive production years

Crop	Year 1			Year 2			Year 3		
	Area, ha	Yield qt/ha	Total production, qt	Area, ha	Yield qt/ha	Total production, qt	Area, ha	Yield qt/ha	Total production, qt
Crop1									
Crop 2									
Crop 3									
Crop N									

Note: total production can be collected or estimated

Format 3: Crop seed and seedling utilization in the project area (sample format)

Crop	Variety	Rate of application,	Method of application		Remarks
			in rows	broadcasting	
Crop 1 (Maize)	BH 540	30 kg/ha	xx		Difficult to access
	BH 660	30 kg/ha		XXX	
	Local	35 kg/ha		XXX	
Crop 2 (wheat)	Local variety	100 kg/ha		XXX	
Crop 3 & +					

Format 4: Fertilizer utilization experiences in the project area (format)

Crop	Type of Fertilizer	Rate of application,	Method of application		Remarks
			in rows	broadcasting	
Crop 1 (Maize)	NPS				
	Urea				
Crop 2 (wheat)	NPS				
	Urea				
Crop 3 &+	NPS				
	. Urea				

Format 5: Agro-chemicals utilization in the project area (format)

Agro-chemicals	Rate of application	Crops treated	Remarks
Insecticide			
.			
Herbicide			
.			
.			
Lime			
.			

Format 6: Livestock population and annual production by kebele

Type of livestock	Average holding per household	Numbers in project kebele	Average milk yield lt/hd/day	Average milking days/annum	Annual estimated production	Remark
Cattle			xxx	xxx	xxx	
Cows						
Oxen			xxx	xxx	xxx	
Equines						
Sheep						
Goats						
Poultry						

Format 7: Livestock population and annual production data collection format (at kebel level)

Type of livestock	Average holding per household	Numbers in project kebele	Average milk yield lt/hd/day	Average milking days/annum	Annual estimated production	Remark
Cattle			xxx	xxx	xxx	
Cows						
Oxen			xxx	xxx	xxx	
Equines						
Sheep						
Goats						
Poultry						

Format 8: Agricultural constraints information collection format

	Major Constraints		Major Constraints
A	Agronomic	C	Environmental
1		1	
2		2	
3		3	
4		4	
5		D	Social constraints
B	Soils and land resources	1	
1		2	
2		3	
3		4	
4		E	Institutional
		1	
		2	

APPENDIX V: Agricultural development scenario determination for cropping pattern development

This Appendix has supporting role in crop selection and cropping pattern determination based on the findings in previous chapters.

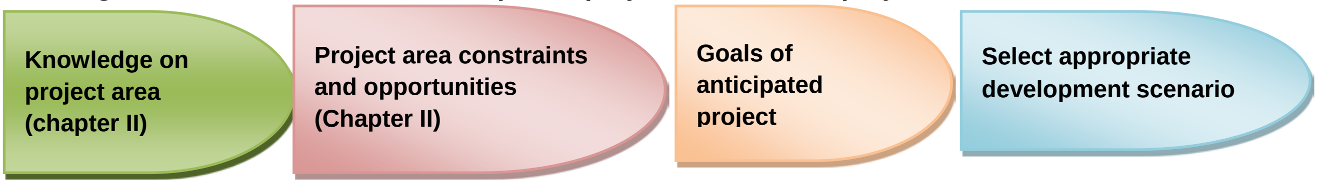
Identifying the project level development scenario or determining development direction to achieve the anticipated irrigated agriculture objectives that could help the agronomists or planners to concentrate on certain potential crops to select the most appropriates. There are several options to be implemented to optimize the resources and attain the maximum project outputs, however the appropriateness of each option need to be analyzed in the context of the local conditions in reference with project area assessment findings.

Purpose:

To give clear direction for crop selection and cropping pattern development

To focus on more promising crops appropriate for chosen project development scenario

To integrate the efforts of other development projects around the project area



Example 1: How to determine the development scenario SSIP in Mid-highland areas

Step1: Knowledge/description of the project area: : through project area assessment the agronomist revealed that the area has mid-highland agro-climate conditions, suitable soil condition and farmers have good experience in cereals production.

Step2: Major constraints: it is indicated that the farmers have critical problems of low crop yielding and shortage of improved seeds for their rainfed and irrigated agriculture.

Opportunities: encouraging regional seed multiplication strategy and long-term improved seed purchasing plan by regional government, availability of seed agency, strong farmers' service cooperative within reasonable radius and potential for back-up by research center.

Step 3: Goals: increase household income of the beneficiaries and promote cash crop cultivation

Step 4: Development scenario option: the existing constraint assessment findings indicate that high demand for improved seed marketing. On the other hand the institutional, social and infrastructure opportunities are favorable to involve in seed multiplication agro-business. Under such circumstance, crop specialization in improved seed production is more appropriate than other scenarios. Lion share of the irrigable land of the project particularly during dry season should be allocated for improved seed production. During crop selection process more potential cereals and pulses should be included in the basket.

As an option the following crop production development scenario are briefed for consideration, but there could be a number of options that the experts could develop from the project area context, and they should be consistent to the national and regional long-term development strategies.

1. **Specialization**

Crop specialization is one of the crop production improvement option focused on single crop or a group of crops. Considering the demand of the agricultural products the project could specialized in certain crop to fulfill the demand and to attain higher income. The existing growing corridor or crops belt zonation could give highlight for planner to identify the crops potential for specialization.

2. **Crop diversification**

The agricultural development of the project area can be maintained by producing different mixed crops by individual farmers that minimize risks which is a typical livelihood strategy of the smallholders. In this option the farmers will get more alternative crops from the crop basket to grow for different markets. The crops could be selected from different crop groups like cereals, pulse, oil seeds, fiber crops, perennials. The crop diversity could include food crops to meet the demand of the household consumption.

3. **Domestic market oriented**

Several market outlet options are available in the country and regions that have sufficient potential to absorb the irrigated crops production. The project could select potential crops considering the capacity of the domestic markets. This scenario is entirely relying on the on the demand of domestic markets mainly around the project area.

4. **Export oriented**

The projects might have location comparative advantage to exploit the export market opportunities. Ethio-Djibuti trade routes through Diredawa, Ethio-Sudan trade routes through Metema or other outlets. Ethio-Putland trade routes and others to be established in future are potential areas for export marketing. The projects those found along the indicated trade routes could plan their production for export market. For smallholder irrigation projects they might need to organize in UNION or cooperative to meet the demand.

5. **Crop-forage mixed**

In agro-pastoral areas, where significant livestock size is managed by the households, the crop-forage mix development scenario is more appropriate by taking into account the livelihood of the beneficiaries.

In agro-pastoral areas, forage crops and vegetables are possible combination where the forage irrigable land would have significant land coverage depends on the purpose of irrigated agriculture development proposal, level of forage resource scarcity and interest of the communities

6. **agro-processing based**

This option is designed to supply raw materials for different agro-processing centres through contractual arrangement. There are wheat flour mill factories, tomato paste processing factory, dye extracting factory, and food complex factory in the country those can be linked with the project to solve the raw material shortages. To apply this development scenario the agronomist should consider the size of command area and volume of the production for consistent supply.

7. **Combined options**

The combined option of the above listed development options can be an alternative strategy for improvement of agricultural sector. Based on the existing production and market conditions the project can combine the above-mentioned alternatives to attain higher farm return.

APPENDIX VI: Sample formats for summary of agricultural input recommendations

Format 6-1: Sample format for presentation of recommended crop varieties and yield potential

No	Type of crop	Recommended varieties	Potential Yield	Remarks

Format 6-2: Sample format for seasonal and annual seed requirements

Crop	Area, ha	Rate	Unit	Seed /seedling requirement, qt
Dry season seed requirement				
X				
Y				
Z				
Sub –Total		-------	------	
Wet season seed requirement				
M				
N				
P				
Sub –Total		-------	------	
Annual Total		-------	------	

Format 6-3: Sample Format for fertilizer rate recommendation

Crop	Fertilizer rate, qt/ha		Remarks
	Blended fertilizer (specify the type), qt/ha	Urea, qt/ha	
X			
Y			
Z			

Format 6-4: Sample Format seasonal and annual fertilizer and lime requirements

	Area, ha	Blended fertilizer ,qt	Urea, qt	Lime	Remarks
Dry season requirement					
X					
Y					
Z					
Sub-total					
Wet season requirement					
M					
N					
P					
Sub-total					
Grand total					

Format 6-5: Sample Format for crop pests and recommneded agro-chemicals

No	Proposed crops	Crop pests	Recommended agro-chemicals	Rate of application	Remarks
	X				
	Y				
	Z				

Format 6-6: Sample Format for seasonal and annual pesticides requirement

Crop	Rate of application Lt or kg/ha	Assumed affected (10-30%) land, ha	Total requirement, qt	Remarks
Dry season				
X				
Y				
Z				
Sub-total				
Wet season				
M				
N				
P				
Sub-total				
Grand total				

APPENDIX VII: Formats for summary of crop yield and production projections

Format 7-1: Formats for summary of Yield estimate and projection (qt/ha)

Crop	**With-out project**	**Year 1**	**Year 2**	**Year3**	**Year 4**	**Year5**	**Year 6+**
Crop 1							
Crop 2							
Crop 3							
Crop 4							

Format 7-2: Format for summary of crop production projection (qt or ton)

Crop	**Projection Year**					
	Year 1	**Year 2**	**Year3**	**Year 4**	**Year5**	**Year 5+**
Crop 1	Crop 1 area X yield at year 1	Crop 1 area X yield at year 2	Crop 1 area X yield at year 3	Crop 1 area X yield at year 4	Crop 1 area X yield at year 5	Crop 1 area X yield at year 6
Crop 2						
Crop 3						
Crop 4						

APPENDIX VIII: Format for Estimation of crop budgets

Format 1: Format for Estimation of crop budget with project intervention

Input	Unit	Qty/ ha	Unit Rate (Birr)	Total season cost (Birr)	Years				
					1	2	3	4	5_25
Labour									
Canal clearing	Person-days								
land clearing	Person-days								
1st plough	Person-days								
2nd plough	Person-days								
Cultivation	Person-days								
Furrowing	Person-days								
Sowing	Person-days								
Fertilizing Basal application	Person-days								
Fertilizing	Person-days								
Irrigation	Person-days								
Spraying	Person-days								
Thinning	Person-days								
Weeding 1	Person-days								
Weeding 2	Person-days								
Weeding 3	Person-days								
Harvesting	Person-days								
Bagging and loading	Person-days								
Labor Sub-total	Person-days								
Land preparation	Person-days								
	Oxen-days								
Threshing (if any)	Machinery-hrs								
Other Inputs									
Seeds	kg								
Fertilizers									
DAP	kg								
Urea	kg								
Pesticides	Lt								
Herbicides	Lt								
Lime	kg								
Packing material	No								
Land tax	LS								
Other inputs Sub-total									
Total cost	**ETB**								
Miscellaneous (2-5% of TC)	ETB								
Yields	qt								
Price per unit	**ETB**								
Gross Income	**ETB**								
Farm return	**ETB**								

Format 2: Reporting Format for Crop budget estimation

Input	Unit	Qty / ha	Unit Rate (Birr)	Total season cost (Birr)	Years				
					1	2	3	4	5_25
Labour	Man-days								
Oxen power	Oxen-days								
Seed	Kg								
Fertilizer									
NPS	Kg								
Urea	Kg								
Pesticide	Lt or kg								
Herbicides	Lt								
Lime	kg								
Packing materials	No								
Land tax	LS								
Total cost	ETB								
Miscellaneous (2-5%)	ETB								
Grand total cost	ETB								
Gross Income	ETB								
Farm return	ETB								

Format 3: Crop Budget estimation for Crop budget without project intervention

Input	Unit	Qty/ ha	Unit Rate (Birr)	Total season cost (Birr)	Current year
Labour					
Canal clearing	Person Days				
land clearing	Person Days				
1st plough	Person Days				
2nd plough	Person Days				
Cultivation	Person Days				
Furrowing	Person Days				
Sowing	Person Days				
Fertilizing Basal application	Person Days				
Fertilizing	Person Days				
Irrigation	Person Days				
Spraying	Person Days				
Thinning	Person Days				
Weeding 1	Person Days				
Weeding 2	Person Days				
Weeding 3	Person Days				
Harvesting	Person Days				
Bagging and loading	Person Days				
Labor Sub-total	Person Days				
Land preparation					
	Oxen-days				
Threshing (if any)	Machinery-hrs				
Other Inputs					
Seeds	kg				
Fertilizers					
DAP	kg				
Urea	kg				
Pesticides	Lt				
Herbicides	Lt				
Lime	kg				
Packing material	No				
Land tax	LS				
Other inputs Sub-total					
Total cost	**ETB**				
Yields	qt				
Price per unit	**ETB**				
Gross Income	**ETB**				
Farm return	**ETB**				

APPENDIX IX: Manual calculation of crop water requirement (Hargreaves Method) and irrigation schedule

Appendix IX-1: Crop & Irrigation water requirement calculation for project site with limited climate data

Crop water requirement which is a function of environmental and crop factors basis for determination of irrigation water requirement of the anticipated small-scale irrigation projects. When the project area do not have adequate climate data, then the reference evapotranspiration (ETo) can be calculated with Hargreaves Equation that require only temperature data**.**

A9-1-1 Estimate Reference Evapo-transpiration (ETo)

Step 1: Collect monthly maximum and minimum temperature data for at least 20-30 years from reliable sources to represent the project area climate condition.

Step 2: Calculate monthly average of temperature

Step 3: Determine the Ra value from given Table A-9-1 by referring in respective of project area location Latitude value in “^{o}”. Take the latitude coordinates of the project site and use the respective monthly values from the tabulated data.

If the latitude value found in between two coordinates not shown in the Table like 9^{o} then calculate the “Ra” average values of 8^{0} and 10^{o} to get reasonable Ra values for the project site. Please see example for Burqa Irrigation project site located at 8.73^{o} latitude and longitude of 41.71^{o}

Step 3: Use the following ETo equation for computation which easily manage on Excel sheet.

$ETo = 0.0023 \times Ra \times Td^{0.5}\ 0.5 \times (TA + 17.8)$ …………………………………………… (A- 1)

Where:

Ra = Extraterrestrial Radiation (Ra) expressed in mm/day

Td = Temperature difference of Maximum and Minimum Values, ^{o}C

TA = Average Temperature, ^{o}C

Table A-9-1 Reference for Extraterrestrial Radiation (Ra) expressed in mm/day

Northern Hemisphere												
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Lat; o**
3.8	6.1	9.4	12.7	15.8	17.1	16.4	14.1	10.9	7.4	4.5	3.2	50
4.3	6.6	9.8	13	15.9	17.2	16.5	14.3	11.2	7.8	5.0	3.7	48
4.9	7.1	10.2	13.3	16	17.2	16.6	14.5	11.5	8.3	5.5	4.3	46
5.3	7.6	10.6	13.7	16.1	17.2	16.6	14.7	11.9	8.7	6.0	4.7	44
5.9	8.1	11	14	16.2	17.3	16.7	15	12.2	9.1	6.5	5.2	42
6.4	8.6	11.4	14.3	16.4	17.3	16.7	15.2	12.5	9.6	7.0	5.7	40
6.9	9	11.8	14.5	16.4	17.2	16.7	15.3	12.8	10	7.5	6.1	38
7.4	9.4	12.1	14.7	16.4	17.2	16.7	15.4	13.1	10.6	8.0	6.6	36
7.9	9.8	12.4	14.8	16.5	17.1	16.8	15.5	13.4	10.8	8.5	7.2	34
8.3	10.2	12.8	15	16.5	17	16.8	15.6	13.6	11.2	9.0	7.8	32
8.8	10.7	13.1	15.2	16.5	17	16.8	15.7	13.9	11.6	9.5	8.3	30
9.3	11.1	13.4	15.3	16.5	16.8	16.7	15.7	14.1	12	9.9	8.8	28
9.8	11.5	13.7	15.3	16.4	16.7	16.6	15.7	14.3	12.3	10.3	9.3	26
10.2	11.9	13.9	15.4	16.4	16.6	16.5	15.8	14.5	12.6	10.7	9.7	24
10.7	12.3	14.2	15.5	16.3	16.4	16.4	15.8	14.6	13	11.1	10.2	22
11.2	12.7	14.4	15.6	16.3	16.4	16.3	15.9	14.8	13.3	11.6	10.7	20
11.6	13	14.6	15.6	16.1	16.1	16.1	15.8	14.9	13.6	12.0	11.1	18

Northern Hemisphere												
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Lat; o**
12.0	13.3	14.7	15.6	16	15.9	15.9	15.7	15	13.9	12.4	11.6	16
12.4	13.6	14.9	15.7	15.8	15.7	15.7	15.7	15.1	14.1	12.8	12	14
12.8	13.9	15.1	15.7	15.7	15.5	15.5	15.6	15.2	14.4	13.3	12.5	12
13.2	14.2	15.3	15.7	15.5	15.3	15.3	15.5	15.3	14.7	13.6	12.9	10
13.6	14.5	15.3	15.6	15.3	15.1	15.1	15.4	15.3	14.8	13.9	13.3	8
16.9	14.8	15.4	15.4	15.1	14.9	14.9	15.2	15.3	15	14.2	13.7	6
14.3	15	15.5	15.5	14.9	14.6	14.6	15.1	15.3	15.1	14.5	14.1	4
14.7	15.3	15.6	15.3	14.6	14.3	14.3	14.9	15.3	15.3	14.8	14.4	2
15.0	15.5	15.7	15.3	14.4	14.1	14.1	14.8	15.3	15.4	15.1	14.8	0

Table A-9:2 Temperature data for Burqa project area

Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min	20.5	19.9	20.9	20.2	19.6	18.1	18.2	18.3	17.5	16.8	16.6	13.2
Max	33.1	33.5	33.4	33.1	32.9	30.4	29.4	31.3	29.9	32.4	33.5	32.9
Ave(TA)	26.8	26.7	27.15	26.65	26.25	24.25	23.8	24.8	23.7	24.6	25.05	23.05
Td	12.6	13.6	12.5	12.9	13.3	12.3	11.2	13	12.4	15.6	16.9	19.7

Table A-9- 1: Estimated Extraterrestrial Radiation (Ra) for Burqa SSIP

Latitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
For 8^0 latitude referred Table A 9-1	13.6	14.5	15.3	15.6	15.3	15.1	15.1	15.4	15.3	14.8	13.9	13.3
Cal. for ~ 9^0 lat	13.4	14.4	15.3	15.7	15.4	15.2	15.2	15.5	15.3	14.8	13.8	13.1
For 10^0 lat referred from Table A9-1	13.2	14.2	15.3	15.7	15.5	15.3	15.3	15.5	15.3	14.7	13.6	12.9

ETo = 0.0023 x Ra x $TD^{0.5}$x (TA +17.8)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ETo	4.88	5.42	5.59	5.75	5.69	5.16	4.87	5.46	5.14	5.68	5.57	5.46

A9-1-2 Crop Water Requirements computation

In order to calculate the crop water requirement of the proposed crops, crop coefficient shall be determined for each crop growth stages.

The following inputs are important to calculate crop water requirements:

- Length of growing period of each proposed crop
- Crop coefficient Kc values for each growing stage
- Planting and harvesting date

Step 1: Set the length of growing period and respective crop coefficient

Step 1-1: Distribute the LGP into different crop growth stages

Crop	Total growing period(days)	Initial stage	Crop dev. stage	Mid-season stage	Late season stage
Maize	**145**	**25**	**40**	**45**	**35**

Step 1-2: Estimate the Kc for each crop growth stage

Kc value can be referred from this guideline **(Appendix XII)**

Crop	Initial stage	Crop development stage	Mid-season stage	Late season stage
Maize	**0.4**	**1.20**		**0.35**

Step 1-3: Compile monthly distribution of actual ETo data, LGP and Kc values

Important data for compiling monthly distribution

- Calculated ETo Table above output of Hagreves equation
- Cropping calendar from proposed cropping pattern Table (for Maize sowing date Nov 25 & harvesting date April 13
- Kc values estimation Table Step 1-2

Table A-9-4: Illustration for monthly distribution of ETo, LGP and Actual Kc

Month	Nov	December	Jan	Feb	March	April	Source
ETo (mm/day)	**5.57**	**5.46**	**4.88**	**5.42**	**5.59**	**5.75**	ETo table
Growing stages	Initial (5days)	Initial (20 days) + development (11days)	Development (29 days) + Mid season stage (2 days)	Mid season stage (28 days)	Mid season stage (15 days) + Late season (16 days)	Late season stage (19 days)	LGP Table
Kc values	0.45	0.45 & 1.20	1.20	1.20	1.20 & 0.35	0.35	Kc table

Planting date Nov 25 then 5 days allocated for Initial stage the remaining 20 days is from next month.

Development stage has 40 days period that falls in two months where 11 days of December remained from initial stage and 29 days from January

Step 1-4 determine the monthly Kc values to calculate monthly crop water requirement

ET crop has to be determined on a monthly basis. It is thus necessary to determine the Kc on a monthly basis as follows

Table A-9-5: monthly Kc value determination

Month	Nov	December	Jan	Feb	March	April	Source
Monthly Kc values	**0.45**	**1.1**	**1.20**	**1.20**	**0.80**	**0.35**	Calculated

December has two Kc values then it needs to be calculated proportionally as follows

$$\frac{5}{30} \times 0.45 + \frac{25}{30} \times 1.20$$

$$= 0.075 + 1 \sim \text{approx } 1.1$$

March has two Kc values then it needs to be calculated proportionally as follows

$$\frac{15}{31} \times 1.20 + \frac{16}{31} \times 0.35$$

$$= 0.58 + 0.18 = 0.78 \text{ ` approx}$$

Step 1-5: Calculate the crop water need based on monthly Kc value & ETo

In order to estimate the crop water requirements of Maize multiply the monthly ETo by Kc from Step 1-3 and step 1-4 respectively

Month	Jan	Feb	March	April	Nov	Dec	Source
ETo (mm/day)	**4.88**	**5.42**	**5.59**	**5.75**	**5.57**	**5.46**	ETo
Monthly Kc values	**1.20**	**1.20**	**0.80**	**0.35**	**0.45**	**1.1**	Step 1-4
ETc of maize	**5.85**	**6.5**	**4.47**	**4.6**	**2.51**	**6.0**	Calculated

Step 1-6: Calculate the monthly crop water requirement based on monthly Kc value & ETo

Table A-9-6: Crop water requirement computation format (Hargraves method)

Crop	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Maize												
ETo (mm/day)	**4.88**	**5.42**	**5.59**	**5.75**							**5.57**	**5.46**
Monthly Kc values	**1.20**	**1.20**	**0.80**	**0.35**							**0.45**	**1.1**
ETc of maize (mm/day)	**5.85**	**6.5**	**4.47**	**4.6**							**2.51**	**6.0**
ETc of maize (mm/month)	**175**	**195**	**134**	**138**							**75**	**180**
Wheat												
ETo (mm/day)												
Monthly Kc values												
ETc of maize (mm/day)												
ETc of maize (mm/month)												
Tomato												
ETo (mm/day)												
Monthly Kc values												
ETc of maize (mm/day)												
ETc of maize (mm/month)												

Note: Assuming that all months have 30 days

Appendix IX-2: Manual-Calculation of Net and Gross irrigation requirements

Step 1: Calculate the Net and Gross water requirements and duty

- Consider the monthly crop water requirement (ETc mm/month) from step 1-6 summary table
- Determine the scheme efficiency (refer the methods from main body of this guideline section 8-8)
- Divide the monthly net crop water requirement by scheme efficiency (if Ep = 48%)
- The required discharge to meet the irrigation demand with given irrigation hours (ex 24hr and 12hr highlighted in the table)
- Determine the peak duty of the irrigation months and it will be used for design and estimation of command area size can be irrigated

Table A-9:7 Estimation of Net and Gross Irrigation Requirement

	Crop	Formula	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Maize													
1	**ETc of maize (mm/month) 1**		175	195	134	138							75	180
2	**Rainfall mm/month**		13.6	7.7	47.2	92.2	**91.5**	**56.6**	**91.9**	**112.3**	**98.5**	**59**	23.1	13.4
3	**Effective rainfall mm/month**	Peff = Pmonth * (125 - 0.2 * Pmonth) / 125 for Pmonth≤250 mm Peff = 125 + 0.1 * Pmonth for Pmonth > 250 mm	13.3	7.6	43.6	78.6	78.1	51.5	78.4	92.1	83.0	53.4	22.2	13.1
4	**Net Irr req mm/month**	NIR = ETc - Peff (Row 1-3)	161.7	187.4	90.4	59.4							52.8	166.9
5	**Project efficiency (Ep)**		0.48	0.48	0.48	0.48							0.48	0.48
6	**Gross Irr Req mm/month**	NIR/Ep	336.9	390.4	188.3	123.8							109.9	347.7
7	**Discharge q (l/s/ha)**	10*GIR/(30***24***3.6)	1.30	**1.51**	0.73	0.48							0.42	1.34
	for 12 hrs irr hours	10*GIR/(30***12***3.6)	2.60	**3.01**	1.45	0.95							0.85	2.68

The duty at peak month has to be determined from the calculated monthly values in row 7 or 8; if the irrigation hours suggested 24 hrs then q value or duty is 1.51 l/s/h and for 12hrs the duty is 3.01l/s/ha.

Appendix IX-3: Manual Estimation of Irrigation depth and interval

A9-3-1 Estimation of Irrigation depth

The irrigation depth of the proposed crops shall be determined based on the soil moisture balance and crop rooting depth. The calculation has to undertake for all proposed crops. The following data are required to compute the irrigation depth:

- Total available soil moisture (Sa) in one meter depth (mm/m) which can be available from soil laboratory data
- Allowable depletion level (p); is the fraction of total available moisture can be referred from Appendix XIV of this guideline by crop
- Maximum rooting depth (D) of proposed crops also available from Appendix XIV of this guideline
- Field application efficiency estimated for given irrigation type and soils; for surface irrigation it ranges from 55% to 70%:

Table A-9-8: Field application efficiency (Ea) of different soil texture classes

Soil texture	Field application efficiency (%)
Light soil	55
Medium	70
Heavy soils	60

Source: Module on Irrigation Agronomy, Mekele University

Table A-9-9: Range of available soil moisture for various soil texture classes, mm/m

Soil type	Available soil moisture (Sa) mm/m
Heavy clay	180
Silty clay	190
Loam	200
Silt loam	250
Silt clay loam	160
Fine textured soils	200
Sandy clay loam	140
Sandy loam	130
Loam fine sand	140
Medium textured soil	140
Medium fine sand	60
Coarse textured soil	60

Source: Guideline on irrigation agronomy MoA 2011

$$d = \frac{(P \times Sa) \times D}{Ea}$$ ……………………………………………Equation 2

where d= depth of irrigation application, mm
p = allowable depletion level in % or decimals
Sa = Available soil moisture, mm/m
D = Rooting depth, m
Ea = Application efficiency

Example for Irrigation depth calculation:

Soil and crop data provided:
Soil: Heavy clay (soil analysis or field observation results)
Crop: maize, wheat, tomato and pepper
Field irrigation efficiency = 50%
Total available moisture (Sa) 180mm/m (from soil analysis result)

Table A-9-10: Summary for irrigation depth in mm

	Crop	P (%)	Sa (mm/m)	D (m)	Ea (%)	d (mm)
	Maize	0.55	180	1.20	0.5	237.6
	Wheat	0.55	180	1.0	0.5	198
	Tomato	0.40	180	0.9	0.5	129.6
	Pepper	0.30	180	0.7	0.5	75.6

Calculation can be easily manipulated in excel sheets

$$d = \frac{(P \times Sa) \times D}{Ea}$$

Irrigation depth for maize

d = [(0.55X180)X1.2]/0.5

= 237 mm

- A9-3-2: Estimation of Irrigation Interval/schedule

The period between the two subsequent irrigation applications is irrigation interval that should rounded to "0" or 5". As discussed earlier this method should be taken as the last option for the agronomist to compute the irrigation interval when he/she doesn't have computer facility. Basically most of the data used for irrigation depth calculation will be useful for this estimation.

$$I = \frac{(P \times Sa) \times D}{ETc} \quad \text{.. Equation 3}$$

p = allowable depletion level in % or decimals
Sa = Available soil moisture, mm/m
D = Rooting depth, m
ETc = Crop water requirement, mm/day (calculated maize ETc taken 195mm/month from above Table and convert to mm/day)

Table A-9-11: Summary of estimated crops' irrigation interval

	Crop	P (%)	Sa mm/m	D, m	Etc, mm/day	I (Days)	
1	Maize	0.55	180	1.2	6	19.8	19
2	Wheat	0.55	180	1.0	5.8	17.07	17
3	Tomato	0.4	180	0.9	5.7	11.37	11
4	Pepper	0.3	180	0.7	6.2	6.097	6

I maize = [(0.55X180)X1.2]/6

= 19.8 days

APPENDIX X: Released crop varieties and their requirements

No	Crop	Variety	Maximum LGP (Days)	Altitude lower range (masl)	Yield (qt/ha)	Seed rate (Kg/ha)	Fertilizer - DAP (Kg/ha)	Fertilizer - Urea (Kg/ha)	Spacing, cm	Maximum water requirement (mm/season)
1	Teff	Quncho	113	1800-2500	20	10	130	80		198
		Tseday	90	1600-2400	22	10	108	93		158
		Simamda	88	300-700	10	10	40	60		154
		Lakech	102	1450-1850	17	10	100	50		
		Dega-Tef	123	1880-2500	20	10	130	80		
		Dima	105	2000-2500	16.8	10	130	80		
		Kena	134	1850-2400	23	10	100			
		Etsub	127	1800-2600	22	10				
2	Bread wheat	Shorima	157	2100-2700	43	150	100	50	5x20	753
		Hoggana	175	2200-2800	54	150	100	50		839
		Tsehay	138	2600-3100	35	175	225	300		662
		Mekelle -01	90	1980-2500	27	150	100	50		432
		Mekelle-02	90	1980-2500	25	150	100	50		432
		Dandaa	145	2000-2600	50	175	150	50		695
		Kakaba	120	1500-2200	47	175	100	50		575
		Gasay	127	1890-2800	47	175	100	50		609
		Manze	127	2800-3100	27	175	138	104		609
		Tay	130	1900-2800	58	175	100	160		623
		Digalu	128	2000-2900	31	175	100	50		614
		Sofumar	134	2200-2400	40	150	100	50		643
		Hawi	128	1600-2400	41	175	100	50		614
		Tuse	130	2000-2500	47	175	100	50		623
		Pavon76	135	1600-2500	45	175	100	50		647
		ET-13A2	150	2200-2700	50	175	100	50		719
		Simba	160	1800-2700	55	175	100	50		767
		Galama	155	2200-3300	65	175	100	50		743
		Kunsa	140	2000-2600	70	175	100	50		671
		Local Bread wheat	175	1500-3100	18	175	225	300		839
3	Durum Wheat	Toltu	135	2300-2600	42	150	100	50	5x20	647
		Werer (Mamuri I)	110	450-1200	35	175	100	220		528

No	Crop	Variety	Maximum LGP (Days)	Altitude lower range (masl)	Yield (qt/ha)	Seed rate (Kg/ha)	Fertilizer - DAP (Kg/ha)	Fertilizer - Urea (Kg/ha)	Spacing, cm	Maximum water requirement (mm/season)
		Yerer	134	2300-2600	35	175	130	80		643
		Ude	132	2300-2600	35	175	130	80		633
		Kilinto	125	1800-2600	50	175	130	80		599
		Local Durum Wheat	135	450-3100	18	175	130	210		647
		Megenagna	128	1900-2800	56	150	100	100		
		Mosobo	132	1900-2800	47	150	**			
		Kokate	120	1900-2800	40	150	100	50		

No	Crop	Variety	Maximum LGP (Days)	Altitude lower range (masl)	Yield (qt/ha)	Seed rate (Kg/ha)	Fertilizer - DAP (Kg/ha)	Fertilizer - Urea (Kg/ha)	Spacing, cm	Maximum water requirement (mm/season)
	wheat	OBSA	131	2300-2600	40	150	100	50		
4	Triticale	DILFEKAR	136	1800-2600	22	175	*	*		652
		Logaw Shibo	135	1800-2600	24	175	*	*		647
		Local Triticale	136	1800-2600	24	175				652
5	Emmer wheat	Lammesso	124	2300-2600	17	100	100	0	5X20	776
		Sinana-01	124	2000-2400	19	100	100	0		776
		Local Emmer wheat	124	2000-2600	17	100	46	46		776
6	Rice	Edget	134	1150-1850	35	80	50	125	5X20	671
		Andasa	135	600-1850	31	80	100	100		676
		Nerica-2	90	100-500	35	60	100	150		450
		Nerica-1	90	100-500	30	60	100	150		450
		Suparica-1	115	100-500	23	60	100	100		575
		Nerica-4	110	100-500	30	60	100	100		550
		Nerica-3	110	100-500	29	60	100	100		550
		Nerica-6	110	100-500	56	60	100	150		550
		Nerica-15	91	100-500	50	60	100	150		455
		Kallafo-1	100	100-500	50	60	100	150		500
		Nerica-14(upland type)	90	100-500	50	60	100	150		450
		SHEBELLE	135	100-500	45	60	100	100		676
		GODE-1	135	100-500	43	60	100	100		676
		Hoden	135	100-500	40	60	100	100		676
		Local Rice	135	100-1850	22	80	100	150		676
7	Maize	BH661	160	1600-2200	85	25	150	200	25 X 75	801
		GIBE 2	144	1000-1800	50	25	100	150		721
		Shala	133	1000-1700	80	25	100	92		666
		Jibat	180	1800-2600	90	25	150	200		901
		Morka	184	1600-1800	60	25	100	104		921
		Melkasa-6Q	120	1000-1750	40	30	100	100		600
		Melkasa-5	125	1000-1700	35	30	100	100		626

No	Crop	Variety	Maximum LGP (Days)	Altitude lower range (masl)	Yield (qt/ha)	Seed rate (Kg/ha)	Fertilizer - DAP (Kg/ha)	Fertilizer - Urea (Kg/ha)	Spacing, cm	Maximum water requirement (mm/season)
		Melkasa 4	105	1000-1600	35	25	100	100		525
		Melkasa - 2	130	1200-1700	40	30	100	100		651
		Local Maize	160	1000-2600	22	30	150	200		801
		Beles	151	1000-2000	60	25	150	141		
		BH543	151	1000-2000	60	25	150	141		
		Bereda	147	1000-2000	70	25	150	141		
		Wolel phb30V53	163	1000-2000	80	25	150	141		
		Shone	162	1000-2000	80	25	150	141		

No	Crop	Variety	Maximum LGP (Days)	Altitude range (masl)	Yield (qt/ha)	Seed rate (Kg/ha)	Fertilizer - DAP (Kg/ha)	Fertilizer - Urea (Kg/ha)	Spacing, cm	Maxium water requirement (mm/season)
8	Sorghum	Mesay	134	100-1850	33	10	100	100	20 X 60	559
		Dagem	158	1600-1900	42	10	100	100		659
		Chare	120	1600-1250	33	10	100	50		500
		Melkam	118	100-1600	43	10	100	50		492
		ESH-1(diqala -1)	115	100-1600	45	10	100	50		480
		ESH-2(diqala -2)	120	100-1600	43	10	100	50		500
		Gubiye	120	100-1600	14	10	100	100		500
		ABSHIR	120	100-1600	14	10	100	100		500
		Local Sorghum	158	100-1900	18	10	100	100		659
9	Finger millet	Necho	175	1900-2500	20	15	50	100		730
		Debatsi(debatsi)	167	1100-1600	20	15	100	50		696
		Local Finger millet	175	1100-2500	14	15	100	100		730
		degu	160	1900-2500	21	15	100	50		
10	Pearl millet	KOLA-1	85	500-1600	30	15	50	50		354
		Local Pearl millet	85	500-1600	30	15	50	50		354
11	Foxtail millet	Fetan1	86	100-1600		10	*	*		359
		Fetan	91	100-1600		10	*	*		379
		Local Foxtail millet	91	100-1600	0	10	*	*		379
12	Food barley	Abdane	111	2300-2600	32	125	50	50		532
		FELAMIT	130	2400-4800	35	125	100	50		623
		Meserach	130	2000-3000	33	125	34	41		623
		Shege	130	2600-2900	33	125	34	41		623
		HB-42	130	2600-2900	33	125	34	41		623
		HB-1307	137	2000-3000	35	125	p41	n46		657
		Local Food barley	137	2000-4800	15	125	46	46		657
		setegn	135	2400-3000	35	85	100	50		
		harbu	106	2300-2600	44	125	50	50		
13	Malt barley	Sabini	148	2300-2500	40	100	100	0		710
		Bahati	158	2300-2800	40	100	100	0		758
		EH 1847/F4.2p.5.2 (BEA/IBON64/91	161	2300-3000	34	100	100	0		772

No	Crop	Variety	Maximum LGP (Days)	Altitude range (masl)	Yield (qt/ha)	Seed rate (Kg/ha)	Fertilizer - DAP (Kg/ha)	Fertilizer - Urea (Kg/ha)	Spacing, cm	Maxium water requirement (mm/season)
		Holker	141	2300-2800	18	100	100	0		676
		Beka	141	2300-2800	25	100	100	0		676
		Kiflu- B	136	1550-2850	37	100	100	50		652
		Local Malt barley	158	2000-2850	18	100	100	50		758
14	Faba bean	Gabelcho	167	19000-3000	30	350	100	0	5 X 40	801
		Degaga	125	1800-3000	35	200	100	0		599
		Messay	125	1900-2300	35	200	100	25		599
		CS-20-DK	165	2300-3000	40	200	100	25		791
		Walki	146	1900-2800	42	270	100	0		700
		Local Faba bean	167	1800-3000	12	270	100	25		801

No	Crop	Variety	Maximum LGP (Days)	Altitude range (masl)	Yield (qt/ha)	Seed rate (Kg/ha)	Fertilizer - DAP (Kg/ha)	Fertilizer - Urea (Kg/ha)	Spacing, cm	Maximum water requirement (mm/season)
15	Field pea	GEDO-1	125	2000-2600	20	200	100	0		599
		LATU K	171	2300-3000	35	150	100	0		820
		BURKITU	163	2050-2800	38	150	100	0		782
		Adii	150	2300-3000	35	150	100	0		719
		Tegegnech	155	2000-3000	35	150	100	0		743
		Local Field pea	171	2000-3000	10	200	100	0		820
		arjo	120	2000-2600	25	150	100	0		
		bariso	130	1800-2600	28	75	100	0		
16	Chickpea	Worku	149	1900-2600	29	120	0	0		217
		Mariye	120	1800-23000	23	140	0	0		175
		Akuri	98	1450-2000	20	120	0	0		143
		KASECH	100	1450-2000	20	120	0	0		146
		Shasho	155	1800-2600	42	125	0	0		226
		Arerti	155	1800-2600	47	115	0	0		226
		Local Chickpea	155	1900-2600	13	140	0	0		226
17	Lentil	Alemaya 98	110	1600-2000	14	90	0	0		505
		Jiru	120	2000-2700	28	80	100	0		
		Local Lentil	110	1600-2000	14	90	0	0		505
		FLIP 96-46L	120	1800-2400	26	90	0	0		
		Alem Tena	120	1600-2000	17	90	0	0		
18	Haricot bean	SARI-1	90	1400-2250	20	70	100	0		432
		SAB 736	90	1000-1200	25	100	100	50		
		Morka	115	1300-2200	26	90	100	60		551
		GLP-2	90	100-1950	26	90	100	60		432
		Nasir	124	1200-1800	17	100	100	0		595
		Red Wolaita	110	1400-2250	26	100	100	50		528
		Melka Awash-98	95	1400-1900	25	100	100	0		456
		Awash	90	1400-1800	26	100	100	50		432
		Hawassa Dume	90	1100-1750	20	60	100	0		432

No	Crop	Variety	Maximum LGP (Days)	Altitude range (masl)	Yield (qt/ha)	Seed rate (Kg/ha)	Fertilizer - DAP (Kg/ha)	Fertilizer - Urea (Kg/ha)	Spacing, cm	Maximum water requirement (mm/season)
		Mexico 142	110	1500-1800	20	100	100	50		528
		Local Haricot bean	115	1500-2250	15	100	100	50		551
		Tibe	103	1300-1900	27	60	100	0		
		Haramaya	114	1650-2200	30	60	0	0		
19	Soya bean	KORME	137	1200-1900	32	75	100	0		657
		KATTA	138	1200-1900	28	75	100	0		662
		ETHIO-YUGOSLAVIA	154	1000-1200	30	75	100	100		739
		Williams	120	1000-1700	30	75	100	100		575
		Local Soya bean	154	1200-1900	12	75	100	100		739
		Awassa 95	120	1520-1800	25	60	100	0		
20	Grass pea	Wasie	118	1700-2800	20	90	0	0		566
		Local Grass bean	118	1700-2800	20	90	0	0		566
21	Mung bean	Rasa	80	900-1670	10	20	100	60		350
		MH-97-6	80	1100-1750	10	40	100	0		350
		Local Mung bean	80	900-1750	7	40	100	46		350
22	Cow pea	Sewinet	93	1000-1600	22	28	100	0		407
		Bole	95	1350-1850	17	20-40	100	50		
		Local Cow pea	93	1000-1600	22	28	100	0		407

No	Crop	Variety	Maximum LGP (Days)	Altitude range (masl)	Yield (qt/ha)	Seed rate (Kg/ha)	Fertilizer - DAP (Kg/ha)	Fertilizer - Urea (Kg/ha)	Spacing, cm	Maxium water requirement (mm/season)
23	Fenugreek	hunda-01	156	1650-2004	6	29	0	0		748
		Chala	128	1700-2600	15	45	0	0		614
		Local Fenugreek	156	1650-2600	13	45	0	0		748
24	Noug	Kuyu	147	1600-2200	4	25	0	0		705
		Fogera	174	1600-2200	4	25	0	0		834
		Local Noug	174	1600-2200	4	25	0	0		834
25	Linseed	CI-1652xOmega /23(Jeldu)	180	1800-2800	11	25	50	50		826
		Chilalo(Kulumsa 1)	141	2000-2800	16	25	50	50		647
		Belay-96	144	2200-2600	12	25	0	0		661
		Chilalo	140	2200-2600	12	25	0	0		642
		CI-1652	204	2200-2600	9	25	0	0		936
		CI 1525	146	2200-2600	14	25	0	0		670
		Local Linseed	180	1600-2800	10	25	0	0		826
26	Rapeseed	Muger	161	2000-2600	3	10	150	41		772
		Tule	152	2000-2600	15	10	150	41		729
		Yellow dodolla	156	2000-2600	17	10	0	0		748
		Local Rapeseed	161	2000-2600	10	10	0	0		772
27	Sesame	Setite	90	560-1130	90	3	0	0		413
		Humera-1	100	760-1130	80	3	0	0		459
		Lidan	90	100-500	80	7	0	0		413
		AHADU	115	750-950	10	5	0	0		528
		Adi	90	100-750	80	10	0	0		413
		Abasen	120	500-1200	80	10	0	0		550
		Local Sesame	115	100-1200	8	10	0	0		528
28	Groundnut	Werer-961	127	750-1650	20	68	0	0	10 x 60	609
		Werer-962	130	750-1650	20	99	0	0		623
		Local Groundnut	130	750-1650	11	99	0	0		623
29	Sunflower	KAZANOVA (Hybrid)	110	100-4800	30	5	80	80		528

No	Crop	Variety	Maximum LGP (Days)	Altitude range (masl)	Yield (qt/ha)	Seed rate (Kg/ha)	Fertilizer - DAP (Kg/ha)	Fertilizer - Urea (Kg/ha)	Spacing, cm	Maxium water requirement (mm/season)
		NS-H-45 (Hybrid)	135	100-4800	35	5	80	80		647
		NS-H-111(Hybrid)	115	100-4800	35	5	80	80		551
		Oissa	150	520-2200	18	5	80	80		719
		Local Sunflower	150	100-4800	12	5	80	80		719
		Turkana	145	1500-2000		20	50	50		695
		Local Safflower	145	1500-2000		20	50	50		-
		Boke Kuni	183	1800-1980	6	10	50	50		-
30	Vernonia	Local Vernonia			0					-
		Abaro	150	700-2000	24	15	0	0		-
31	Castor	Local Castor			0					-
		Bubu	99	1650-2330	210	1800	150	119	35 X 70	475
32	Irish potato	Gudanie	120	1600-2800	210	2000	423	193		575
		Jalenie	120	1600-2800	291	2000	423	193		575
		Local Irish potato	120	1600-2800	82	2000	423	193		575
		gabisa	110	1700-2700	310	1800	250	160		
		Hundee	133	2400-3350	500	2000	200	160		

No	Crops	Variety	Maximum LGP (Days)	Altitude range (masl)	Yield (qt/ha)	Seed rate (Kg/ha)	Fertilizer - DAP (Kg/ha)	Fertilizer - Urea (Kg/ha)	Spacing, cm	Maxium water requirement (mm/season)
33	Sweet potato	Ma'e	120	500-750	334	10	0	0	40 X 100	575
		Jari	133	1650-1850	165	10	0	0		638
		Birtukanie (Saluboro)	150	1650-1850	114	10	0	0		719
		BERKUME	195	1650-2000	204	10	0	0		935
		ADU(Cuba 2)	180	1650-2000	204	10	0	0		863
		Local Sweet potato	195	500-2000	84	10	0	0		935
		temesgen	120	1200-2200	150	55555	0	0		
34	Taro	Kiyaq	300	1200-1800	450	*	*	*		1,376
		Denu	300	1200-1800	640	*	*	*		1,376
		Local Taro	300	1200-1800	77	*	*	*		1,376
35	Tomato	Rainbow	105	1000-2300	499	0.15	70	220	45 X 100	504
		Galilea	105	1000-2300	659	0.15	70	220		504
		Bridget 40	105	300-2000	539	0.15	70	220		504
		Anna F1	105	850-2100	478	0.15	70	220		504
		EDEN F1	105	950-2300	485	0.15	70	220		504
		TOPSPIN F1	105	1500-2200	550	0.15	70	220		504
		Barnum	141	850-2100	285	0.15	70	220		676
		Melka Shola(Red Pear)	105	850-1800	499	0.15	70	220		504
		Melka Salsa (Serio)	105	850-1800	499	0.15	70	220		504
		Commonly circulated Tomato	141	300-2300	81	0.15	70	220		676
		fetane	75	500-2000	454					
		Marglobe	110		300					
		Money maker	120		300					
		Roma VF	100		350					
36	Garlic	Kuriftu	140	2100-2400	41	1200	92	0	10 X 30	584
		Qoricho	138	1900-3350	20	400	200	0		575
		Bishoftu Netch	132	1900-2400	79	1200	92	0		550
		Tsedey 92	138	1900-2400	85	1200	92	0		575

No	Crops	Variety	Maximum LGP (Days)	Altitude range (masl)	Yield (qt/ha)	Seed rate (Kg/ha)	Fertilizer - DAP (Kg/ha)	Fertilizer - Urea (Kg/ha)	Spacing, cm	Maxium water requirement (mm/season)
		Local Garlic	141	2100-3350	20	400	200	0		588
		Holeta (G-HC)	128	> 1800	65	8-12	200	150		
37	Onion	Red Passion F1	110	1500-2200	450	3	90	160	10 X 30	321
		Sivan	105	400-2000	478	3	100	250		306
		Jamber F1	90	540-1750	560	3.5	200	120		263
		Red King	100	750-2250	556	3	100	250		292
		Adama Red	130	700-2000	200	4	100	250		379
		Melkam	135	1100-1800	485	3	100	250		394
		Bombie red	135	1100-1800	485	3	100	250		394
		Nafis (Franciscana)	100	500-2200	300	5	200	100		292
		Neptune	105	500-2000	570	3	100	250		306
		Commonly circulated Onion	135	500-2250	96	5	200	250		394

No	Crops	Variety	Maximum LGP (Days)	Altitude range (masl)	Yield (qt/ha)	Seed rate (Kg/ha)	Fertilizer - DAP (Kg/ha)	Fertilizer - Urea (Kg/ha)	Spacing, cm	Maxium water requirement (mm/season)
38	Shallot	Minjar	101	1600-2000	255	1000	0	0		421
		Yhera(Vethalam)	115	500-2500	250	1000	100	74		480
		Negele	109	2000-4800	432	1000 or 2.5 seed	92	105		455
		Huruta	111	1800-2400	84	1000	100	74		463
		Local Shallot	115	2000-4800	84	1000	92	105		480
39	Chili pepper	Melka Shote	114	1000-2200	25	0.7	200	100	40 X 60	499
		Melka Awaze	100	1000-2200	20	0.7	200	100		438
		Oda Haro	139	1400-2200	12	0.7	200	100		609
		Melka Zala	135	1200-2200	19	0.8	0	0		591
		Commonly circulated Chili pepper	139	1000-2200	12	0.8	200	100		609
40	Sweet/hot pepper	Serenade	70	300-2000	94	5	0	0	40 X 60	306
		Melka Dima(Papri king)	130	100-1900	94	5	0	0		569
		Melka Eshet (Papri Queen)	110	100-1900	94	5	0	0		482
		Commonly circulated pepper	130	100-2000	22	5	0	0		569
41	Head Cabbage	K500	75	1300-2500	330	0.3	110	235	40 X 60	328
		OXYLUS F1	75	750-1560	327	0.15	110	235		328
		VICTORIA F1	75	830-1780	320	0.15	110	235		328
		ROTONDA F1	85	1500-2200	600	0.55	110	235		372
		THOMAS F1	80	1500-2200	580	0.55	110	235		350
		LUCKY F1	75	1500-2200	220	0.3	60	225		328
		Commonly circulated Head Cabbage	85	750-2200	220	0.55	110	235		372
42	Carrot	SAMSON	112	1500-2200	250	3	100	125	5 X 25	490
		Commonly circulated Carrot	112	1500-2200	250	3	100	125		490

No	Crops	Variety	Maximum LGP (Days)	Altitude range (masl)	Yield (qt/ha)	Seed rate (Kg/ha)	Fertilizer - DAP (Kg/ha)	Fertilizer - Urea (Kg/ha)	Spacing, cm	Maxium water requirement (mm/season)
43	Coriander	INDIUM 01	125	1600-2300	9	35	0	0		521
		Walta-1	135	1650-2004	5	30	0	0		563
		Local Coriander	135	1600-2300	5	35	0	0		563
44	Black pepper	TATO	240	300-1500	2	0.7	200	100		1,051
		GACHEB	240	300-1500	3	0.7	200	100		1,051
		Commonly circulated Black pepper	240	300-1500	2.3	0.7	200	100		1,051
45	Ginger	YALI	300	100-1750	241	250	200	100		1,251
		BOZIAB	300	100-1750	214	250	200	100		1,251
		Local Ginger	300	100-1750	214	250	200	100		1,251

No	Crops	Variety	Maximum LGP (Days)	Altitude range (masl)	Yield (qt/ha)	Seed rate (Kg/ha)	Fertilizer - DAP (Kg/ha)	Fertilizer - Urea (Kg/ha)	Spacing, cm	Maxium water requirement (mm/season
46	Turmeric	DAMEY	300	100-2000	30	250	0	0		1,251
		Local Turmeric	300	100-2000	30	250	0	0		1,251
47	Pigeon pea	Dursa	130	1000-1650		60	40	0		623
		Local Pigeon pea	130	1000-1650		60	40	0		623
48	Oat	Bonsa	149	2300-3000	27.6	80	100	50		715
		Bona bas	164	2300-3000	19.6	80	100	50		786
		CI-8237	120	2300-3000	9	100	0	0		575
		Local Oat	164	2300-3000	9	100	0	0		786
49	Cotton	YD206	134	400-1100	46	15	0	0		626
		YD211	133	400-1100	43	15	0	0		621
		YD223	133	400-1100	16.2	15	0	0		621
		Ionia	135	700-800	29	*	*	*		631
		NEBAH	125	700-800	14.3	*	*	*		584
		Deltapine 90	150	300-1000	40	*	*	*		701
		Acala 1517/70	135	300-800		*	*	*		631
50	Banana	williams-1	543	< 1500	556qt (Research)				2.5x2.5	
		Grand Nain	523	< 1500	436qt (Research)					
		poyo	flowering to harvest 160 days	< 1500	481qt (Research)					
		giant cavandish	516	< 1500	372qt (Research)					
		Dwarf cavandish	flowering to harvest 160 days	< 1500	531qt (Research)					
		giant cavandish	516	< 1500	372qt (Research)					
		ducasse hybrid	502	<2000	260					
51	Pineapple	Smooth cayenne	14-20months	1200-1800	400 (farmers)	44444	1400-1800mm		90x60x 30	
52	Avocado	Hass		<2000	223		>1000mm		6mx6m	
		Ettinger		1500-2500	342		>1000mm			
		Pinkerton		<2000	138					
		Nabal		<2000	154					
		Fuerte		1500-2700	257		>1000			

APPENDIX XI: Summarized description of the major agro-ecological zones of Ethiopia

Major agro-ecology zone	Symbol	Altitude m.a.s.l	Mean Temp °C	Mean Rainfall mm	LGP In days	Soils	Crops grown	Potential devt	Areas
Hot arid lowland plains	A_1	126 - 500	27	100-400	<45	Caclcisols, Gypsisols, Fluvisols,	Cotton, sorghum, maize, banana, citrus,	Livestock, irrigation, incense	North Afar, South Somali RNS
Warm arid lowlands	A2	0 - 1400	21 – 27.5	100-600	< 45	Solonchaks, Calcisols, Fluvisols	Cotton, sorghum, maize, banana, citrus,	Livestock, irrigation, incense	South Afar, North Ogaden
Tepid arid mid highland	A3	500-1200	16 - 20	350 - 800	< 45	Eutric Regosols, Eutric Vertisols, Eutric Cambisols	Sorghum, maize and chat	Livestock rearing	Lefa Isa in Soamli RNS
Hot Semi-arid lowlands	SA1	500 – 1000	>27	300 - 800	~ 60	Vertisol *Fiuvisols* and *Leptosols*	*Accacia spp**	Eco-trousim	Arround Lake Turkana SNNPR
Warm semi-arid lowlands	SA2	400-1500	21 – 27.5	300 - 800		Luvic Phaeozem, Eutric Regosols	Sorghum, maize, papaya, and banana	Livestock production	NW Tigray, SW Moyale
Tepid semi-arid mid highland	SA3	1600-2200	16 - 20	--	46 - 60	Eutric Regosols and Leptosols	Accacia spp, Balanite Aegyptica etc	Livestock production	Rift Valley
Hot sub-moist lowlands	SM1	400 - 1000	27	200 - 1000	61- 120	Nitosols, Cambisols, Fluvisols and Leptosols	*Accaecia spp, Balanities Spp*, and *- abysinica.*	Livestock production	Southern Somali RNS
Warm sub-moist lowland	SM2	400-1400	21 - 27	--	61- 120	Vertisols, Nitosols, Cambisols and Leptosols	*Oxytenathera abysnica* and *Accacia species*	Sesame, cotton, sorghum, kenaf etc	West Amhara, SE oromia NRSs
Tepid sub-moist mid highlands	SM3	1000 - 2000	16 - 21		61- 120	Camblsols, Vertisols with inclusion of Fluvisols	*Accacia species*	Rainfed agriculture	E and NE Tigray NRS
Cool sub-moist mid highland	SM4	1400 - 2200	11 - 15		61- 120	Leptosols and Cambisols	*Accacia and Balanities species*	Eco-trousim	In Amhara NRS
Cold sub-moist mid highland	SM5	2800 - 3200	7.5 -10		61-120	Humic Andosols and Leptosols	*Juniperus procera, Erica arborea, Hagenia abyssinica,*	high potential for afforestation and low potential for	In mid highlands of Amhara NRS

Major agro-ecology zone	**Symbol**	**Altitude m.a.s.l**	**Mean Temp °C**	**Mean Rainfall mm**	**LGP In days**	**Soils**	**Crops grown**	**Potential devt**	**Areas**
							Hypericum revolutum and *Olea europae*	agriculture	
Very cold sub-moist mid highlands	SM6	2800 - 4200	<7.5		61-120	Andosols, Leptosols and Cambisols	*Juniperus procera, Erica arborea, Hagenia abyssinica, Hypericum revolutum* and *Olea europae*	For biodiversity reserve	In Amhara NRS
Hot moist lowlands	M1	400 - 1500	>27		121-180	Nitosols and Cambisols	Accacia	Livestock rearing and irrigated agriculture	Omorate in SNNPR
Warm moist lolands	M2	400 - 1500	21 - 27		12 -180	Cambisols	Accacia	Wild life reserve and tourism.	North Moyale, SW Afar RNS
Tepid moist mid highlands	M3	1000 - 2000	16 - 21		121-180	Cambisols	Cereal production	Agriculture and livestock production	In Amhara, Oromia, SNNPR
Cool moist mid highland.	M4	1000 - 2100	11 - 15		121-180	Leptosols	Vegetation of Hagena, Olea, Ficus, Croton, Cordia etc species	Forestry production	In Amhara, Oromia,
Cold moist sub afro-alpine to afro-alpine	M5	2600-2800	7.5 - 10			Cambisols, Andosols, Leptosols	Hagenia, Cordia, Ficus species	Eco-tourism.	In Adiarkay Chewber in Amhara NRS
Very cold moist sub afro-alpine to afro-alpine	M6	2800 - 3000	<7.5	1000-1800		Leptosols	*Hagenia abyssinica*, *Cordia*, *Podocurpus*, etc	Wildlife conservation and eco-tourism.	North Amhara NRS
Hot sub-humid lowlands	SH1	1000 - 2000	27	1000-2000	180-240	Vertisols and Nitosols	*Comberatum molle*, *Accacia* species	Mechanized farming and wild life conservation	Gambella NRS
Warm sub-humid lowlands	SH2	1000-2000	21 - 27		181-240	Nitosols, Vertisols and Leptosols	*Accacia, Combratum, Oxyteranthera abyssinica*	Oil crops, and cotton production	BG NRS, western Oromia

Major agro-ecology zone	Symbol	Altitude m.a.s.l	Mean Temp °C	Mean Rainfall mm	LGP In days	Soils	Crops grown	Potential devt	Areas
Tepid sub-humid mid highlands	SH3	2000 - 2800	16 - 21		181-240	Fluvisols and Cambisols	*Accacia* spp, *Comberatum* spp	vegetables, fruits, cereals production and wildlife conservation	BG NRS, western Oromia
Cool sub-humid mid highlands	SH4	1600-3200	11 - 15	900-1200	181-240	Vertisols, Nitosols, Cambisols	*Podocarpus gracilior, Croton mychrostachys, Cordia africana, Junieperus procera, Hagenia* etc	Mainly for crop and livestock production	Oromia NRS and SNNPR
Cold sub-humid sub-afroalpine to afroalpine	SH5	2600-3200	7.5-10		181-240		*Podocurpus, Croton, Junieprus*	Forest production	SE Chencha in SNNPR & Jima zone Oromia Region
Very cold sub-humid sub-afroalpine to afroalpine	SH6	3200-4300	<7.5	700-1500	181-240	Leptosols, Nitosols and Vertisols		Forestry and wildlife production	Mountain Guge in SNNPr SW Omo nada
Tepid humid mid highlands	H3	2000 - 3000	16 - 21	900 - 2000	241-300	Vertisols, Luvisols, Cambisols and Leptosols		Cereal production and forestry	Oromia NRS
Cool humid mid highlands	H4	1800-3200	11 - 15	700 - 2200		Nitosol, Vertisol and Cambisol	Intensively cultivated to moderately cultivated land and high forest, wood land and bush land	Forest production, wildlife conservation and tourism	Oromia NRS
Cold humid sub-afroalpine to afroalpine	H5	3000 - 4000	7.5 - 10	700 - 2000	241-300	Cambisol and Leptosols	Open bush, shrub and grass land.	Eco-tourism	Arsi zone in Oromia NRS
Very cold humid sub-afroalpine to afroalpine	H6	3000 - 4200	<7.5	1000 - 2200	241-300	Cambisol	High forest, dense bush and shrub land	Eco-tourism	Bale zone in Oromia NRS
Hot per-humid	PH1	800- 1000	>27	1000	>300	Vertisols and	*Balanites aegyptica,*	Forestry	In SNNPr &

Major agro-ecology zone	Symbol	Altitude m.a.s.l	Mean Temp °C	Mean Rainfall mm	LGP In days	Soils	Crops grown	Potential devt	Areas
lowlands						Cambisols	*Erythrina*	production	Gambella NRS
Warm Per-humid lowlands	PH2	800 -1200	21 - 27	1100-2200	>300	Nitosols, Vertisols, Cambisols and Fluvisols.	*Balanites aegyptica, Erythrina*	Forestry production	In SNNPR
Tepid per-humid mid highlands	PH3	1000-2600	16 - 21	1100-2200	>300	Nitosols, Vertisols, Cambisols and Fluvisols	*Enset*, coffee, banana, papaya, mango etc.	Agricultural and forestry development	In SNNPR

APPENDIX XII: Single crop coefficient (Kc) for different crops and mean maximum crop height

Crop	Kc ini1	Kc mid	Kc end	Maximum Crop Height (m)
a. Small Vegetables	**0.7**	**1.05**	**0.95**	
Broccoli		1.05	0.95	0.3
Brussel Sprouts		1.05	0.95	0.4
Cabbage		1.05	0.95	0.4
Carrots		1.05	0.95	0.3
Cauliflower		1.05	0.95	0.4
Celery		1.05	1	0.6
Garlic		1	0.7	0.3
Lettuce		1	0.95	0.3
Onions, dry		1.05	0.75	0.4
Onions, green		1	1	0.3
Onions, seed		1.05	0.8	0.5
Spinach		1	0.95	0.3
Radishes		0.9	0.85	0.3
b. Vegetables – Solanum Family (*Solanaceae*)	**0.6**	**1.15**	**0.8**	
Egg Plant		1.05	0.9	0.8
Sweet Peppers (bell)		1.052	0.9	0.7
Tomato		1.152	0.70-0.90	0.6
c. Vegetables – Cucumber Family (*Cucurbitaceae*)	**0.5**	**1**	**0.8**	
Cucumber – Fresh Market	0.6	1.002	0.75	0.3
Pumpkin, Winter Squash		1	0.8	0.4
Squash, *zuchini*		0.95	0.75	0.3
Sweet Melons		1.05	0.75	0.4
Watermelon	0.4	1	0.75	0.4
d. Roots and Tubers	**0.5**	**1.1**	**0.95**	
Beets, table		1.05	0.95	0.4
Cassava – year 1	0.3	0.803	0.3	1
– year 2	0.3	1.1	0.5	1.5
Parsnip	0.5	1.05	0.95	0.4
Potato		1.15	0.754	0.6
Sweet Potato		1.15	0.65	0.4
Sugar Beet	0.35	1.2	0.705	0.5
e. Legumes (*Leguminosae*)	**0.4**	**1.15**	**0.55**	
Beans, green	0.5	1.052	0.9	0.4
Beans, dry and Pulses	0.4	1.152	0.35	0.4
Chick pea		1	0.35	0.4
Faba bean (broad bean) – Fresh	0.5	1.152	1.1	0.8
– Dry/Seed	0.5	1.152	0.3	0.8
Green Gram and Cowpeas		1.05	0.60-0.35	0.4
Groundnut (Peanut)		1.15	0.6	0.4
Lentil		1.1	0.3	0.5
Peas – Fresh	0.5	1.152	1.1	0.5
– Dry/Seed		1.15	0.3	0.5
Soybeans		1.15	0.5	0.5-1.0
h. Oil Crops	**0.35**	**1.15**	**0.35**	

Crop	Kc ini1	Kc mid	Kc end	Maximum Crop Height (m)
Castorbean (*Ricinus*)		1.15	0.55	0.3
Rapeseed, Canola		1.0-1.159	0.35	0.6
Safflower		1.0-1.159	0.25	0.8
Sesame		1.1	0.25	1
Sunflower		1.0-1.159	0.35	2
i. Cereals	**0.3**	**1.15**	**0.4**	
Barley		1.15	0.25	1
Oats		1.15	0.25	1
Wheat	0.4,0.711	1.15	0.25-0.41	1
Maize, Field (grain) *(field corn)*		1.2	0.60,0.35	2
Maize, Sweet *(sweet corn)*		1.15	1.05	1.5
Millet		1	0.3	1.5
Sorghum – grain		1.00-1.10	0.55	2
– sweet		1.2	1.05	2
Rice	1.05	1.2	0.90-0.60	1
j. Forages				
Alfalfa Hay – averaged cutting effects	0.4	0.9514	0.9	0.7
– individual cutting periods	0.4015	1.2015	1.1515	0.7
– for seed	0.4	0.5	0.5	0.7
Bermuda hay – averaged cutting effects	0.55	1.0014	0.85	0.35
– Spring crop for seed	0.35	0.9	0.65	0.4
Clover hay, Berseem – averaged cutting effects	0.4	0.9014	0.85	0.6
– individual cutting periods	0.4015	1.1515	1.1015	0.6
Rye Grass hay – averaged cutting effects	0.95	1.05	1	0.3
Sudan Grass hay (annual) – averaged cutting effects	0.5	0.9014	0.85	1.2
– individual cutting periods	0.5	1.15	1.1015	1.2
Grazing Pasture, Rotated Grazing	0.4	0.85-1.05	0.85	0.15-0.30
Grazing Pasture, Extensive Grazing	0.3	0.75	0.75	0.1
Turf grass, cool season16	0.9	0.95	0.95	0.1
Turf grass, warm season16	0.8	0.85	0.85	0.1
k. Sugar Cane	0.4	1.25	0.75	3
l. Tropical Fruits and Trees				
Banana – 1st year	0.5	1.1	1	3
– 2nd year	1	1.2	1.1	4
Cacao	1	1.05	1.05	3
Coffee – bare ground cover	0.9	0.95	0.95	3-Feb
– with weeds	1.05	1.1	1.1	3-Feb
Date Palms	0.9	0.95	0.95	8
Palm Trees	0.95	1	1	8

Crop	Kc ini1	Kc mid	Kc end	Maximum Crop Height (m)
Pineapple17 (multiyear crop) – bare soil	0.5	0.3	0.3	0.6-1.2
– with grass cover	0.5	0.5	0.5	0.6-1.2
Rubber Trees	0.95	1	1	10
Tea – non shaded	0.95	1	1	1.5
– shaded18	1.1	1.15	1.15	2
m. Grapes and Berries				
Berries (bushes)	0.3	1.05	0.5	1.5
Grapes –`Table or Raisin	0.3	0.85	0.45	2
– Wine	0.3	0.7	0.45	1.5-2
Hops	0.3	1.05	0.85	5
Almonds, no ground cover	0.40	0.90	0.6519	5
Apples, Cherries, Pears20				
· no ground cover, killing frost	0.45	0.95	0.70	4
· no ground cover, no frosts	0.60	0.95	0.75	4
· active ground cover, killing frost	0.50	1.20	0.95	4
· active ground cover, no frosts	0.80	1.20	0.85	4
Apricots, Peaches, Stone Fruit20,21				
· no ground cover, killing frost	0.45	0.90	0.65	3
· no ground cover, no frosts	0.55	0.90	0.65	3
· active ground cover, killing frost	0.50	1.15	0.90	3
· active ground cover, no frosts	0.80	1.15	0.85	3
Avocado, no ground cover	0.60	0.85	0.75	3
Citrus, no ground cover22				
70% canopy	0.70	0.65	0.70	4
50% canopy	0.65	0.60	0.65	3
20% canopy	0.50	0.45	0.55	2
Citrus, with active ground cover or weeds23				
70% canopy	0.75	0.70	0.75	4
50% canopy	0.80	0.80	0.80	3
20% canopy	0.85	0.85	0.85	2
Conifer Trees24	1.00	1.00	1.00	10
Kiwi	0.40	1.05	1.05	3
Olives (40 to 60% ground coverage by canopy)25	0.65	0.70	0.70	5-7

Source: FAO Irrigation Manual, 2006 Module 4: Crop water requirements and irrigation scheduling

First figure: Under high humidity (R Hmin > 70%) and low wind (U < 5, /sec).

Second figure: Under low humidity (R Hmin < 20 %) and strong wind (>5 m/sec).

APPENDIX XIII: Crop Coefficient for Four crop development stages

Crop	Crop Development Stages					Total growing period
	Initial	Crop development	Mid season	Late season		
Banana	0.4-0.5	0.7-0.85	1.0-1.0	0.9-1.0		0.7-0.8
Bean green	0.3-0.4	0.65-0.75	0.95-1.05	0.9-0.95		0.85-0.9
Bean dry	0.3-0.4	0.7-0.8	1.05-1.2	0.65-0.75		0.7-0.8
Cabbage	0.4-0.5	0.7-0.8	0.95-1.1	0.9-1.0		0.7-0.8
Cotton	0.4-0.5	0.7-0.8	1.05-1.25	0.8-0.9		0.8-0.9
Grape	0.35-0.55	0.6-0.8	0.7-0.9	0.6-0.8		0.55-0.75
Groundnut	0.4-0.5	0.7-0.8	0.95-1.1	0.75-0.85		0.75-0.8
Maize sweet	0.3-0.5	0.7-00.9	1.05-1.2	1.0-1.15		0.8-0.95
Maize grain	0.3-0.5*	0.7-0.85*	1.05-1.2*	0.8-0.95		0.75-0.9*
onion dry	0.4-0.6	0.7-0.8	0.95-1.1	0.85-0.9		0.8-0.9
onion green	0.4-0.6	0.6-0.75	0.95-1.05	0.95-1.05		0.65-0.8
Pea, fresh	0.4-0.5	0.7-0.85	1.05-1.2	1.0-1.15		0.8-0.95
Pepper fresh	0.3-0.4	00.6-0.75	0.95-1.1	0.85-1.0		0.7-0.8
Potato	0.4-0.5	0.7-0.8	1.05-0.2	0.85-0.95		0.75-0.9
Rice	1.1-1.15	1.1-1.15	1.1-1.3	0.95-1.05		1.05-1.2
Safflower	0.3-0.4	0.7-0.8	1.05-1.2	0.65-0.7		0.65-0.7
Sorghum	0.3-0.4	0.7-0.75	1.0-1.15	0.75-0.8		0.75-0.85
Soybean	0.3-0.4	0.7-0.8	1.0-1.15	0.7-0.8		0.75-0.9
Sugar beat	0.4-0.5	0.75-0.85	1.05-1.2	0.9-1.0		0.8-0.9
Sugarcane	0.4-0.5	0.7-1.0	1.0-1.3	0.75-0.8		0.85-1.05
Sunflower	0.3-0.4	0.7-0.8	1.05-1.2	0.7-0.8		0.75-0.85
Tobacco	0.3-0.4	0.7-0.8	1.0-1.2	0.9-1.0		0.85-0.95
Tomato	0.4-0.5	0.7-0.8	1.05-1.25	0.8-0.95		0.75-0.9
Water melon	00.4-0.5	0.7-0.8	0.95-1.05	0.8-0.9		0.75-0.85
Wheat	0.3-0.4	0.7-0.8	1.05-1.2	0.65-0.75		0.8-0.9
Alfalfa	0.3-0.4					0.85-1.05
Citrus clean weeding						0.65-0.75
Citrus no weeding control						0.85-0.9
Olive						0.4-0.6

First figure: Under high humidity (RH min > 70%) and low wind (U<5m/sec)
Second figure: Under low humidity (RH min > 20%) and strong wind (U>5m/sec)
Source: FAO, Irrigation and Drainage Paper 33, By J. Doorenbos, 1986, Rome

APPENDIX XIV: Ranges of maximum effective rooting depth (Zr), and soil water depletion fraction for no stress (p), for common crops

Crop	Maximum Root Depth 1 (m)	Depletion Fraction 2 (for ET ≈ 5 mm/day) p
a. Small Vegetables		
Broccoli	0.4-0.6	0.45
Brussel Sprouts	0.4-0.6	0.45
Cabbage	0.5-0.8	0.45
Carrots	0.5-1.0	0.35
Cauliflower	0.4-0.7	0.45
Celery	0.3-0.5	0.20
Garlic	0.3-0.5	0.30
Lettuce	0.3-0.5	0.30
Onions		
- dry	0.3-0.6	0.30
- green	0.3-0.6	0.30
- seed	0.3-0.6	0.35
Spinach	0.3-0.5	0.20
Radishes	0.3-0.5	0.30
b. Vegetables - Solarium Family *(Solanaceae)*		
Egg Plant	0.7-1.2	0.45
Sweet Peppers (bell)	0.5-1.0	0.30
Tomato	0.7-1.5	0.40
c. Vegetables - Cucumber Family (*Cucurbitaceae*)		
Cantaloupe	0.9-1.5	0.45
Cucumber		
- Fresh Market	0.7-1.2	0.50
- Machine harvest	0.7-1.2	0.50
Pumpkin, Winter Squash	1.0-1.5	0.35
Squash, Zucchini	0.6-1.0	0.50
Sweet Melons	0.8-1.5	0.40
Watermelon	0.8-1.5	0.40
d. Roots and Tubers		
Beets, table	0.6-1.0	0.50
Cassava		
- year 1	0.5-0.8	0.35
- year 2	0.7-1.0	0.40
Parsnip	0.5-1.0	0.40
Potato	0.4-0.6	0.35
Sweet Potato	1.0-1.5	0.65
Turnip (and Rutabaga)	0.5-1.0	0.50
Sugar Beet	0.7-1.2	0.553
e. Legumes *(Leguminosae)*		
Beans, green	0.5-0.7	0.45
Beans, dry and Pulses	0.6-0.9	0.45
Beans, lima, large vines	0.8-1.2	0.45
Chick pea	0.6-1.0	0.50
Fababean (broad bean)		
- Fresh	0.5-0.7	0.45
- Dry/Seed	0.5-0.7	0.45
Grabanzo	0.6-1.0	0.45
Green Gram and	0.6-1.0	0.45

Crop	Maximum Root Depth 1 (m)	Depletion Fraction 2 (for ET ≈ 5 mm/day) p
Cowpeas		
Groundnut (Peanut)	0.5-1.0	0.50
Lentil	0.6-0.8	0.50
Peas		
- Fresh	0.6-1.0	0.35
- Dry/Seed	0.6-1.0	0.40
Soybeans	0.6-1.3	0.50
f. Perennial Vegetables (with winter dormancy and initially bare or mulched soil)		
Artichokes	0.6-0.9	0.45
Asparagus	1.2-1.8	0.45
Mint	0.4-0.8	0.40
Strawberries	0.2-0.3	0.20
g. Fibre Crops		
Cotton	1.0-1.7	0.65
Flax	1.0-1.5	0.50
Sisal	0.5-1.0	0.80
h. Oil Crops		
Castorbean *(Ricinus)*	1.0-2.0	0.50
Rapeseed, Canola	1.0-1.5	0.60
Safflower	1.0-2.0	0.60
Sesame	1.0-1.5	0.60
Sunflower	0.8-1.5	0.45
i. Cereals		
Barley	1.0-1.5	0.55
Oats	1.0-1.5	0.55
Spring Wheat	1.0-1.5	0.55
Winter Wheat	1.5-1.8	0.55
Maize, Field (grain) *(field corn)*	1.0-1.7	0.55
Maize, Sweet *(sweet corn)*	0.8-1.2	0.50
Millet	1.0-2.0	0.55
Sorghum		
- grain	1.0-2.0	0.55
- sweet	1.0-2.0	0.50
Rice	0.5-1.0	0.204
j. Forages		
Alfalfa		
- for hay	1.0-2.0	0.55
- for seed	1.0-3.0	0.60
Bermuda		
- for hay	1.0-1.5	0.55
- Spring crop for seed	1.0-1.5	0.60
Clover hay, Berseem	0.6-0.9	0.50
Rye Grass hay	0.6-1.0	0.60
Sudan Grass hay (annual)	1.0-1.5	0.55
Grazing Pasture		
- Rotated Grazing	0.5-1.5	0.60
- Extensive Grazing	0.5-1.5	0.60

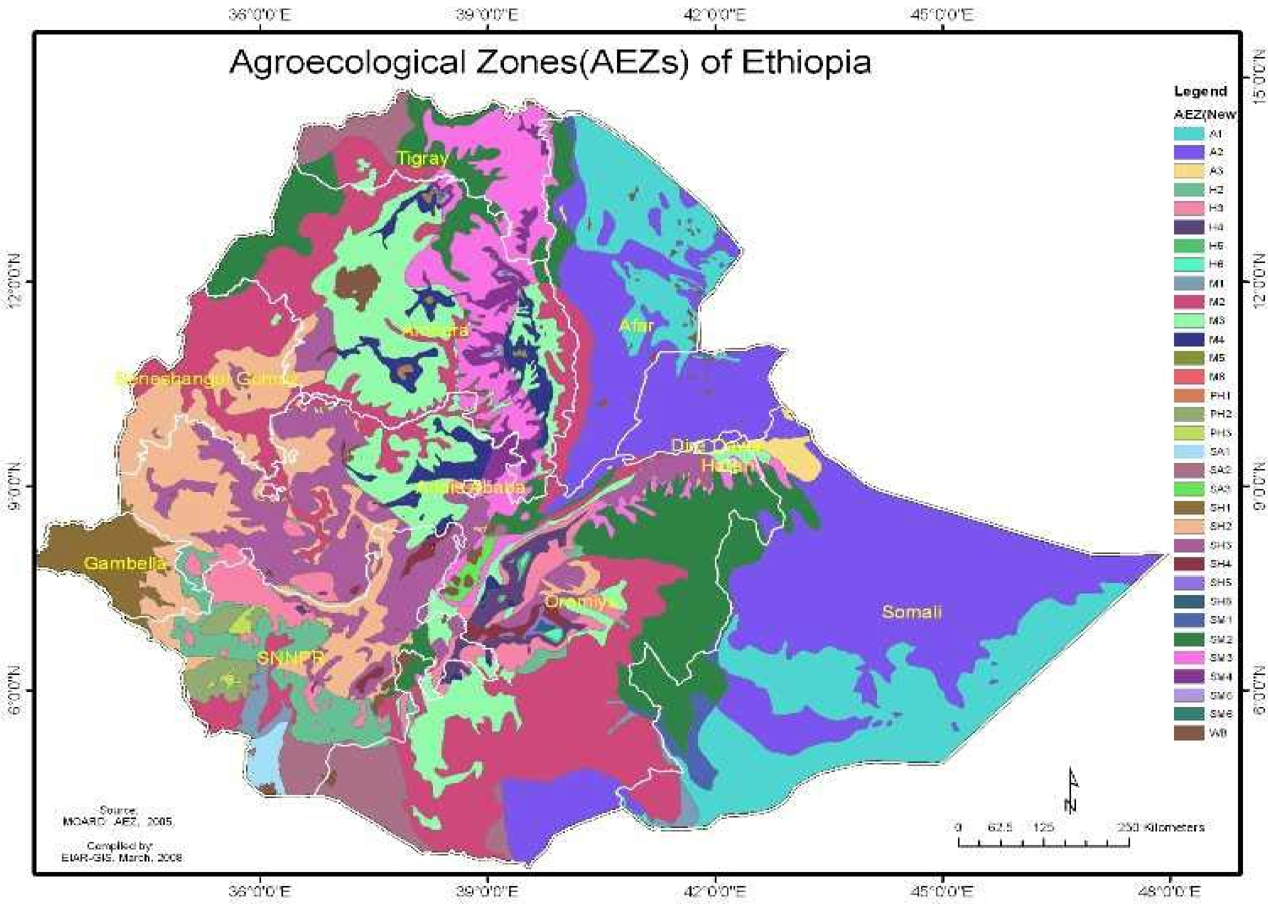
Crop	Maximum Root Depth 1 (m)	Depletion Fraction 2 (for ET ≈ 5 mm/day) p
Turf grass		
- cool season 5	0.5-1.0	0.40
- warm season 5	0.5-1.0	0.50
k. Sugar Cane	1.2-2.0	0.65
l. Tropical Fruits and Trees		
Banana		
- 1st year	0.5-0.9	0.35
- 2nd year	0.5-0.9	0.35
Cacao	0.7-1.0	0.30
Coffee	0.9-1.5	0.40
Date Palms	1.5-2.5	0.50
Palm Trees	0.7-1.1	0.65
Pineapple	0.3-0.6	0.50
Rubber Trees	1.0-1.5	0.40
Tea		
- non-shaded	0.9-1.5	0.40
- shaded	0.9-1.5	0.45
m. Grapes and Berries		
Berries (bushes)	0.6-1.2	0.50
Grapes		
- Table or Raisin	1.0-2.0	0.35
- Wine	1.0-2.0	0.45
Hops	1.0-1.2	0.50
n. Fruit Trees		
Almonds	1.0-2.0	0.40
Apples, Cherries, Pears	1.0-2.0	0.50
Apricots, Peaches, Stone Fruit	1.0-2.0	0.50
Avocado	0.5-1.0	0.70
Citrus		
- 70% canopy	1.2-1.5	0.50
- 50% canopy	1.1-1.5	0.50
- 20% canopy	0.8-1.1	0.50
Conifer Trees	1.0-1.5	0.70
Kiwi	0.7-1.3	0.35
Olives (40 to 60% ground coverage by canopy)	1.2-1.7	0.65
Pistachios	1.0-1.5	0.40
Walnut Orchard	1.7-2.4	0.50

Source: FAO Irrigation Manual, 2006 Module 4: Crop water requirements and irrigation scheduling

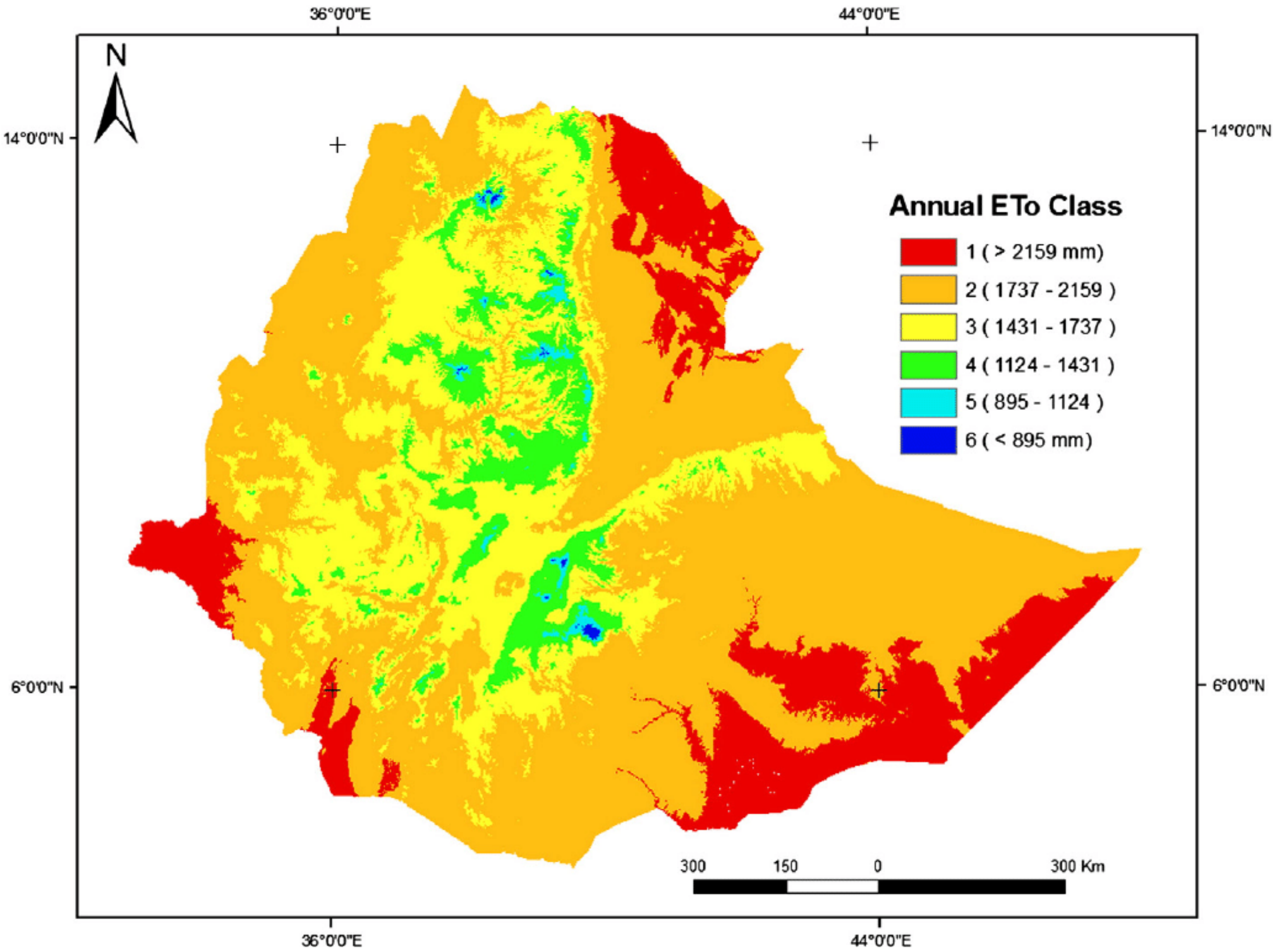
1 The larger values for Zr are for soils having no significant layering or other characteristics that can restrict rooting depth. The smaller values for Zr may be used for irrigation scheduling and the larger values for modeling soil water stress or for rainfed conditions.

2 The values for p apply for ETc ≈ 5 mm/day. The value for p can be adjusted for different ETc according to p = p table + 0.04 (5 - ETc), where p is expressed as a fraction and ETc as mm/day.

APPENDIX XV: Agro-ecological Zones Map of Ethiopia



APPENDIX XVI: Map of Annual Evapotranspiration Class



APPENDIX XVII: Maximum ecological amplitudes for some tropical crops

Common name	Life length	Tolerances			From FAO 33
		pH	Rainfall cm	Temp ^{o}C	Temp ^{o}C
Okra	Annual	5.1-7.8	30-250	13-27	
sisal	Perennial	5.0-8.3	20-260	15-27	
leek	Biennial*	5.2-8.3	40-270	7-23	
onion	Biennial*	4.5-8.3	30-410	6-27	15-20 (10-25)
garlic	Perennial*	4.5-8.3	30-260	6-27	
Giant taro	Perennial*	5.8-7.3	70-420	15-27	
Amaranths	Annual	5.2-7.5	70-270	8-27	
cashew	Perennial	4.3-7.5	70-410	19-28	
Pineapple	Perennial	3.5-7.8	70-410	16-28	
celery	Biennial*	4.2-8.3	30-460	5-27	
peanut	Annual	4.5-8.3	30-410	10-27	22-28 (18-33)
Bread fruit perennial	Perennial	5.9-8.0	70-400	17-27	
asparagus	Perennial	4.5-8.2	30-400	6-27	
cabbage	Biennial*	4.3-8.3	30-460	5-27	15-20 (10-24)
Chinese cabbage	Biennial*	4.3-6.8	70-410	15-27	
Pigeon pea	Perennial*	4.3-8.3	30-400	15-27	
Tea	Perennial	4.5-7.3	70-310	14-27	
pepper	Annual	4.3-8.3	30-460	9-27	18-23 (15-27)
papaya	Perennial	4.3-8.0	70-420	17-29	
pyrethrum	Perennial	5.2-7.5	70-260	8-27	
chickpea	Annual	5.5-8.6	30-250	6-27	
Cinnamon	Perennial	5.8-8.0	150-390	20-27	
watermelon	Annual	5.3-8.0	30-400	11-29	22-30 (18-35)
Sour orange	Perennial	4.8-8.3	20-400	13-28	
lemon	Perennial	4.8-8.3	30-410	11-28	
Grape fruit	Perennial	4.8-8.3	30-410	13-28	
Sweet orange	Perennial	4.3-8.3	30-410	13-28	Citrus 23-30 (13-35)
Coconut	Perennial	4.3-8.3	70-420	11-27	
Coffee	Perennial	4.3-8.0	80-460	11-27	
taro	Perennial*	4.3-7.4	70-410	11-29	
cucumber	Annual	4.3-8.3	20-460	6-27	
pumpkin	Perennial*	4.3-8.3	30-280	7-32	
turmeric	Perennial*	4.3-6.8	70-420	18-27	
Lemon grass	Perennial	4.3-7.3	70-410	18-27	
carrot	Biennial*	4.5-8.3	30-460	3-27	
African yam	Perennial*	5.1-5.8	140-280	23-27	
cardamom	Perennial	4.8-7.4	70-420	21-27	
strawberry	Perennial*	4.5-8.3	30-260	5-21	
soybean		4.3-8.2	40-410	7-29	20-25 (18-30)
cotton	Annual	4.3-8.3	30-270	7-32	20-30 (16-35)
sunflower	Annual	4.5-8.3	20-400	6-27	18-25 (15-30)
kenaf	Annual	4.5-7.4	50-400	13-27	
rubber	Perennial	4.3-8.0	110-420	23-28	
Sweet potato	Perennial*	4.3-8.3	30-460	9-27	
Lablab bean	Perennial*	5.9-7.8	20-250	9-27	

Common name	Life length	Tolerances			From FAO 33
		pH	Rainfall cm	Temp °C	Temp °C
lettuce	Biennial*	4.2-8.3	30-410	5-27	
flax	Annual	4.8-8.3	30-130	6-25	
tomato	Perennial*	4.3-8.3	30-460	6-27	18-25 (15-28)
mango	Perennial	4.3-8.0	20-420	17-29	
cassava	Perennial	4.3-8.0	50-400	15-29	
alfalfa	Perennial	4.3-8.3	20-250	5-25	
Moringa tree	Perennial	5.7-7.4	70-400	19-29	
Velvet bean	Annual	5.1-6.8	70-310	17-27	
banana	Perennial	4.3-8.3	70-260	18-27	25-30 (15-35)
tobacco	Tobacco	4.3-8.3	30-400	7-27	20-30 (15-35)
olive	Perennial	5.3-8.6	30-170	13-23	
rice	Annual	4.3-8.3	50-420	9-29	22-30 (18-35)
Passion fruit	Perennial	4.3-8.0	70-420	15-29	
Pear millet	Annual	4.5-8.3	20-260	9-27	
avocado	Perennial	4.3-8.3	30-410	13-27	
Lima bean	Annual	4.3-8.3	30-420	9-27	
Common bean	Annual	4.3-8.3	30-460	5-27	15-20 (10-27)
Black pepper	Perennial	4.3-7.4	70-420	20-27	
guava	Perennial	4.3-8.3	20-420	15-29	
Sugarcane	Perennial	4.3-8.3	50-420	16-27	122-30 (15-35)
eggplant	Perennial*	4.3-8.3	20-420	7-27	
potato	Perennial*	4.3-8.3	30-460	4-27	15-20 (10-25)
sorghum	Perennial*	4.5-8.3	40-310	8-27	24-30 (15-35)
clove	Perennial	6.8-7.3	70-400	24-26	
cacao	Perennial	4.3-7.4	70-420	18-28	
vanilla	Perennial	4.3-8.0	70-420	19-28	
Mung bean	Annual	4.3-8.3	40-410	8-27	
cowpea	Annual	4.3-8.3	30-410	13-27	
corn	Annual	4.3-8.3	30-400	5-29	
Grape					20-255-30)
Miaze					24-30 (15-35)
Pea					15-18 (10-23)
Wheat					15-20 (10-25)

Source: www.Ecocommunity.site.com

Doorenbos, J., and A.H, Kassem. Yield response to water. Irrigation and drainage paper No. 33, FAO, Rome 1986; " *" grown as annual

Figures in bracket are minimum and maximum ranges

APPENDIX XVIII: Compost preparation

It is an important organic fertilizer can be prepared from easily available crop residues and other decomposed materials.
The following five points should be taken into consideration in compost preparation.

- **Transportation:** The heap should be situated as close as possible to the source of organic materials and where the compost to be used to save times and labor in transport of organic materials and compost.
- **Space around the heap:** There should be enough space around the heap to enable the compost to be turned or examined: a space about 2 to 3 times that of the heap itself is the most practical.
- **Air :** Remember that the materials in the heap should be able to get enough air. Therefore, do not put the compost heap right up against a wall or dike so that it could be possible to walk around the heap easily.
- **Vermin:** A compost heap should always be outside, and not too close to living accommodation or stables.
- **Moisture:** The heap should be protected against drying out
    - A shade place out of the wind is ideal
    - A water source near the heap is convenient for sprinkling if too dry weather
    - Under wet conditions the heap will have to be protected against excess water
    - A compost heap under a shade tree will be well protected against excess water
    - Both dry and wet weather conditions are likely to play an important role in determining a suitable place for making a compost heap

Size and setting up of the heap

Size: the heap has to conform to a certain size; if too broad or too high, aeration is poor.

- A good basic size is 2 to 2.5 meters wide and 1.5 to 2 meters in height
- The length depends on the quantity of organic materials but it is better to make a shorter heap quickly than a longer heap slowly
- It is strongly advised to start with a heap greater than one cubic meter, otherwise, the temperature in the heap remains low and decomposition is too slow and incomplete

Setting up: start the heap by the foundation of coarse plant materials so that;

- The outside air can easily flow in and any excess water flows away more quickly
- Decomposition is easier if the materials put on in layers;
- Layers of easily decomposable material alternated with material difficult to decompose
- The individual layers should be preferably not be thicker than 10 cm for plant materials and 2 cm for manure

Composting Methods
There are many ways of making compost. The Indore and Bangalore methods are the common ones. The essential differences between the methods will be elaborated below taking into account the factors mentioned before, such as available material and weather conditions. However, the most suitable will depend on individual experience. In the long run, everyone should work out a method to suit oneself.

Indore Method of Composting
The Indore method is much used for compost in layers. The basis of the heap should consist of branches. The following successive layers are piled on top of this:

- A layer of about 10 cm material which is difficult to decompose
- A layer of about 10 cm material which decomposes easily
- A layer of 2 cm animal manure, if at hand
- A thin layer of soil which should come from the top layer of arable land to bring the right microorganisms to the heap.

- On top of these prepared layers, again 10 cm of difficult to decomposable and 10 cm of easily decomposable material, 2 cm manure and a thin layer of soil is added.

This has to be repeated until the heap has reached a final height of 1.5 to 2 meters. During decomposition, the heap has to be turned over regularly, so that it remains well aerated and all the material is converted into compost.

The first turning over process of the heap:
Should be done after 2 to 3 weeks

- The heap is broken down and built up again next to the old heap
- The layers are mixed and the heap is as it were, turned upside down and inside out
- Again, a foundation of coarse plant material is mad first
- Then the drier and outer, less decomposed part of the old heap is placed in the central part of the new heap
- The drier material will have to be watered before the heap can be built up further

The second turning over takes place after 3 weeks of the first turning over and it may even be necessary to turn the heap over again for a third time. Decomposition is complete if the plant material has changed into unrecognizable crumbly, dark masses. Under favorable conditions, the decomposition process in the Indore method takes there month, but under adverse conditions it may take longer than 6 months.

Bangalore Method
The heap is constructed in a similar way to the Indore method. Here too, a compost heap of several layers is set up in a week's time. It differs from the Indore method as follows: A few days after completion of the heap, it is completely covered with mud or grass sods, thus closing it off from outside air. Decomposition of organic material continues, but now other types of microorganisms keep the processing going. These microorganisms decompose the materials much more slowly. Therefore, it takes longer before compost is formed than in the Indore Method, although the quality of the compost is about the same. Compost should be used as quickly as possible; otherwise it will lose its fertility. To keep compost quality:

- The compost should be covered against rain and sun
- The rain-washes out the nutrients and the sun can cause burning
- Some useful covers are: banana leaves, or a sheet of plastic
- If the compost is left too long, it may also become a breeding place for unwanted insects

Compared to fertilizers compost contains considerably less nutrients, which are also much more gradually released to the plants. So, if compost is to be used for fertilizing, 2 to 5 tons per hectare are needed. However, compost has obvious advantages over chemical fertilizers:

- It contains an abundance of essential microelements
- The nutrients are made available for plant growth more slowly
- It improves the soil structure

Recommendation: For maize and hot pepper, 5t ha^{-1} compost with 35 kg urea ha^{-1} and 50 kg DAP ha^{-1}

Time and method of application: the compost and DAP applied at planting for maize and at transplanting for hot pepper. Urea is applied at 'babbaqaa' for maize, and one and half months of transplanting for hot pepper. If the shortage of inorganic fertilizers is encountered, sole application of compost at the rate of 5-tons ha^{-1} is economical. The same recommendation could be used for the other cereals and vegetables production

APPENDIX XIX: Major type of farming System of Ethiopia

Some of the major farming systems in Ethiopia are briefly described as follows to be used for reference in description of the farming system of the project area.

Highland cereals mixed farming system: It is the major crop production system in the highlands with altitude above 2300 m.a.s.l. receiving the high rainfalls that begin around June /July and small rains around mid of February to mid of May (Belg). Livestock production is an intrinsic part of the crop production system in which wide range of cereals, pulses and oil crops are grown on small farmers' plots. This farming system can be sub-divided in different sub-farming systems considering the major crops growing in the project area. For instance in extreme highland areas the farming system can be specified as barley based highland cereals mixed farming system in barley growing highlands.

Lowland cereals mixed Farming system: it is to a large extent a sedentary system of production in which crop and livestock productions are run side by side in lowland and dry mid highland areas. A wide spectrum of temporary and permanent crops is grown in both seasons. Lowland cereals maize, sorghum, and millet, are the major crops adopted and extensively produced in combination with pulses.

The pastoral/ agro-pastoral farming system: it is essentially a livestock production based system in which crop production is gaining momentum in recent times. Crops are grown with varying intensities in different parts depending on the moisture obtained during the major and small rainfall seasons that begin around March/April and August/ September respectively.

Perennials horticulture complex farming system: it is a mixed farming system in which perennial crops like enset, coffee, chat, root crops and fruits along with some cereal and pulses are produced through multiple cropping practices.

Commercial farming system: it is more specialized farming system mainly involved in production of cash crops or market oriented farming system. The farming system could have a sub-farming systems basically in reference to the size of the farm such as large-scale and smallholder commercial sub-farming systems. Vegetables are the major components of the farming system mainly produced for market due to favorable infrastructure.

Irrigated farming system: it's the production system supported with irrigation water supply system either traditional or modern scheme. In most cases the commercial farming and irrigated farming systems can be practiced in the same place due to the availability of water resources. It's characterized by highly intensive farming practices and high farm return. The agronomist can identify the farming system pertained in the command area during focus group discussion session.

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