Ministry of Agriculture
Sustainable Land Management Program

Climate Smart Agriculture
A Field Manual for Extension workers

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Addis Ababa

List of Acronyms

ARP	Adaptive Research Plan
BoO	Basket of Options
CA	Conservation Agriculture
CO_2	Carbon di Oxide
CO_2^e	Carbon di Oxide equivalent
CBPWDG	Community-Based Participatory Watershed Develoment Guideline
CRGE	Climate Resilient Green Economy
CSA	Climate Smart Agriculture
DA	Development Agent
ESMF	Environmental and Social Management Framework
FAO	Food and Agriculture Organization
FTC	Farmer Training Centers
GCCA	Global Climate Change Alliance
GDP	Gross Domestic Product
GHG	Green House Gases
IGA	Income generation activities
INDC	Intended Nationally Determined Contribution
ISFM	Integrated Soil Fertility Management
MoANR	Ministry of Agriculture
Mt	Million tonne
NAPA	National Adaptation Program of Action
NGOs	Non Governmental Organizations
SLMP	Sustainable Land Management Programme
SWC	Soil and Water Conservation
SWM	Soil and Water Management

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1. Background on Climate change and Agriculture

Climate change refers to a observable change in the climate of the earth that lasts for an extended period of time (30 years or longer). Climate change is mainly caused by emission of harmful gases known as greenhouse gases (GHG) such as methane, carbon dioxide, and nitrous oxide to the atmosphere due to human activities. Climate change is a major environmental and development challenge to the world today, with significant threats to ecosystems, food security, water resources and economic stability overall. Climate change is associated with extreme climate events such as droughts, floods, heat waves, untimely rains and strong winds and it has the potential to irreversibly damage the natural resource base on which agriculture depends, and in general adversely affects agricultural productivity (Reynolds, 2010). Climate change affects agriculture through changes in average temperatures, rainfall, and climate extremes; changes in pests and diseases conditions; and changes in the nutritional quality of foods among other (Niang et al., 2014).

Climate has a prominent role in Ethiopia, and climate extreme events such as droughts and floods are causing significant damage to life, property, natural resources and the country’s economy; making the most important economic systems highly vulnerable. Ethiopia is one of the countries that are most vulnerable to the impacts of climate change due to its dependence on agriculture (Kassie et al., 2013). The sensitivity of Ethiopia’s agriculture to climate arises from the fact that it is primarily rainfed and practiced by smallholder farmers who have limited capacity to respond to climate variability and extremes. Climate variability, particularly rainfall variability and associated droughts, have been major causes of food insecurity and famine in Ethiopia (Conway and Schipper, 2011). Frequent drought events caused sharp reductions in agricultural output and rural employment with multiplier effects on the economy and profound social impacts (Tesfaye et al., 2016). Climate change affects Ethiopia’s agriculture by adversely affecting both the crop and livestock sectors and the natural resource base. The negative impacts of climate change on the crop sectors include shortening of crop growing seasons, shrinking of suitable areas, declining crop productivity levels, aggravation of existing or new crop diseases and pests, and declining surface and subsurface water resources. Climate affects the livestock sector by affecting livestock feed availability and price; changes in livestock pastures and forage crop production and quality; changes in the distribution of livestock diseases and pests; and the direct effects of weather and extreme events on animal health, growth and reproduction (Smith et al. 1996; Valtorta, 2002). Climate change affects the natural resource by aggravating the causes of several land degradation factors (Tesfaye et al., 2016).

Because of these overwhelming impacts of climate change on agriculture and natural resources, Ethiopia is engaged in several climate change adaptation and resilience initiatives; one of which is climate smart agriculture (CSA). Therefore, this manual is developed to provide concepts, practices and implementation of CSA at different landscape levels.

2. Structure of the Manual

The Manual is divided in two sections: Section 1 describes the operational criteria and procedures to be applied for all CSA interventions. Section 2presents a detailed description of practicesthrough individual “infotechs”.

The “Infotechs” contain all necessary technical information (including specific norms for implementation) as a stand-alone fact sheet, and form the core element for field practitioners to advice farmers on CSA practices selected for the seven types of priority CSA interventions. As such they represent the basis for the planning and selection of practices as well as for budget calculations.

Several interventions have already been identified for the development of CSA in the context of Ethiopia’s SLMP. For each intervention, a specific Infotech has been developed based on current local and international knowledge. The infotech contains a list of recommended CSA practices. The infotechs are considered “living” documents, and as such are expected to be modified, updated and/or refined by the results and practical experience generated during the pilot phase of CSA implementation in selected SLMP watersheds. The initial infotechs developed cover the following intervention areas:

- **Agroforestry**(defined as land management involving growing of trees, including bamboo, in association with food crops or pasture)
- **Conservation agriculture** (Conservation Agriculture is a farming system that promotes maintenance of a permanent soil cover, minimum soil disturbance (i.e. reduced tillage), and diversification of plant species.)
- **Agro-biodiversity** and **Crop production (**includes a wide range of crop management practices as well as adoption of improved native varieties)
- **Integrated Soil Fertility Management (ISFM)**(specific to Composting and Acid soil management)
- **Improved forage development**(improved grass species, Browse species, Legumes and root crops etc)
- **Agricultural water management (**Basin, furrow and border-Irrigation, manual tube well, irrigation scheduling, crop-water requirement and community pond lined with Geo-membrane)
- **Climate Information and weather forecast and others**

3. Rationale and Scope of the Manual

3.1 Rationale

Ethiopia has developed different agricultural extension guidelines and manuals that guide the implementation of natural resources management and agricultural practices. However, the guidelines and manuals dedicated to cover specific topics such as SWC, agronomy, soil management, forestry, livestock forage management are lacking in addressing current and emerging issues such as climate smart initiatives. There is a growing drive to increase climate action through scaling up both climate change mitigation and adaptation interventions while maintaining agriculture production and productivity at an increasing trend until it reaches at equilibrium. The effect of climate change and variability on agricultural production requirespromoting CSA actions in an integrated approach to improve agricultural productivity, adaptation and ensure mitigation in sustainable manner.

Therefore, it is found necessary to prepare the CSA field manual that will guide the planning and implementation of climate-change responsive interventions(natural resources management, agriculture and related interventions) in an integrated manner using landscape approach so as to build climate resilient and sustainable agricultural production system, among others.

3.2 Scope of the Manual

The CSA Field Manual is complementary to the existing CBPWMG and livelihood development strategies. Many of the practices that make up CSA already exist in the guideline and are currently used by farmers in a fragmented manner to cope with various production risks. This manual focuses on mainstreaming climate change issues into the existing agricultural practices through improving their implementation approach. If CSA is implemented in highly degraded SLM watersheds, 75% of the watershed should be treated with biophysical measures. This ensures that the on-farm activities are fully integrated within the landscape and contribute towards the goal of making climate resilient landscapes. Note that the manual can assist the extention workers to implement CSA in watersheds at any stage of development by considering existing conditions on the ground.

This manual

- aims to contribute to making sustainable agricultural production system by exploiting opportunities and reducing risks of climate change in agriculture.
- is intended to help extension workers to guide farmers in the adoption of CSA practices. It will contribute to integrate a climate-smart approach that helps smallholder farmers to increase productivity and incomes, build resilience to climate change, reduce greenhouse gas emissions where possible, and ultimately, enhance national food security.
- describes the operational approach of integrating climate smart activities in a landscape. It provides tools and methodologies on how to plan, identify, operationalize and monitor climate smart agriculture practices.

4. Climate Smart Agriculture

4.1. Definition and Concepts of CSA

The term “climate-smart agriculture” (CSA) emerged in the course of the international debate on climate change as it soon became obvious that “business-as-usual” cannot be an option for tackling the impacts of climate change on agriculture and vice versa. Being both a significant contributor to GHG emissions and at the same time strongly affected by climate change, agriculture requires a substantial revision of methods and techniques of production. Climate smart agriculture (CSA) is an approach for transforming and reorienting agricultural development under the new realities of climate change (Lipper et al. 2014). The most commonly used definition is provided by FAO which defines CSA as “agriculture that sustainably increases Productivity, enhances resilience (Adaptation), and reduce/removes GHGs (Mitigation) where possible and thereby enhance achievements of national food security and development goals (Fig. 1). In short, CSA aims to promote the adoption of technically, financially and environmentally sound production practices, while incorporating resilience to climate effects and contributing to reduced GHG emissions. As opposed to conventional agricultural development which mainly focuses on production and productivity, income generation and food security, CSA systematically integrates climate change in terms of adaptation and/or mitigation objectives.

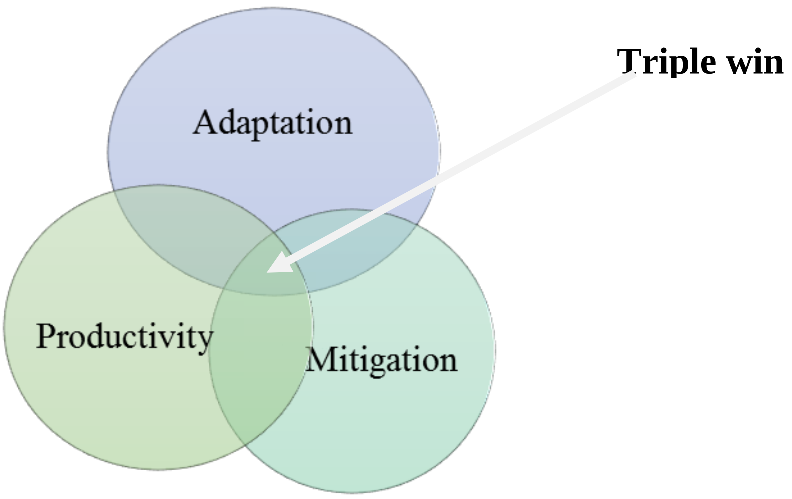

Fig.1: The three pillars of Climate-Smart Agriculture

4.2. Definition of the three pillars of CSA

The three pillars of CSA can be defined as follows:

Productivity: CSA aims to sustainably increase agricultural productivity and incomes from crops, livestock and fish while minimizing negative impacts on the environment.

Adaptation: CSA aims to reduce exposure of farmers, agropastoralists and pastoralists to short-term climatic variability, while also strengthening their resilience by building capacity to adapt to climate-related shocks in the longer term. Therefore, adaptation also refers to resilience which involves reducing vulnerability and risks, and improving ecosystem services (e. g. clean water, fertile soils) to farmers and society, which are also essential for maintaining productivity and the ability to adapt to climate change.

Mitigation: CSA is also expected to reduce and/or remove greenhouse gas (GHG) emissions wherever and whenever possible. This involves reducing emissions from production systems, avoid deforestation and manage soils and vegetation (crops, pastures and trees) in ways that maximize their potential to act as carbon sinks and absorb CO_2 from the atmosphere.

As shown in Figure 2, CSA aims to increase agriculture productivity sustaianbly, improve ecosystem services and enhance resilience and reduce or avoid greenhouse gas emissions from agriculture. Implementation of CSA, therefore, requires managing synergies and trade-offs of multiple interventions.

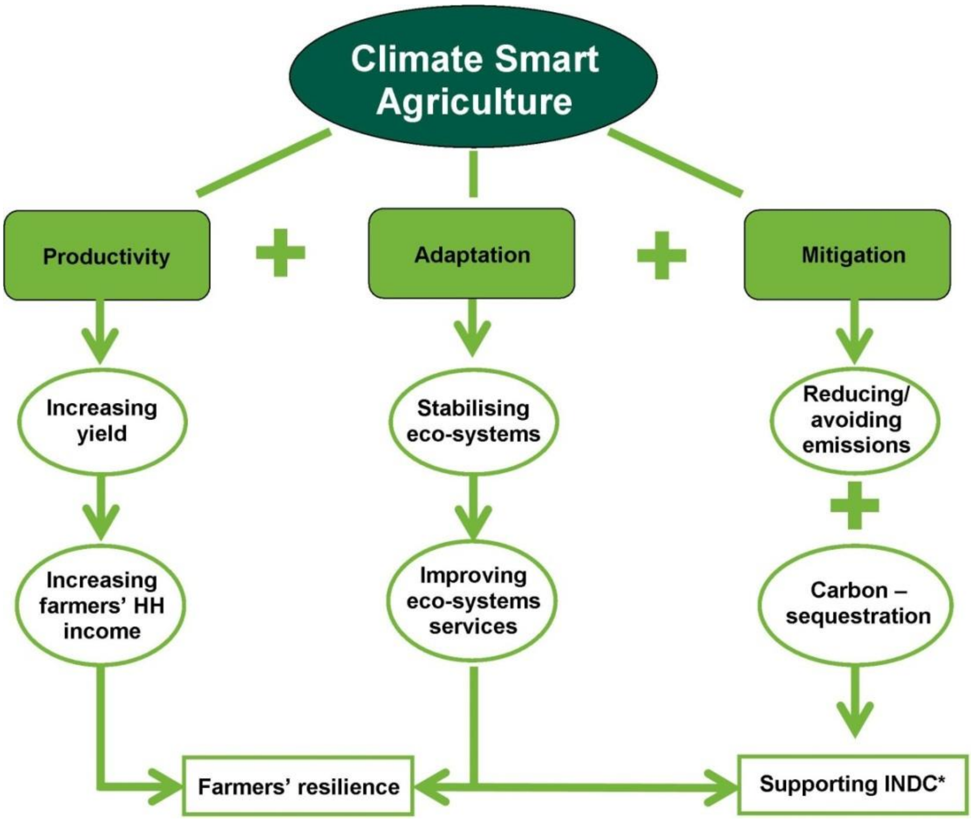

Fig.2: Conceptual dimensions of Climate-smart Agriculture (CSA)

The following key characteristics further describe CSA:

- CSA integrates multiple goals and manages trade-offs. Ideally CSA produces triple-win outcomes of increased productivity, enhanced resilience and reduced emissions. But often it might not possible to achieve all three at the same time. As such, trade-offs must be acknowledged when implementing CSA activities, and managing these trade-offs requires identification of synergies, costs and benefits of the different options.
- CSA maintains eco-system services. It is imperative that CSA interventions enhance ecosystem services such as clean air, water and healthy soil and do not by any means contribute to the degradation of ecosystem.
- CSA is context-specific. Interventions must take into account how different practices interact at the landscape level including farmland and within or among ecosystems to achieve climate smartness.
- CSA has many different entry points. CSA interventions can go beyond single technologies at farm level and may include the integration of multiple interventions at the food system, landscape, and value chain or policy level.

In general, what is new about CSA is that the approach invites to consider these three objectives together at different scales: from farm to landscape – at different levels - from local to global - and over short and long time horizons, taking into account national and local specificities and priorities. It also makes an explicit consideration of climate risks that require changes in agricultural technologies and approaches.

4.3. Identifying climate-smartness

When identifying climate-smart interventions one has to be aware that climate-smartness is not a “yes” or “no” matter, but rather a continuum where some interventions are more climate smart than others. For example, an intervention with a strong impact on reducing emissions might not necessarily generate much income for a farmer. Moreover, climate-smartness can be achieved by doing different things and mostly by doing things differently.

“Climate Smartness” depends largely on the way how agricultural activities are being implemented rather than what is being produced. It requires ecological and social resilience factors (i.e. natural, human and social capital) to be developed, Adger (2000), instead of simply focusing on income generation.

The degree of climate smartness of an intervention depends also on the quality and method by which it is implemented. For example, the effect of mulching on farm depends on the amount of crop residue or other organic material that is used to cover the soil; or the effect of reduced tillage will depend on the actual number and depth of ploughings. The climate smartness of CSA practices is normally measured by their contribution to the three pillars of CSA using well defined indicators. One example of systematic classification of climate-smartness of individual practices is the “basket-of options” developed and applied on a pilot basis by GIZ-SLM in Ethiopia. Although the climate smartness of individual practices has been used to select the practices included in the Infotechs of this Manual, the basket of options methodology can be applied as an orientation for practitioners using this Manual, especially for the selection of packages of practices. The detailed classification of CSA practices is included in Annex 12.

5. Climate Change and Sustainable Land Management in Ethiopia

Like most developingcountries the agriculture related sub-sectors in Ethiopia have the greatest share of GDP and a relative large share of GHG emissions. Figure3 shows the breakdown of calculated greenhouse emissions in Ethiopia by sector or sub-sector in 2010. The agriculture sector represents an estimated 63% of total emissions. Out of the total GHG emissions of 150 metric tons CO_2 equivalent (Mt CO_2e) in 2010, the livestock subsector had the highest share with 65 Mt CO_2e (42%) followed by deforestation and forest degradation due to agricultural expansion, cutting and burning of fuel wood and logging with 55 Mt CO_2e (37%) and crop cultivation with 12 Mt CO_2e (9%).

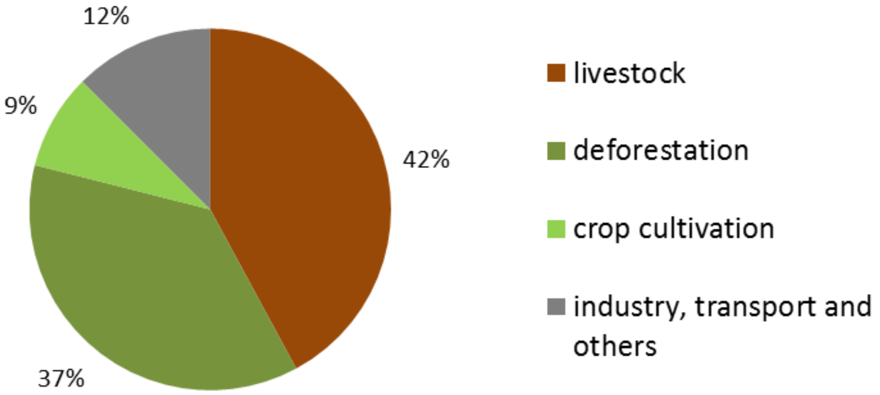

Figure 3. Economic sub-sectors emitting a total 150 Mt CO2e in Ethiopia 2010 (Source: Ethiopia NDC)

For several years, the Ethiopian government has been addressing climate change. The Government developed a number of strategies and plans, including:

- National Adaptation Program of Action (NAPA, 2007)
- The Ethiopian Strategic Investment Framework for Sustainable Land Management (ESIF 2010)
- Ethiopian Program of Adaptation to Climate Change (EPAAC, 2011)
- Climate Resilient Green Economy Strategy (CRGE, 2011)
- Agriculture Sector Adaptation Strategy
- Nine Regional State and two City adaptation plans

The CRGE is Ethiopia's strategy for addressing both climate change adaptation and mitigation objectives. The CRGE defines that Ethiopia intends to limit its net GHG emissions in 2030 by 64% as compared to a projected "business-as-usual" scenario. At the same time, Ethiopia also intends to undertake adaptation initiatives to reduce the vulnerability of its population, environment and economy to the adverse effects of climate change. The long-term goal is to ensure that adaptation to climate change is fully mainstreamed into development activities. Considering that agriculture is a major contributor to GHG emissions and smallholder farming systems produce the majority of Ethiopian agricultural output, the focus on adaptation is fully justified. The main effort in the near-term is to build the capacity needed to mainstream adaptation to climate change into all public and private development activities.

For several years, the Ministry of Agriculture has been addressing climate change impacts also within the Sustainable Land Management Programme (SLMP) in the Ethiopian highlands.

In SLMP, the entry point for the SLM approach is the micro-watershed. The prime focus lies in the rehabilitation of degraded areas (hillsides, gullies, etc.) through soil and water conservation (SWC) measures. SLMP addresses the challenges in the Ethiopian highlands through a three-stage approach (Fig. 4) where community mobilization is achieved in Phase I followed by soil and water conservation in the micro-watershed and finally the rehabilitated land is put into productive use through agriculture and livestock production. This approach works not only in the SLM watersheds but also in any watershed in Ethiopia that aims to achieve land rehabilitation and sustainable use of landscapes

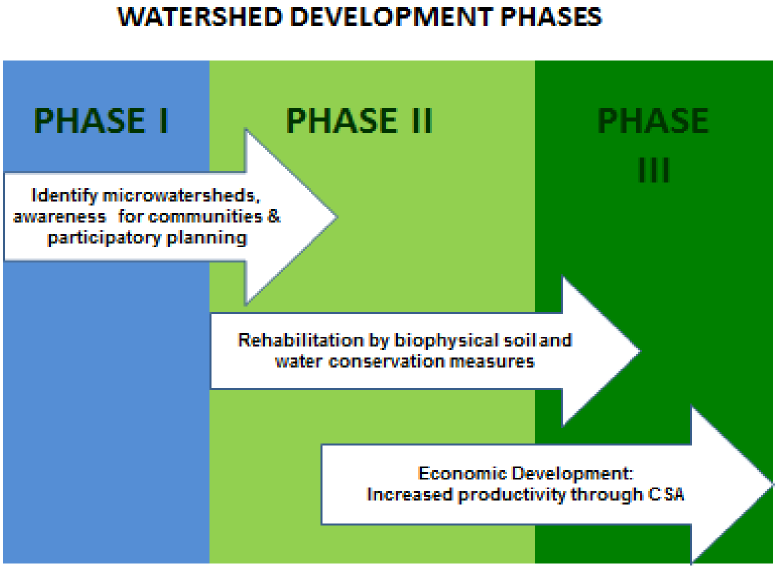

Fig.3: Three phases of SLM implementation

SLMP is guided by an ecosystem-based approach to food security, whereSWC measures, afforestation/reforestation and area closure are implemented at the landscape level to decrease soil erosion rates and increase moisture, among others. These measures represent a pre-condition to sustainably intensifying crop and livestock production on private farmland as well as communal lands.

For the implementation of SLMP, MoA developed and documented comprehensive Community Based Participatory Watershed Development Guideline (CBPWDG). The guidelineincludes detailed actions with regard to the implementation of phases 1 and 2. In particular, the guidelines describe the steps for identifying the critical watersheds, establishing various watershed development teams, and developing watershed investment and management plans with the community.

Besides government-led SLM Programme coordination Unit, the government and several NGO’s have been involved in the implementation of SLM activities across several watersheds in Ethiopia. Therefore, CSA can also be implemented in those watersheds given that the watersheds are properly treated with biophysical measures

6. Operational Approach for CSA Implementation

6.1 Target Areas

While this CSA manual is primarily intended to guide implementation of CSA practices in SLM watersheds, it can also be applied in other watersheds across the country

6.2 TechnicalStrategy for Implementation of CSA

The implementation of CSA practices involves the following considerations:

- Within a watershed, CSA interventions are designed and implemented at a micro-watershed level.

- CSA interventions would be linked to existing soil and water conservation practices, allowing synergies between different efforts in a watershed such as forage utilization from zero/controlled grazing on hillsides and from increased soil moisture and water availability; and enhance the climate smartness of individual CSA practices

- The primary eligibility criteria for the selection of areas (micro-watersheds) for CSA interventions in SLM watershed would be the treatment of highly degraded areas through biophysical measures. Yet, CSA can be implemented in any watershed considering the conditions of the watershed.

- Although CSA practices can be implemented on individual farms, CSA is more successful when it is implemented by organized farmers within a micro-watershed.

- The process for implementation of CSA practices assumes that each practice presents synergies and trade-offs that need careful consideration. This manual contains infotechs that are at different levels of adoption experience:

  - Practices ready for farmer adoption with appropriate supports
  - Practices requiring field testing/demonstration prior to adoption by farmers
  - Practices where significant barriers exist, either due to limited availability of inputs or equipment, or to the need to conduct adaptive research to validate the practice within local conditions.

- Support CSA adoption through establishing on farm demonstration plots (ideally at Farmer Training Centres (FTC) located in the watersheds).

- Build capacity of farmers and extension workers on implementation of CSA practices.

- Collaborate with research institutions to conduct adaptive action research to address the adoption barriers.

- Use micro-watersheds as learning watersheds to scale up CSA at a landscape level.

- Implement CSA practices as a package of different practices or individual practice (if it addresses at least two of the CSA pillars).

- Collaborate and coordinate with relevant stakeholders for effective and efficient implementation and ensuring sustainability.

- Ensure social inclusiveness (gender, youth, dis-advantage) in CSA implementation.

By applying these principles, promotion and adoption of CSA practices is a dynamic process, which involves not only financial support but also intensive knowledge transfer to beneficiaries through technical assistance, training, demonstration and exchanges, and participatory validation. The diagram below summarizes the main steps of CSA adoption. The specific guidelines and actions to implement each of the steps in the CSA cycle are described in the following sections of the Manual.

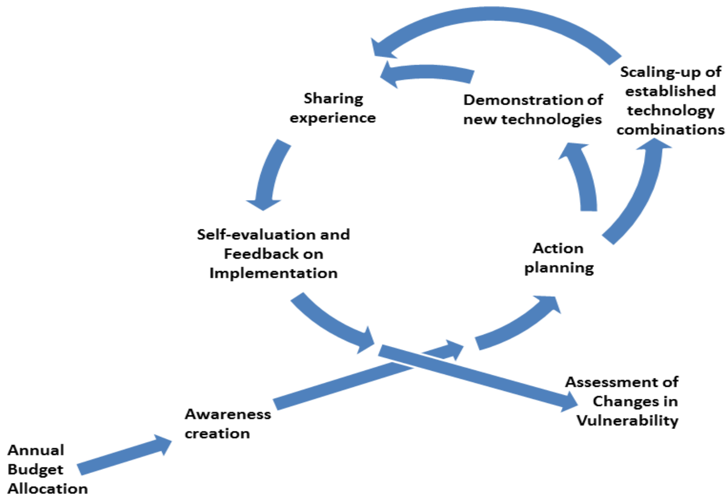

Fig 5: CSA Cycle

7. Operational Procedures

7.1 Planning Phase

7.1.1 Integration of CSA interventions into overall Watershed Development Plans

Recognizing that CSA planning requires the understanding of the sequence of the measure of activities or segment of the work that are involved in to a given development sector, thevalue chain concept of any agricultural production system should be well addressed when planning CSA.

It is also essential that we put appropriate target and indicator, based on the agreed CSA interventions of the given development works. This will enable to determine the entry points and suggest the climate inclusions that will reduce/manage the environmental odds

As part/ continuation of the watershed development planning, CSA interventions are normally planned on multi-year and annual basis. CSA interventions under SLM will be implemented primarily in micro-watersheds that have already been supported with biophysical measures. In order to ensure complementarity of CSA interventions with existing biophysical SWC measures, the planning of CSA interventions should be integrated and aligned with the watershed management plans, as described in the CBPWMG (see process flow adapted to CSA).

A key aspect of the CSA operational approach is the regional and local assessment of infotechs. with due consideration of the CSA initiatives are implemented iteratively.For this, prior to engaging the individual communities at the micro-watershed level, the extension workers will conduct a review of the infotechs with the objective of adjusting, if needed, the specific recommendations for each practice to the local agro-ecological conditions. CSA planning need to consider the interest and work load of women and children in the household

Steps for Major watershed development planning		Steps for CSA planning and implementation
Step1 Prioritization and selection of watersheds at Woreda Level based on the criteria set in the guide line. • Focus on identifying major and micro-watersheds • Formation of Kebele Watershed Team (KWT)	⟺	Prioritization and selection of CSA watersheds. • Create general awareness on climate variability, climate change and impacts
Step 2 Forming and organizing community level watershed planning team (CWT) • Agree on timing for planning work		Make sure community watershed team in place otherwise establish. • Establish CSA farmer groups and leaders.

Step 3 Biophysical and Socio-economic Survey DAs & communities jointly assess the socio-economic & biophysical situations 3.1 Socio-economic survey • Getting to know the watershed, people's interactions, opportunities and limitations • Trend analysis • Transect walk • Village mapping • Stakeholder analysis • Getting to know people needs, strength, problems • Vision of change exercise • Problem Identification (PI) and Ranking • Socio-economic baseline survey (Questionnaire and other document reviews) 3.2 Biophysical Survey • Mapping ○ Base map ○ Present land use map • Resource survey and assessment ○ Land use ○ Soil depth ○ Degradation level ○ Slope	⟺	Identify climate risks and vulnerabilities through discussions with kebele/community watershed teams and observations within a micro-watershed. • Prioritize the risks and vulnerabilities with the watershed team and map them within the micro-watershed. • Present inventory of CSA options to the farmers groups
Step 4 Identification and Prioritization of Interventions that Bring Change Technologies are selected to address major problems (socio-economic and biophysical problems) and opportunities		Identification and prioritization of CSA interventions with households /communities (farmer groups). • Provide CSA awareness training • Rank CSA interventions based on need, synergies and trade-offs
Step 5 Getting the options and interventions discussed and approved by the general assembly		The CSA packages of practices discussed and approved by farmer groups
Step 6 Preparation of Development Plan Map, Inputs and Action Plan		Prepare and approve CSA action plans • [1] technical and financial inputs at micro-watershed level by each farmer group (CSA action plan)

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[1] in the case of SLM, aggregation and approval of CSA plan at woreda and region level by respective steering structure is required.

Step 7 Implementation Strategies • prparation for implemetation • institutional reaponsibilities • resource identification and mobilization • organizational arrangement at ommunity level • training and experience sharing		Implementation strategy • Provide technical training (skill enhancement • Implement the identified CSA practices at on farm and FTCs (whenever and wherever needed)
Step 8: Participatory Monitoring and Evaluation • Participatory monitoring • Participatory evaluation • Reporting and documentation • Plan revision		Participatory CSA Monitoring and Evaluation • Conduct regular monitoring and provide support as needed • Evaluate implementation and benefits of the implemented CSA interventions • Draw lessons and incorporate them in the next planning

Table 1: Process flow for Integrating CSA into the SLM Planning

CSA planning starts from the information and knowledge of the identified watershed. It is linked to the biophysical information and the prevailing conditions of the selected watershed. Parallel to the watershed planning process appropriate CSA measures are integrated and supported with clear indicators and targets for the proper follow up. Budget requirements are estimated based on the planed targets and the nature of the intervention, as some of the practices are mainstreamed into the scheduled watershed development.

7.1.2 Selection of Microwatersheds to receive CSA support(Eligibility Criteria)

As indicated in the CRGE, Ethiopia's growth path envisages Climate smart landscape throughout the country, however as resource are limited and for a quick win in promoting CSA, intervention watersheds should be prioritized based on the following eligibility criteria. Note that some of the criteria might not be applicable for waterhseds outside the SLMP.

Within the selected watersheds, the micro-watersheds where groups of farmers will be supported in adopting CSA practices should meet the following eligibility criteria:

- SWC interventions completed, or well advanced with over 75% of the planned activities finalized, and the remainder scheduled for completion simultaneously with the initiation of CSA support)
- Zero grazing bylaw adopted and enforced (a CSA practice in itself and precondition for implementation of additional climate smart practices related to both crops and livestock)
- Team of woreda experts and DAs fully staffed
- Allocation of adequate time of regional advisers to support CSA planning and implementation
- forage development along gullies, farm bunds, pasture lands and homestead are partly implemented
- Access to functional Farmer Training Centres (FTCs)

- local knowledge or traditional practice of multi-cropping system; and
- Performance/functionality of community and kebele watershed teams

7.1.3 Awarness raising on climate rsiks and vulnerability

Awareness raising/sensitization of the community watershed teams on the climate change impacts and adaptation measures is important entry point for CSA planning at micro-watershed level. Documentary films, photos and other info kits can be used to visualize climate impacts and adaptation options. Sharing experience through locally esteemed persons can be used to sensitize the community.

7.1.4 Identification and prioritization of climate risk and vulenerability at micro-watershed level

Following the awareness raising meetings, the DA and woreda extension workers identify the climate risks, vulnerability and production potentials of the farming systems in consultation with the community watershed teams. Identified climate risks and vulnerabilities are prioritized by the community watershed teams based on ranking with the facilitation of the DAs.

7.1.5 Group eligibility and formation for the selection of CSA practices

The ultimate goal of CSA adoption in SLM watersheds is to achieve a CSA landscape, where all land and all farmers have adopted practices conducive to increased climate-resilient productivity, while contributing to reduced overall GHG emissions.

Due to technical, financial and operational limitations, this ambitious goal can only be achieved gradually, most likely over a number of years. Consistent with the existing limitations, the operational unit for CSA interventions in eligible micro-watersheds will be a group of organized farmers. The number of groups will be determined during the planning phase based on the budget allocated to the woreda for CSA.

CSA groups would be organized by the DAs assisted by woreda experts. In each group, the number of members should ideally range between 20 and 30 farmers. The actual number of farmers in the group (and the number of groups to be organized within each micro-watersheds will be decided by DAs and woreda specialists, based on the available budget, the number and complexity of practices to be implemented, the number of households in the village, and the capacity of DAs to provide regular technical support during the entire adoption process.

Groups and individual farmers eligible to participate in CSA adoption groups will be required to meet the following criteria:

- At least one member with recognized leadership
- Farming in contiguous plots or located in the same area (slope, village)
- All member comply with zero grazing
- Group members participated actively in SWM activities
- At least one member willing to participate in field days and/or demonstration events
- All members agree to contribute the necessary labor to implement the selected practices, as a form of counterpart financing

- When women headed households are available, at least 20 percent should be women headed households or the 20% of parcels should be owned by women

7.1.6 Selection of Interventions and Practices

Once the CSA group has been established, the CSA Plan ofthe group is prepared in a participatory manner. For this, DAs and Woreda experts organize a CSA group meeting (or groups within a village, if appropriate) ideally in the context of the watershed development planning. In the meeting, the DA will make the community aware about CSA; will explain to the community the concept of climate-smartness and especially what is understood as adaptation. In the same meeting the DA also presents the range of interventions available for adoption according to the Infotechs, and emphasizes that the anticipated CSA interventions need to have a clear linkage to the previously implemented SWC measures. Consequently, the meeting will also review the previous SWC measures and build upon them towards creating a climate-smart landscape.

Based on all the information provided, the DA and group members prepare the CSAPlan by agreeing on the main priority for CSA implementation, and subsequently assessing and selecting –from the available infotechs-- the intervention(s) from which the practices will be selected. Finally, from the selected infotechs, the group decides the specific practices that would comprise the CSA package to be adopted. Once the package has been selected, the CSA Plan is completed with the calculation of physical (i.e. inputs) and financial requirements, including not only the investments at the farm level, but also the training and technical assistance needs.In addition, the DA and the group conduct a similar process to select the practice (or package of practices) to be established by the group and used for demonstration purposes. The resources required are also included in the CSA Plan, under a separate category.

Basic guidelines to be followed for developing packages of climate smart interventions and/or practices are as follows:

- A package can have a combination of multiple interventions which must fulfill the objective of CSA (adaptation, mitigation and productivity enhancement). The number of combinations will depend on the synergies and trade-offs of the candidate CSA practices within the target micro-watershed. During the selection it is advisable to consider gender aspect particularly women’s preference including capacity and ability to implement.

  NB: A package refers to a combination of two or more practices which can be developed by looking into the complementarity of each intervention

The CSA Plan should include the following items: (template to be designed)

- Woreda/Kebele/Watershed/MW name
- Identification of the CSA group, including total and individual area (land size) and herd of livestock of households on which the package of farmland, livestock or homestead CSA activities will be implemented
- List of interventions and practices to be implemented (per group and individual farmer)
- No. of male and female headed households participating in the CSA group
- Type and location of demonstration plot to be established
- Type and quantification of equipment and inputs needed

- Expected commitment and contributions (labour, inputs in kind or cash) from the beneficiaries
- Parameters to be recorded and reported in order to monitor the successful implementation and performance of the CSA package
- Training and technical assistance needs for field activities
- Training and dissemination plan for demonstration activities
- Identification of nearby FTC

7.1.7 Development of the CSA Plan (planning, selection and budgeting of practices)

Once the package has been selected, the CSA Plan is completed with the calculation of physical (i.e. inputs) and financial requirements, including not only the investments at the farm level, but also the training and technical assistance needs.In addition, the DA and the group conduct a similar process to select the practice (or package of practices) to be established by the group and used for demonstration purposes. The resources required are also included in the CSA Plan, under a separate category.
The process of aggregating the group CSA plans will be the same as for the community watershed plans.

7.2 Implementation strategy

7.2.1. Training and backstopping of CSA farmers group and DAs

Prior to implementation of planned activities extension workers/DA and farmers will be trained on the technical standards and application of the selected CSA practices and technologies. Training of farmers will be supported by practical field exposure to pilot CSA watersheds where relevant technologies, controlled grazing and other sustainable Land management approaches are tested. DAs and technical experts willprovide timely support including access to inputs and required information during the implementation of planned CSA measures. Lead farmer will play important role in providing technical advises to their respective farmer groups and communicate to DA and extension workers based on skill gaps during implementation. Regular exchange between the CSA farmer groups will be facilitating at micro-watersheds and woreda level through the extension workers.

7.2.2. Agreement and categorization of CSA practice(s)

For the purposes of this Field Manual, implementation of CSA interventions at field level (i.e., watersheds) will follow two modalities: (i) direct field adoption and (ii) pre-adoption testing and demonstration (FTC, model farmers). In both cases, the selection of practices to be included under each modality will be decided jointly by DAs and beneficiaries, based on the technical specifications and recommendations included in the infotechs. A third complementary modality (CSA Adaptive Research) will be implemented following a different set of operational and institutional arrangements, described below.

(i) Direct Field Adoption

The practices selected for direct adoption will be implemented by all members of the CSA groups in the form of packages. As part of the development of the CSA Plan, the DAs and the members of the CSA group must jointly agree on the priority intervention to be implemented, and the set of CSA practices to be included in the implementation package. This will be achieved through a participatory process, in which the DA explains (i) the basic principles of CSA, (ii) the specific SLM objectives, criteria and mechanisms to promote the improvement of production systems through the adoption of CSA practices, and (iii) the different practices recommended in the infotechs for implementation in the micro-watershed. Based on this information, the group and the DA discuss and agree on the specific CSA practice, or set of practices, to be implemented by the group. This will include the on-farm practice(s) and the practice(s) proposed for testing and demonstration.

The DA prepares the detailed physical and financial CSA Plan, specifying the quantities of inputs and supplies required and the estimated budget. In those cases, where more than one CSA group is established in the micro-watershed, the individual CSA plans are consolidated prior to submission for review and approval by the woreda.

(ii) Pre-Adoption Demonstration

Farmers are not expected to make informed decisions on innovations that they have not seen or applied before. To address this, in each micro watershed, beneficiaries will also select CSA practices for pre-adoption testing and demonstration. These practices will be established either in Farmer Training Centres (FTC) or in smaller plots owned by beneficiaries willing to make land available for demonstration purposes. The FTCs should demonstrate a number of technologies that have been screened by the region and woreda as potential for implementation. Farmers can see them in the field and make an informed decision. The required budget for implementation of demonstration practices would be developed by DAs and included in the annual micro watershed CSA Plan.

The individual demonstration plots will be used to conduct CSA formal field days or informal farmer exchanges in appropriate periods of the year, while results related to the three dimensions of CSA will be monitored and evaluated using a methodology to be developed in accordance to the type of practice to generate appropriate information for planning, training, and extension purposes.

(iii)CSA Adaptive Research

Complementing this CSA adoption strategy, a third modality will be applied for those potential CS practices which are identified in the infotechs as requiring additional technical, operational or financial validation prior to demonstration or farmer adoption. These practices, or combination of practices, will be included in a parallel CSA Adaptive Research Plan (ARP). This plan will be designed and implemented with SLMP financing, with strong inputs from technical staff and beneficiaries, by appropriate national and regional institutions, with international support when required. The content of the CSA ARP will be defined by the PCU based on the recommendations from the infotechs and with inputs from national, regional and local technical specialists from MoA and SLMP.

8. Enabling environment

8.1 Capacity building

CSA is knowledge intensive and entails moving toward more agro-ecology based approach rather than conventional intensification. Implementing and scaling up of CSA at a watershed orlandscape level is even a greater knowledge intensive endeavour. What makes CSA different from the conventional agricultural practices is that it requires capacity to identify and implement synergetic activities with minimum trade-off that ensure high productivity, enhance resilience, and reduce GHG emissions. Therefore, all implementers of CSA at different scales need to be trained and equipped with the necessary knowledge and skills.

8.1.1 Building the capacity of farmers

For proper implementation of CSA, there is a need to build the capacity of farmers on understanding and identifying climate related risks, identifying the relationship between climate risks and other environmental problems, understanding the synergies and trade-offs of different agricultural practices and technologies, estimating required inputs for CSA practices and evaluating the productivity and environmental benefits of CSA. The trainings could be provided through targeted trainings sessions, meetings, FTCs, demonstrations, social gatherings and other relevant methods.

8.1.2. Building the capacity of experts and development agents

CSA is generally a practice of analysing the synergies and trade-offs of a set of agricultural practices within a farm, a watershed and/or a landscape level and then implement, monitor and adjust as required. Although the issue of CSA is high in the agenda globally, its implementation on the ground is still difficult because of the limited experience on proper planning, analysis of synergies and trade-offs for a set of CSA practices, and lack of scaling up strategies. Equipping extention agents with skills and techniques to implement CSA at the required scale (plot or landscape) is required.   Hence, there is a need to develop a standardized CSA training materialto train Extention workers including DAs.   The trainings need to focus on, among others, understanding the challenges of climate change and variability, concepts and practices of adaptation and resilience, ecosystem services, concepts of CSA, analysis of synergies and trade-offs at a farm, micro and macro watershed level, planning and implementation of CSA and monitoring and evaluation of implemented CSA. The training of CSA experts can be done following the procedures:

(a) Develop a standardized training materialfor CSA implementers,
(b) Identify training- of-trainers (TOTs) from project implementer Woredas,
(c) Train the TOTs in theoretical and hands on sessions,
(d) Help and monitor the TOTs to train CSA implementers at grass root level,
(e) Provide refreshing TOTs with additional skills based on their field experience, and
(f) Monitor and support the TOTs and their CSA implementation capacity at the field level.

8.1.3. Continuous support

Building the capacity of farmers, DAs and experts at a given time is not enough to ensure proper implementation of CSA and its sustainability. Therefore, there is a need to allocate additional time and resources to (i) conduct periodic visits to the plots of farmers implementing CSA practices, (ii) establish more demonstration plots, and (iii) organize and conduct dissemination activities such as field days and farmer exchange visits. Equally important, the regional structure should be capable of providing technical backstopping to DAs, through periodic joint field visits, on-farm refresher training, as well as assistance in planning and conducting demonstration activities

8.2 Additional Enablers

In order to successfully implement CSA at different levels and reap its benefits, collaboration and partnerships are necessary across the implementation chain. The enablers indicated below will play a significant role for ensuring success and sustainability:

- **Timely availability of inputs**: inputs identified by the implimnetation team need to be available on time and with the required quantity and qulaity;
- **Administrative support**: positive adminstrative support and engagement at all levels in planning, implementation and evaluation phases of CSA;
- **Availability of resouces:** although it is not always possible to get all resources required, there is a need to avail the minimum level of financial and material resources required to impliment CSA.

8.3 **Gender and Social Inclusion**

Gender refers to the social attributes and opportunities associated with being male and female and the relationships between women and men and girls and boys, as well as the relations between women and those between men. (see http://www.un.org/womenwatch/osagi/conceptsandefinitions.htm).

Addressing the gender aspects of land degradation and natural resource use helps to devise a mechanism to reverse the degradation and optimize utilization of the natural resources. Women comprise 50 percent of the agricultural labour force in parts of Africa(FAO, 2011).

Furture engagements to reverse environmental degradation and improve resilience of landscape and rural livelihoods call for, among others (i) equitable participation of both men and women, with an emphasis on gender-sensitive technologies that save women labor and time, and protect their health, such as improved cookstoves; (ii) enhancing capacity of implementing institutions to mainstream gender issues; (iii) improving entitlement of women to land and enforcement of these rights; and, (iv) enhancing monitoring, evaluation and reporting of gender outcomes.

Lessons show that women farmer in the southern Africa,where CSA is relatively advanced, face barriers in their ability to adopt CSA practices. This includesunequal access to credit, land, technology and agricultural input as well as capacity building. According to FAO, if women had the same access to productive resources as men, they could increase yields on their farms by 20–30 percent. This could raise total agricultural output in developing countries by 2.5–4 percent, which could in turn reduce the number of hungry people in the world by 12–17 percent (FAO, 2011).

To implementCSA, understanding the needs, priorities and challenges of different stakeholders is important. It must be noted that gender relations, opportunities, socio-cultural norms, access to resources and power dynamics across social lines may lead women and men to have different knowledge, skills and perspectives. They may also have different opportunities and constraints that may help or hinder the adoption of CSA. *In fact, if implemented without consideration of gender and social inequalities, CSA practices will fail to take advantage of opportunities to improve livelihoods and may instead increase these inequalities*(World Bank Group, 2015).

The Ethiopian SLM programme has established mechanism to address gender issues. The programme has gender mainstreaming guideline to ensure the inclusion of gender issues in its activities. The programme has provided equal job opportuinities for men and women. The programmehelps men and women to acquire land certificate which ensure land tenure rights. The programme also provides technical and financial supports to avail technologies which help reducing workload on women. These are fuel saving cookstoves, spring capping for drinking water, backyard forage development for livestocks and in some places biogas digesters.

The existing experience in SLM programme (gender mainstreaming guideline, access to land and other recources) can be considered as benchmark to improve gender dimension in CSA.

8.4 Monitoring and Evaluation

CSA M&E should be participatory, among others. As much as possible the M&E should be compatible with the CBPWDG M&E principles. Each stakeholder should involve in identifying and measuring the indicators. Participation of CSA farmer groups or community at large in identification of indicators will ensure that those indicators chosen are meaningful to them. Review of the indicators has to be made jointly together with the community, the extension workers/experts and other stakeholders. Decision to make any modifications in the project/program being implemented must also be taken jointly based on consensus. M&E provide a more complete picture of a project’s or regular government programme’s issues, progress, outcomes, and impacts.

All CSA interventions and/or combinations need monitoring with regards to the inputs provided, their performance and results (outputs). Monitoring parameters will need to be defined for all three elements of climate-smartness of productivity (livelihood), adaptation and mitigation. Planning and monitoring of CSA interventions may be streamlined into the regular SLM tools used for all project interventions when it is possible to do it. Otherwise, it is always advisable to develop detailed M&E protocol to ensure adequate quantification and assessment of inputs, activities, outputs, outcomes and impacts related to adaptation, agriculture productivity and mitigation. These inputs, activities and results should be assessed annually, at the middle and end of the project or regular government programme.

8.4.1 Monitoring

Monitoring activities will be done in order to collect and process information, compare target and actual performance of planned activities, inputs of resources and assumptions. Furthermore, the monitoring and follow up activities will focus on assessing deviations of outputs from objectives of CSA interventions. In this process, extension workers will routinely record and analyze the information in order to ensure the accountability and getting learning inputs timely from initiated activities and from observed results. These include progress tracking using activity and indicator sheets on quarterly basis. To do the tracking, CSA plans and targets will be defined on annual basis.

Monitoring of CSA interventions at farmland level will be conducted quarterly basses using data collection tools which help to capture progress on implementation of CSA activities at outputs level. Furthermore, monitoring updates will be prepared and send to MoA every three months to check progress against plan. Monitoring and follow-up activities will be done using questionnaire, assessment checklists, interviews and FGDs with CSA farmer groups at field level. Over all, a combination of quantitative and qualitative data will be used.

More than half of the Ethiopian population are female. In this respect, gender has been an integral part in the planning, implementation, monitoring and evaluation of SLM programme, and therefore will continue being essential aspect throughout the CSA cycle (refer the CSA cycle on page 13.). The gender aspect of CSA monitoring will ensure inclusion/participation of female headed households and women in CSA activities, access to CSA inputs and capacity building interventions, adoption of CSA practices and how CSA practices benefit women.

Effective M&E comprises clear and unambiguous indicators, definition of indicators, CSA technologies and their definitions, units of indicators, frequency of assessment, data source, calculation and collection, methodology, and others.

Table 2: CSA indicators

Input	Activities	output	Midterm outcomes	outcomes	Impacts and long term goals

Results will be assessed through annual case studies based on surveys collecting physical information, beneficiary perceptions, and financial results, including gross margins where possible. The methodology and resources required to conduct CSA M&E will be developed prior to initiating the on-farm CSA interventions. Accordingly, extension workers will be trained on the M&E tools.

Measuring mitigation in agriculture and livestock production is a difficult and costly process. Therefore, mitigation effects will be estimated using internationally accepted reference formulas. The EX-ACT tool developed by FAO has proven to be very useful in this regard and will therefore be applied. As the formula requires a number of input data, these will be identified for the respective interventions and will need to be recorded accordingly. Other appropriate tools can be used for other government regular programmes.

8.4.2 Evaluation

CSA interventions will have mid and end evaluation to assess achievement of expected results sustainability, efficiency, effectiveness and relevance against baseline. Mid-Term evaluations will primarily focus on CSA interventions performance at the middle of the implementation period in order to analyse the relation between implemented CSA activities, outputs and intended outcomes (agriculture productivity, adaptation and mitigation where possible) & inform decisions regarding the progress.

End evaluation will be conducted at the end of CSA implementation period (project/programme period) and results of the evaluation will be used to measure how far the CSA interventions were effective in proper implementation of the activities and how the interventions contributed for realization of outputs and the overall outcomes (productivity, adaptation and mitigation where possible). To make use of the evaluation results, baseline and target values will be defined at the start of CSA interventions. The findings of the evaluation will help to improve CSA interventions, support managerial decisions and future CSA project development. Document review, field visit, focus group discussions, evaluation checklists, reports and beneficiary discussion will be used as major tools to acquire the expected findings.

9. The InfoTechs

- **Title of Infotech**
- **Brief description of CSA intervention.**
  The description should include “what” the intervention is about, based on which land use type, and its linkage to the SWC measure.
- **Assessment of climate-relevant potential (adaptation, mitigation and income generation) of theCSA intervention.**
  This describes the expected effects on climate relevance, that is the expected adaptation and mitigation effects. These effects are described as single measures and with possible combinations with other measures. The description should be based on the rating and justification as in the “basket-of-options”. This chapter should also provide an estimate of the economic benefits for the individual farmer as well as eco-system benefits for the community at large. Here also it is described whether the intervention needs further testing/demonstrating or whether it can be implemented in upscaling mode already.
- **Geographical range and land use type of the CSA intervention**
  This chapter should describe to which agro-ecological zone the CSA intervention is most suitable and why. It should also describe for which land use type the intervention can be most effectively applied for according to degraded hill sides, farm land, grazing land or homestead development.
- **Level of group formation/organization required.** This should refer to the different degree of group formation required, e.g. an area closure might need a different group than a soil fertility management intervention. This chapter should also describe what, which part of the intervention should be performed as a group, and which could be done as individuals. For example, the beekeeping could be done as individuals, but the marketing of honey and other products could be done as a group.
- **Envisaged target group of this CSA intervention.**
  This describes which should be the preferred target group considering poor, vulnerable, women headed households, landless, youth, any farmer or a combination of this groups. The chapter should also describe to what extent the CSA intervention is gender specific.
- **Inputs and skills required for this CSA intervention.**
  This chapter should list the necessary inputs and skills required for implementing the CSA intervention. All inputs should be tight up with at least one accompanying management or implementation practices, e.g. drought resistant seed provision should be combined with intercropping, row planting, reduced tillage or crop residue management. This chapter also outlines the necessary knowledge and skills that are required for successful implementation of the CSA intervention. This will form the basis for identifying training needs in a particular situation (see steps of implementation).
- **Outlook on sustainability.**
  This chapter should describe the elements that need to be put into place for the CSA intervention to be sustainably practiced.
- **Possibility of up-scaling the CSA intervention.**
  This chapter should describe possibilities and conditions (institutional, economic, social and environmental) to replicate and up-scale the CSA intervention.
- **Monitoring the performance of the CSA intervention.**
  This chapter should provide measurable parameters that allow evaluating the performance of the CSA intervention preferably with regard to all three aspects of CSA, which are adaptation, mitigation and livelihood (through income generation and measurable eco-system benefits).
- **References and contact details.**
  This chapter should provide references, further technical materials and contact details for deeper understanding of the CSA intervention

Technical information kit	(1) Brief Description of the technology and what makes it important	(2) Main objective/benefit and promotion
9.1 Conservation Agriculture	Conservation Agriculture (CA) is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. CA is characterized by **three linked principles**: **1. Principle of continuous Minimum soil disturbance**. i.e. Tillageis reduced to ripping planting lines or making holes for planting with a hoe. The ideal is to plant directly into the soil without plaoughing. **2. Principle of permanent organic soil cover/Keep the soil covered as much as possible;**crop residues left on the field, mulch and special covercropsprotectthesoil from the deleterious effects of exposure to rain and sun; to provide the micro and macro organisms in the soil with a constant supply of "food"; and alter the microclimate in the soil for optimal growth and development of soil organisms, including plant roots.cover crops are planted to provide a soil cover, improve soil fertility and produce food and feed. They are normally grown during dry season or as an intercrop. Cover crops can be legumes, shrubs, grasses and others. The type of cover crops you choose influences the quality of mulch it provides. Some of the cover crop species are listed at the end of this infotech. **3. Principle of Mixing and Rotating Crops**: plantingthe right mix of crops in the same field, and rotating crops from season to season.The rotation of crops is not only necessary to offer a diverse "diet" to the soil micro-organisms, but as they root at different soil depths, they can explore different soil layers for nutrients. These practices also reduce pest build-up and damage. This is an effective CSA strategy since it both increases productivity and helps farmers adapts to climate uncertainty	***Economic benefit:*** result from CA implementation includes time saving and thus reduction in labour requirement, reduction in costs, e.g. fuel, machinery operating costs and maintenance. ***Agronomic benefits:*** include improvement of soil productivity through organic matter increase, in-soil water conservation and improvement of soil structure, and thus rooting zone ***Environmental benefits:*** includes reduction in soil erosion since the residues on the soil surface reduce the splash-effect of the raindrops. Maintaining soil cover will reduce erosion with the consequent loss of soil fertility, soil compaction, and, eventually, landscape change. Promoting CA demands different activities as indicated in the following figure(IRR and ACT, 2005). 

through reducing risk of crop failure. It also keeps soils covered with living plants for a longer period.

(3) Planning and Implementation Modality

Be aware that short term solutions and immediate benefits always attract farmers and the full technical and economic advantages can be seen only in the medium – long – term run, BUT when its principles (minimum tillage, permanent cover crop and crop rotation) are well established within the farming system. when CA practices are combined with good fertility management, economic benefits can be realised in the short run, particularily in drier climates.

Steps to follow for planning and Implementation

(i)Revisit the already developed CA Guideline, Amharic version and make ready for mass production and distribution of CA technology package for users

(ii) organise meetings, trainings, site visits on demo site including farmer's field day for farmers, extension services and decision makers.

(iii) Identify suitable areas for CA within the watershed. Select part of a field where you feel able to take a risk, have good conditions for learning, and have a good chance of success. If you start with a field with good potential, you are likely to see results quickly. Start small. Try out what works on one field first. Observe closely and learn what works and what doesnot.

Is the soil is compacted or has a hardpan? Is the soil has ridges and furrowa? Is the soil acidic?

Focusing on areas where the technology has already been adopted by farmers andof course distinguish between the technologies appropriate to areas where large-seeded crops predominate and those where small grain cereals predominate.

(iv) Ensure that production inputs are readily available for beneficiary farmers on timely basis

(v) help farmers and agropastoralists to develop alternative feed supply from different sources, in order to reduce free grazing.

(vi) Ifthereareterraceson thefarm,planton them livematerialsuch asnapier,vetch,pigeonpea,sebaniaandother strong-rootedcrops

(vii) Create an agricultural technology information pool/center at EIAR (research information).

(4) Suitability and adaptability to localconditions and knowledge

Farmers in Ethiopia have the experience of rotating pulse crops with cereal and in some areas planting with a single plough. Besides this, erosion and moisture stress in farm land is the main threat to increase crop productivity. So CA is proposed as one of the most promising means of reducing soil erosion, increasing moisture retention and stabilizing crop yields in the rain fed farming systems

CA is more suitable in areas where there is a capacity to grow cash crops (in order to purchase inputs), markets for a diverse range of crops (to support crop rotation),. In addition, CA can be easily adaptable and expand in areas where bimodal rain is common i.e. high value crops are grown widely like in Arsi and Bale highlands and mid-areas which is excess amount of crop residues are available for mulching. In some part of west Oromia region especially eastern wellega CA have been started and implemented by many farmers on farm lands.

Integration requirement and opportunities

Erosion and lack of rainfall are problems that many African farmers face. CA can help overcome both by conserving soil and by storing water in the soil. If erosion is severe farmers can combibe CA with other techniques for control erosion. The measure may include, but not limitted to: contour and cutoff ditches, gully treatment, grass strip, stone lines, level contour bunds, Fanya Juu terraces, Bench terraces.

CA should be combined with production of feed for livestock and tree planting for biomass energy to keep crop residue in the field continousely.

Minimum Technical Standards and steps

Practicing or Adopting CA – First Steps

Conservation agriculture, especially no-tillage and direct planting, is not entirely new cropping system. There are some farmers who have indigenous knowledge of

○ practicing minimum tillage like using stick to create a hole for planting seeds and/or placing chemical or organic fertilizer. Or they might have knowledge of minimum tillage from their ancestors. In such circumstance, it would be better to start from what the farmers would know than starting from scratch. Main changes apart from direct sowing are:

- Early planting, even dry planting in semi-arid regions
- Diversified crop rotation, wherever possible three to four years rotation including leguminous and forage crops.
- Stubble retention – controlled grazing.

Choose a field

- Start with fields where the straw and chaff from the previous crop or find sufficient crop residue and spread it on the soil surface as mulchor plant cover crops such as lablab
- Plant a cover crop during the first season → choose a cover crop which is suitable for your AEZ. The cover crop is preferred if it has deep roots to improve the fertility and soil structure. Good care of the crop, to enhance good growth, is required.
- Grow a cover crop on a nearby field → then cut it and spread it on the soil at the beginning of the second season. The cover crop can also produce seeds for the farmer to sow or sell to neighbours.
- Control weeds -it is vital to control weeds, particulrily during the first few years of conservation agriculture.

Reduced plough

- Donot plough –instead of ploughing direct plant your crops through the mulch, or dig planting basins where you can sow seeds. Otherwise, based on the spacing of the crop type open a narrow planting furrow with a ripper without turning the soil or use a hoe (jab planter) to make small planting holes for direct-planting of the crop or planting through the mulch
- Since tillage is being eliminated, know how to use the herbicides that will replace it; to begin don't chose a heavily weed infested field.

Planting

- Sow seed directly in to the ripped lines of planting holes, or drill seed in to undisturbed soil using direct planters. Inter crop with legumes or sow a cover crop a few weeks later in the growing season to protect the soil.
- Grow crops- you can grow the crops you normally do but add an intercropping or rotate crop if possible.

When to plant:

- Deciding when to plant is one of the most important decisions a farmer has to make. The main aim is to make sure the seeds germinate quickly and evenly. Try to finish planting a field in one day
- Plantseedsduringheavyrain,orwithin48hoursafteritstops.
- Plant at the right depth for the crop. This helps the seeds to germinate and emerge evenly.

Fertilization

- To adapt the CA technologies, it needs to follow the integrated soil fertility management approach. Apply manure and compost long before the rain and basal fertilizer (DAP, NPK or Blended fertilizers) during planting time. Urea fertilizer mainly applied after planting in a split manner but some time applied during planting depends on the crop type. In CA soil fertility management mainly relies on organic sources (compost, manure and green manure), supplemented by inorganic fertilizers based on crop type

Leavethesoilcovered Atharvest;leavetheresidueonthefieldtocoverthe soil during the dry season. Leave the cover cropgrowing, or plant another maincropifyoucan

Second and following seasons

- There should now be enough cover on the field. If not, carry in extra residues from nearby and spread them on your field. It is much simpler to prepare for planting in the second season.

Check for weeds Hand-pull them, slash them.

Crop residues Decide if it's possible to produce enough crop residues on the field for the third season. If not, advise farmers to grow some cover crops nearby, then cut them and spread them on the conservation agriculture field in the third season.

Make sure

Availability of Equipment: the right equipment is required. The equipment should be suitable for both men and women. Ingeneral hoe may be used to practice CA but to save farmers and agro-pastoralists work the followings are required:

- Jab-planter
- Ripper or planter
- No-till planter
- Sprayer or weed wiper

Availability of Seed: can farmers and agro-pastorlists get the right type of seed?

Availability of Inputs: will the farmers and agropsastoralaits be able to purchase herbicides and fertilizers or prepare compost or use manure to imprve yields?

Availability of Labour: CA generally saves work. More work may be encountered in the first year. Will the farener abd aor-pastoralist be able to handle this work by himself/herself, can the family members assist or hire labourers?

Availability of Storage and markets: CA should help to grow more and produce a greater variety of crops. Think of harvesting, storing and maketing aspects from the begning.

Livestock are out of CA farm: farmers and agropastoralists should keep their livestocks out of their CA filed. Advice farmers and agro-pastoralists to do one or more of the followings:

- Cut the cover crop and carry it to the animal pen
- Make hay or silage to feed to the animals in the dry season
- Plant an extra plot of forage to feed to the animals
- Sell less-productive animals to keep fewer to feed

Note: animals are used to plaughung, transportation and threshing. Technologies affordable by CA groups or individuals to resolve issues of farming, transport and threshing should be provided torugh various mechanisms such as agriculture mechanisation departments at MoA and Regional Bureaus.

Information and Support: where can farmers and agor-pastorlaists get advice from? Extetnion workers, other faremers? NGO staff? Input suppliers? Traders? The mass media? This manual?

Climate Smartness	**Challenge and constraints in implementing CA**
Carbonstorage in the soil(Mitigation) Some studies show an increase in SOC when minimum tillage is applied even though it is difficult to make definitive quantitative statements, because the effects are highly dependent on the individual site (*inter alia* soil type, climate, crops grown, previous intensity of tillage, new regime). • In general, SOC will increase (**mitigating** climate change) and soil properties (physical, chemical and biological) will improve (**adapting** to climate change). Coarse-textured soils are damaged more by tillage (loosing SOC) than are fine ones, therefore will show greater increase in SOC following adoption of reduced tillage. • A change from conventional tillage to no-till can sequester 0.57 ± 0.14 t C/ha yr-1 (West and Post, 2002) and the accumulation of SOC will continue (provided the soil is not tilled). Levels can be expected to peak after five to 10 years, with SOC reaching a new equilibrium in 15 to 20 years. Overall, rates of SOC are lower in hotter climates. Nevertheless, a field monitoring site in western Nigeria recorded that no-tillage combined with mulch application increased SOC from 15 to 32.3 t/ha in four years (Ringius, 2002). The IPCC (2000) estimated that conservation tillage can sequester between 0.1 and 1.3 t C/ha yr-1 globally and could feasibly be adopted on up to 60 percent of arable lands ➢ Highersustainedyieldsatlowercosts • Environmentalconservation • Increasessoilorganicmatterandnutrients,thus reducingtheneedforchemical fertilizers • Improvessoilstructureanditsabilitytoabsorbandhold more moistureforcrop growth. • Reduced the risk of crop failure due to unpredicted rainfall even allowingthe elderlyfarmerstostillpractiseCA.	**Competition for crop residue and biomass:** The competition for crop residues between livestock (fodder) and soil (fertility) is the main challenge for CA to be adopted by farmers in Ethiopia This requires efforts to increase forage availability and to control free grazing. Knowledge management:Many farmers are accustomed to plough many times as an essential part of agriculture and may find it difficult to accept the idea that repeated ploughing is not required for successful planting. CA relies on better management of crop residues on or near the soil surface. It is very effective for conserving soil and water resources in high moisture stress areas. However, a major pre-requisite is to havesufficientresidues for surface mulch. This requires increase of crop productivity and control of free grazing. Reducing soil tillage may initially result in increased weeding requirement. Weed problem can be minimized by controlling weed seed movement and applying mulch Very limited supply of legume forage seeds, which could be used in intercrops systems.

(5) Selected CA technologies for each AEZ

Aspect	Selected Practices /Technologes	Agro-ecological zone of Ethiopian highland (>1500 m.a.s.l.)			
		High Potential Perennial zone (warmer and humid with >240 days growing	HPC –High Potential Cereal zone (intermediate with > 180 days growing period)	LPC – Low Potential Cereal zone (high rainfall variability with 90-150	Agropastoral and pastoral drylands - rainfall is limited and the growing

		period)				days growing period)		period is too short for most crops
		<2500	>2500	<2500	>2500	<2500	>2500	<1500 m
Improvement of production efficiency (reduction in labour requirements and costs)	Reduced tillage (row planting, herbicide application initially)			X	X	X	X	X
Improvement of soil productivity and environment (reduction in soil erosion, biodiversity increase and carbon sequestration)	Cover crops (leguminous – pigeon peas, beans)	X	X	X	X	X	X	X
	Crop residue on the farm (30% cover after cut and carry)	X	X	X	X	X	X	
	Crop rotation	X	X	X	X	X	X	X
	Mulching	X	X	X	X	X	X	
	Intercropping of food crops and legumes	X	X	X	X	X	X	X
Crop-tree-livestock integration (critical to livestock keeping system)	Planting of forage species with food crops	X	X	X	X	X	X	X
	Planting of fodder trees	X	X	X	X	X	X	X

Conservation Tillage practices example in Ethiopia (south Achefer, Amhara region)

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Technical information kit	(1) Definition of Residue Management	(2) Period/ phases forimplementation
9.1.1.Crop Residue Management	Crop residue management means maintaining cover on sixty (60) percent of the soil surface at planting. Crop residue management provides seasonal soil protection from wind and rain erosion, adds organic matter to the soil, conserves soil moisture, and improves infiltration, aeration and tilth.	Planning for residue cover begins at harvest. Ensure ample residues are spread evenly over the field. Reduce the number of unnecessary tillage passes. Generally 1. Follow a crop rotation sequence that includes high-residue-producing crops such as maize and grain sorghum with low-residue-producing crops such as soybeans. 2. Strive for even distribution of residue from a combine. 3. Recognize that fragile residue from crops such as soybeans decompose quicker than the non-fragile residue from maize, grain sorghum, and wheat.

(3) Main objective/purpose

- Crop residue management provides seasonal soil protection from wind and rain erosion, adds organic matter to the soil, conserves soil moisture, and improves infiltration, aeration and tilth. Benefits may include reduction in soil erosion, sedimentation and pollution from dissolved sediment-attached substances.
- The presence of crop residues on the soil surface minimizes soil evaporation, and in regions of low rainfall can conserve water and increase crop water use efficiency thus improvingcrop yields**.**
- crop residue improves in the manner that occur in the native ecosystems, including maintenance of porous and soft soil layers through litter accumulation, intense biological activity, movement of soil fauna, and root growth. These functions improve efficient water, heat, and gas transfers within the entire soil profile. And the accumulation of organic matter from crop residue increases carbon sequestration.

(5) Main land use and agro ecology

Agro ecology influences the diversity and biomass of crop production. Larger proportion of crop residue is left on plots in humid than semi-arid agro ecologies due to the availability of other alternative sources for feed, construction and firewood in the humid parts (Erenstein (2003)

Moreover, human and livestock population density, availability of feed and grazing land, etc. are agro ecology specific. Thus, households in different agro ecologies could use available crop residue resources in unique pattern.

The amount of crop residue retained on farm plots as soil mulch is subject to plot characteristics which include soil depth, soil fertility, and slope and distance from homestead. Plots with fertile and deep soils usually produce more biomass that could increase the volume of residue produced and made available to be used as soil mulch. Households could use crop residue as soil mulch to

(4) Suitability and adaptability to local knowledge

The amount of cereal residue used as soil amendment increases as crop production increases, along with better access to alternative resources and small herds.Normally in Ethiopia crop residues are removed for animal feed (Araya and Edwards, 2006; Elias, 2002). But according to a study by Elias (2002) about 42 percent of farmers in Kindo Koisha apply crop residues for improving their soil fertility. While others immediately plough fields to protect roaming of animals due to the free-range grazing practices (Araya and Edwards, 2006). Many farmers in the southern and northern part of Ethiopia rely principally on the recycling of organic matter to sustain agricultural productivity. Crop residues have long played key roles in this process.

Farmers set fire on crop residue to control potential pests.(Erensteinet al., 201).However, pests could be controlled biologically for example by planting greenleaf desmodium.Crop rotation helps to control pests and disease.

reduce the intensity of run-off and increase rainfall infiltration into the soil particularly in plots with steep slopes (Thierfelder and Wall, 2009)	Crop Residue for soil amendment is common in only three specific cases: (i) moderate levels of cereal production, low demand for biomass and significant access to alternative feed resources (Giller et al., 2009, Valbuena et al., 2012 and Tittonell et al., 2012).

(6) Potential to increase/sustain productivity and environmental protection (impacts)

Both wind and water erosion are controlled most effectively by residues left on the surface, with the degree of erosion control increasing as more of the field is covered by residues. Doubling the mass of 25 cm high wheat residue (from 0.56 to 1.12 t/ha) can cut wind erosion by more than 95% (Finkel 1986). When 20% of the soil surface is covered by residues, soil erosion will be 50% less than that of a residue-free field (Shelton et al. 1991), and a 90% cover can reduce water erosion by as much as 93% compared with bare soil (Wischmeier and Smith 1978). **Reduced erosion and increased soil water storage in turn result in higher crop yields**. In addition, the presence of residues reduces surface runoff of soil particles because it increases water infiltration rates. Even long straws are good absorbers of water, averaging 2–3 kg of water per kg of straw; shredding further enhances this capacity to 3–3.8 kg per kg of crop residue.**Retention of crop residues on farm plots can be beneficial in the long term to improve crop productivity and hence production of more biomass to meet the competing residue use for soil fertility. High grain yields result in more residue**.

(7) Description of the technology and steps

Crop residue is one of the most important conservation tillage factors for improving soil's physical and chemical properties. Residue helps reduce surface runoff and soil loss, conserving soil moisture and improving soil microorganism populations, soil organic matter content, and soil hydraulic/physical properties.

Crop residues include the above-ground biomass of plants remaining in the field after grains, tubers and other products have been collected. The crop residues are incorporated into the soil and /or left as mulch (Elias, 2002). It is a way of directly recycling nutrients into the soil taken by the plants from the soil earlier. It is used for soil protection and soil fertility improvement (Smith and Elliott, 1990).

Steps

1. Leave at least 60% (2-7cm thickness) of crop residues on the land. Leaving last year's crop residue on the surface before and during planting operations provides cover for the soil at a critical time of the year. The residue is left on the surface by reducing tillage operations and turning the soil less.
2. Must maintain 60% ground cover at planting. This may require the previous crop to be no-tilled or followed by a cover crop. Cover crops must be planted after harvest of low residue crops (i.e. peanuts, cotton, etc)
3. Crop residue must be managed at harvest for maximum land cover.
4. No burning of residue is allowed.
5. Two inspections of fields will be made; one after fields is planted and the second before the soil is disturbed before planting a subsequent crop.

NB,Crop residues should be seen not as wastes but as providers of essential environmental services, assuring the continuation of productive agro ecosystems. Recycling of crop residues—both directly, by leaving them to decay on field surfaces after the harvest or by incorporating them into soil by plowing, or , by using them in mulches and composts or returning them to fields in animal wastes.

Generally, reducing the demand for crop residues as livestock feed through the introduction of alternative feed sources, better extension services on the use of crop residue as soil mulch and designing agro ecology specific strategies and interventions could facilitate the adoption and expansion of CA-based practices in mixed crop-livestock systems.

(8) Challenges and Constraints(limitations)

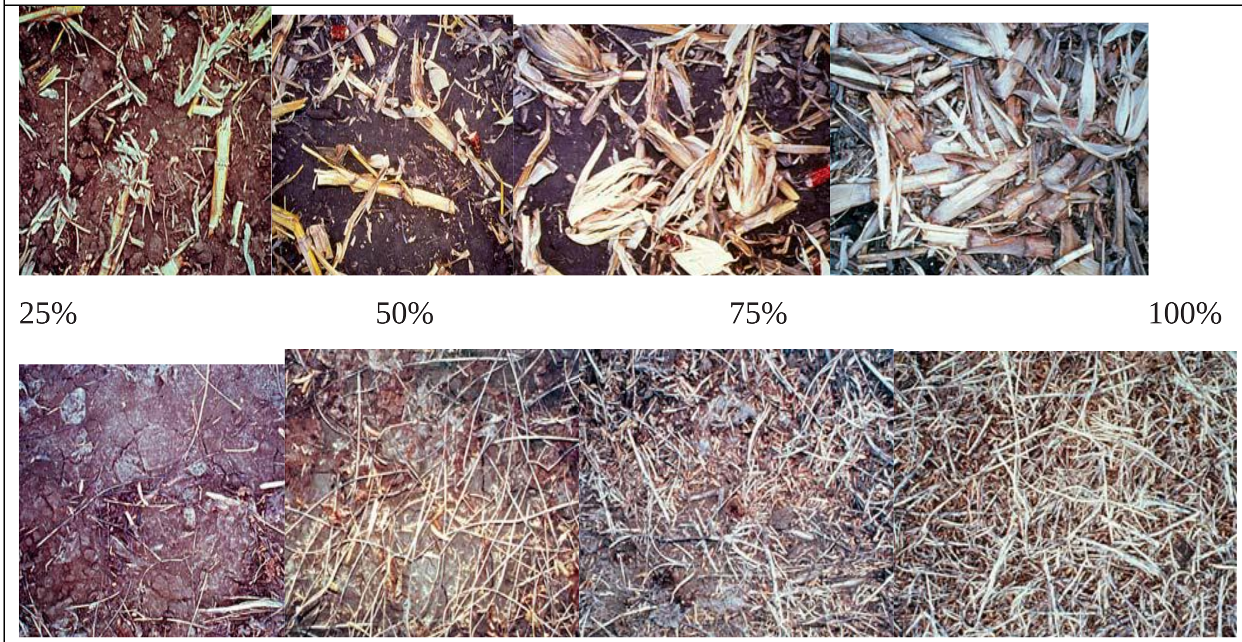
Crop residue use as soil mulch in conservation agriculture is challenged in mixed crop livestock systems and particularly by smallholder farmers owning cross-bred and exotic dairy animals.Residue use is critical in areas where farmers experience long dry spell between successive cropping seasons and with no or limited alternative feed sources.

The major cereal residue use is free grazing by livestock (~50–90% of cereal residue) and only few farmers leave cereal residue in the field specifically for soil amendment. Residue left on the soil might however also be grazed during the dry season or eaten by termites.

Crop residues (CR) have become a limited resource in mixed crop-livestock farms. As a result of the increasing demand and low availability of alternative resources, CR became an essential resource for household activities, especially for livestockkeeping; a major livelihood element of smallholder farmer. Farmers' decisions on use are determined by farmers' preferences, total crop production, availability of alternative resources and demand for CR. Interaction of these determinants can result in pressures and trade-offs of CR use. Cereal residues tend to be rather used as livestock feed than for soil amendment at sites with high cereal residue production per farm and moderate demand for feed.

NB:Provision of extension and training services on the importance of crop residue use as soil mulch helps in increasing awareness among farmers and could enhance their current level of residue use as soil mulch

In the no-till farming system, significant amounts of crop residue remain on the soil surface,
Protecting it from water erosion and improving soil quality.
Source: www.ipm.iastate.edu/ipm/icm/node/451



25% 50% 75% 100%

25% 50% 75% 100%

Photographs of maize and soybean residue cover at different percentages respectively

ECHNICAL INFORMATION KIT

9.1.2. Crop Rotation

(1) Definition Of Crop Rotation

Crop rotation is “the sequence of crops grown in succession on a particular field” (Wibberley, 1996).

Example Planting maize one year, and beans the next. This means changing the type of crops grown in the field each season or each Year (or changing from crops to fallow).

Crop rotation is a key principle of CA because it improves the soil structure and fertility, and because it helps control weeds, pests and diseases.

(2) Period/ phases forimplementation

Rotation decisions integrate time and space. Rotation management requires understanding the needs of the whole farm and each individual field or bed on both an annual and multi-year basis.

To implement rotation 1st Identify Plant Families (cabbage family, bean family, onion family, potato family, etc) that to grown. By type (more reliable)

By feeding categorization

Then, rotate subsequent years’ crops by following a rotation plan. What crops should you plant next year or season, and the year after that, depends on many things. The final choice of sequence is primarily a management decision based on a desire to optimize, for example, financial;generally, crops in the same family should not follow one another in the field. At a minimum, crops from a particular family should be separated by *at least* two years of crops from other families, as closely related crops are more susceptible to the incidence of diseases, pests etc

(3) Main objective(s)/purposes

The main objectives of crop rotation are to help manage soil fertility and to help avoid or reduce problems with soil borne diseases and insects. Specific objectives of Crop rotation are to:-

- Maintain healthy soil (e.g., chemical balance, drainage, humus, vitality, biological health, fertility management, erosion, nutrient cycling, tilth, organic matter.
- Control diseases, especially soil-borne diseases, insect
- Reduce weed pressure
- Increase profitability
- Approach holistically; good rotation leads to healthy crops
- Manage farm as a whole system
- Stabilize farm economically and Minimize off-farm inputs
- Add N & other nutrients in a way that is environmentally safe

(4) Suitability and adaptability to local knowledge.

Crop rotation can be practiced by all sizes of farming,. it is one of the oldest and most fundamental agronomical practices (Lawes *et al.*, 1895) known to man for fertility restoration and pest/disease control and it consists of growing different crops one after the other on the same piece of land. **In Ethiopia Rotations is integral part farming systems**. To a various extent they have been affected by factors related to food insecurity and the need to increase staple cereals. However, improved solutions for sound rotations are possible and can be integrated into extension and conservation packages.

(5) Potential to increase/sustain productivity and environmental protection (impacts)

Crop rotation can have an influence on the success of conservation tillage practices, especially no-till and the distribution of plant residue from the previous crop. For example long-term studies show that a corn-soybean rotation improves yield under no-till compared to continuous corn.

Crop rotations support sustainable crop production and soil quality over time by structuring the temporal succession of crops in fields. It is often key to a sustainable agricultural production system and can reduce the need for fertilizer and pesticides. Fertilizer applications are often adjusted for prior nitrogen-fixing crop.

A study showed in the Midwestern US well-managed legume rotation can add 150 pounds/acre of nitrogen about half the inorganic nitrogen applied to corn (http://people.oregonstate.edu/~muirp/sustfert.htm).

The improvement of plant cover and soil structure through sound crop rotations sustainably influences the effect of runoff and levels of soil loss.

Benefits of crop rotation in soil conservation can be illustrated by the results obtained in Kenya (see table below) at 20% slope, with loamy soils and rainfall about 960mm/year.

The effect of crop rotation with pasture leys (legume and grass) on runoff and soil loss

practice	Run off	Soil loss ton/ha
Continuous maize	40	242.21
Maize in rotation	24	103.81
Wheat in rotation	25	14.83
First year ley	18	1.48
Second year ley	13	0.49
Permanent pasture	4	0.0049

Crop rotation in addition helps to control rodents infestations. It is well known that different crops are not equally suitable to the same kinds of pests or diseases. Growing the same crop year after year will provide an opportunity for pests to multiply and outbreak virulently after two or three years of continuous cultivation, eventually leading to serious loss of crop yield. The same problem holds true for weed infestation.

Generally planned crop rotations can increase yields, improve soil structure, reduce soil loss, conserve soil moisture, reduce fertilizer and pesticide needs, and provide other environmental and economic benefits. Farmers that practice long-term crop rotation can reduce soil erosion on their land. A study conducted in 1988 found 6 inches more topsoil on an organic farm than on an adjacent conventional farm in Washington.

(6) Description of the technology and steps

Rotations are most effective when combined with such practices as manuring, composting, cover cropping, green manuring, and short pasturing cycles. Together, these practices create soil quality improvements such as increased soil aggregate stability, decreased crusting of soil surfaces, and increased granular structure and friable consistence. Crop rotation allows the plants' effects on the soil to benefit the next crop. Basically, crop rotation capitalizes on what is already happening when plants grow, and prevents the negative consequences that can result from random plantings. In rotations, farmers can also plant crops, like soybeans and other legumes that replenish plant nutrients thereby reducing the need for chemical fertilizers. For instance, corn grown in a field previously used to grow soybeans or cowpea needs less added nitrogen to produce high yields. Crop rotation hasvarious advantages:

- **It improves the soil structure** Some crops have strong, deep roots. They can break up hardpans, and tap moisture and nutrients from deep in the soil. Others have many fine, shallow roots. They tap nutrients near the surface and bind the soil. They form many tiny holes so that air and water can get into the soil.
- **It increases soil fertility** Legumes (such as groundnuts and beans) fix nitrogen in the soil. When their green parts and roots rot, this nitrogen can be used by other crops such as maize. The result is higher, more stable yields, without the need to apply expensive inorganic fertilizer.
- **It helps control weeds, pests and diseases** Planting the same crop season after season encourage certain weeds, insects and diseases. Planting different crops breaks their life cycle and prevents them from multiplying.
- **It produces different types of output** Growing a mix of grain, beans, vegetables and fodder means a more varied diet and more types of produce to sell.
- **It reduces risk** A single crop may fail because of drought. It may be attacked by pests. Or its market price may be low when time comes to sell it. Producing several different crops reduces these risks.

In Ethiopia the rotation should be seen with in a dual perspective .i.e. within the year and between successive years of cropping. Within the year refers to the possibility to intercrop different species or double cropping based upon the available moisture and crop water requirements. Between years refers to the alternance of conserving and depleting crops or pastures (leys) in a sound manner.In Ethiopian moisture deficit areas, crop rotations should also be moisture based within plots (see konso experiences) i.e. spatial as well as temporal moisture based rotations. Besides, the possibility to introduce improved verities of legumes and other crops, existing cropping patterns offer ample scope for improvement in terms of optimizing the sequence of crops, their arrangements and sawing dates. In this respect, accessibility to improved verities of legumes (locally improved), possibly inoculated with highly efficient strains of rizhoobia would significantly improve fertility and yield of crops. In all circumstances legumes need to be rotated with cereals and compost applications need to become regular feature of the farming systems in all agro climatic zones

(6) Integration opportunities/requirements

- Sound rotation can be easily introduced when fields are properly conserved and fertility restored(compost, manure, etc)
- Ley and intercropping are also best practices to encourage rotation.
- It is important to rotate different species, especially species that causes the different pests and diseases.
- Best economic returns from rotations can be expected if legumes are included, because of the nitrogen they add to the system.
- The most effective rotations combine crops with different growth strategies (deep versus shallow rooting, nutrient accumulating vs nutrient depleting; water accumulating vs water consuming etc…)

(7) Challenges and Constraints(limitations

Crop rotations may reduce profits when the acreage and frequency of highly profitable crops are replaced with crops earning lower returns. If not implemented properly, certain insect pests and diseases may spread easily from one crop to the next through the crop residues. **Avoid crop combinations** where this is a problem.

Markets do not always exist for new crops you may want to plant as part of your rotation. It may be hard to find seed, you can’t find anyone to buy the yield, or prices are too low to make it worthwhile growing the crop.

- ❖ Advice farmers and agro-pastoralists to check the source of seeds and price of the outputs before they decide which crops to plant.

The challenge for farmers practicing crop rotation is: to define systems that maintain farm profits with practices that improve soil quality and prevent environmental degradation. Farmers may want to consider such options as alternative crops, double and triple cropping, value-added enterprises (such as producing cover crop seed or forages and green manures for composting), or a combination of all of these

Technical information kit	**(1) Brief description of Agro-forestry**	**Objective/benefit**
9.2. Agro forestry	**Agroforestry** is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. This definition implies that: • Agroforestry normally involves two or more species of plants (or plants and animals), at least one of which is a woody perennial; • An agroforestry system always has two or more outputs; • The cycle of an agroforestry system is always more than one year	The major objective of Agroforestry focuses on the wide range of working trees grown on farms and in rural landscapes. Among these are **Economicbenefits:**a source for Constructionandhouseholdtools, Foodandfodderproducts:for nutrition and income generation,improve smallholder livestock production,medicine to combat disease,etc **Environmentalprotection**: Treeplantingorretentionprotectssoilandamelioratesthe environment by controlling soil erosion, minimizing land degradation **Reclaiming marginl lands**: Improve soil structure drainage, control weeds through mulching and upper canopy cover., bring leached nutrient to the surface and Improve fertility status of the soil through nitrogen fixation

(3) Suitability and adaptability to local knowledge	**(4) Attributes of Agro-forestry/ Potential to increase productivity, Adaptation and mitigation**
Local communities are active managers of woody resources within the local land use systems. Very often they practice already a form of agro-forestry. Improved or new agro-forestry technologies can easily be introduced in new areas as they conform to local knowledge and farming practices. More and more agro-forestry is seen as a land use system that is attractive, well understood and easily accepted by small holder farmers.	***Productivity:*** Most, if not all, Agroforestry systems aim to maintain or increase production as well as productivity (of the land). Agroforestry can improve productivity in many different ways. These include: increased output of tree products, improved yields of associated crops and reduction of cropping system inputs, ***Sustainability****:* By conserving the production potential of the resource base, mainly through the beneficial effects of woody perennials on soils, agroforestry can achieve and indefinitely maintain conservation and fertility goals. ***Mitigation:*** Integration of Improved Agroforestry in different land use system will tremendously increase the carbon sequestration as both Above and below ground biomass where the practice is promoted

(5) Tree Management in Agro-forstry	***(6) choice of species in Agroforestry***
The major role of tree management in agro-forestry is restoration of healthy co-existence among integrated crops of a given land use system. The following are some major tending operations in Agro-forestry system These are Watering, manuring, weeding, mulching, replacement planting and others including : **Pollarding**: the cutting back of the crown of the tree at a height of 2m or more from the ground. **Lopping**: a practice of cutting one or more branches of a standing tree for fuel or fodder. **Pruning**: removal of live or dead branches or multiple branches from the standing tree when shade impact is increasing. **Thinning**: removal of part of a standing crop when the stocking is more than necessary and to allow the remaining	The main Characteristics of a tree that are important for agro-forestry are: ➢ Adaptability of the species for the specific environment ➢ Ability to withstand adverse condition ➢ Palatability of the selected fodder, tree growth rate and growth habit specially on its branching and root system ➢ Capability to withstand management practices (pruning, lopping etc) and its ability to nutrient cycling and nitrogen fixation.

<table>
<tr><td>trees to grow at their optimum rate</td><td></td></tr>
<tr><td>(7)Inputs and skills required for Agro-forestry</td><td>(8) Constraints and limitation of Agro-forestry</td></tr>
<tr><td>Input: seed/seedling, provision of tools for tending operation i.e hoe, reck etc How to collect seed from the locality
Skill: seed propagation system, seed storage, seed germination and seedling handling are among others.
In addition, the skill on how to select the right species for the right place has also a paramount importance</td><td>o Free grazing problem makes seedlings exposed to browsing animals,
o Problem of provision of high quality seedling,
o Problem on species–site matching (selecting the right species for the right place),
o lack of seed/seedling source,
o poor follow up after planting in the field(weeding and cultivation etc),
o The mindset by farmers that trees compete for light and space with associated plant on the lower strata,
o Scarcity of trained personnel to handle or improve the existing agro-forestry system and demonstrate at FTCs</td></tr>
<tr><td colspan="2">(9) Agroforestry technologies and activities recommended to be integrated into the SLM programme</td></tr>
<tr><td colspan="2">1. <u>Agroforestry for enhancing land productivity:</u> Agroforestry practices that can improve soil fertility, increase crops yield and provide shade based on the local conditions and existing indigenous knowledge. These include trees arranged irregularly or in some kind of systematic manner on croplands as an intercropping of cereals withfertilizer trees, conservation agriculture with trees (CAWT), promotion of different shade trees in the coffee and spice farming system. And promotion of Multipurpose legume trees and shrubs that fix nitrogen and form association with mycorrhiza to enhance soil fertility
2. Boundary Planting, shelterbelt and livefence: these comprises trees and shrubs planted along and around the farm for protective purpose and boundary marking. They are mainly used or boundary markers, live fence soure of fodder or windbreak.
3. <u>Agroforestry for SWC</u> An Agro-forestry practice that stabilizes the physical structure of the bunds, terraces and raisers in the farm and communal lands integrated with or without grass.
. <u>4.Agroforestry for food and income diversification</u>: high-value fruit and leafy-tree technologies can be introduced around homestead based on farmer’s preference, the species requirements and land availability. Under this technology, Common fruit trees, under-utilized perennial food crops, improved high value tree crops and Vegetable trees can be promoted.
<u>4.Agroforestry for fodder/forage</u>: Agroforestry that enhance availability of fodder for livestock and bees based on local conditions and farmer’s preference. These include establishment of fodder banks around homestead as live fence, boundary planting and parkland systems.
<u>5. Agroforestry for reclaiming degraded sites</u>: it is intended to restore degraded sites to increase the carbon sequestration potential of degraded farm land as a mechanism to mitigate climate change. Enrichment planting and Farmer Managed Natural Regeneration (FMNR) on ex-closures and degraded natural forests using valuable trees/shrubs; rehabilitation of gullies using local and improved grasses, and lowland and highland bamboos to increase the carbon stock of existing land uses to help in the reduction of greenhouse gas (GHG) emission through C-sequestration in above- and Below-ground tree biomass.</td></tr>
</table>

FAIDHERBIA ALBIDA

DESCRIPTION:

The name Faidherbiaalbida was used to be called Acacia albida. Faidherbiaalbida is a tree up to 30 m high with light-brown bark and hairy leaves with thorns at the base. It bears leaves only during the dry season. It has light-yellow flowering spikes and crescent shaped or circular light-brown pods. Its roots can reach aquifers up to 80 m below the surface. Young trees have inverted cone-shaped crown, old trees with a hemispherical largecanopy.

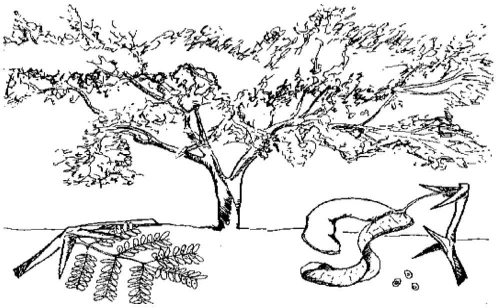


Figure 1: Faidherbiaalbida tree, leaves and pods

Context: The unique characteristics, wider distribution, available local knowledge and information, and multipurpose benefits and services make it one of the best climate smart agroforestry tree. As a result, the national scaling up program on *F. albida* by the Ethiopian government to plant/establish 100 million trees in five years has designed. It is also considered as the best agroforestry trees for incorporating with crops as a main entry for EverGreen Agriculture that aims to sustain a green cover on the land throughout the year while increasing food and fodder production to improve the livelihoods of smallholder farmers and sustain the natural resources, which they depend upon.

Distribution and potential niches

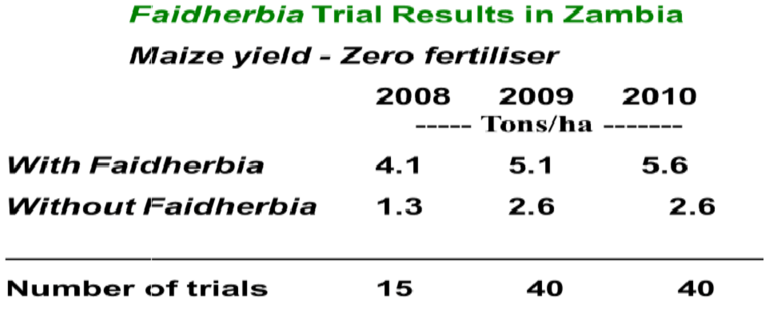
Faidherbiaalbida is widely distributed in Ethiopia. It occurs over a wide range of ecological conditions, mainly on deep, sandy, well-drained soils having water tables that can be easily reached by the roots (2 to 3 m and more). Its natural range extends throughout low to mid-high land ranged from 270-2400 m.a.s.l. but in Ethiopian context dominantly found within the range of 1600 to 2300 m. a.s.l. It grows in a wide range of climates and habitats, mainly as parkland, backyard & rangeland agroforestry systems either in scattered or grouped, in woodland, cultivated and rangeland areas. It develops into large populations and mainly found around many of the rift valley lakes or riverine and valley bottoms and in many parts of Tigray, Oromia and Amhara regions. *Faidherbiaalbida* is adapted to grow at mean annual temperature ranging from 18°C to 30°C, low to medium rainfall (250–1200mm yr^{-1}) and thrives in climates characterized by long summer, or dry season with long days.

Benefits and environmental services

Faidherbiaalbida can smarten agricultural systems to create resilience to climate change, to reduce food insecurity and improve community's livelihood. The following are some of the main merits of *F.albida*why it is considered as a climate smart agroforestry tree in the Ethiopia context.

- It has a high ecological adaptability (across a range of soil types and altitudinal ranges)
- It is very compatible with crops as it drops its leaves at the beginning of the rains and is dormant during the wet season (a practice known as 'reverse phenology'). As a result, the trees provide less competition with the crops growing beneath its canopy and actually increase crop production and productivity.
- Under its canopy a fertile, protected micro-climate is created for crops and pasture grasses with better moisture retention and rainfall infiltration, reduction of evapotranspiration and protection from extreme temperatures.
- Its roots fix nitrogen, which is captured in the fallen leaves providing a nitrogen-rich mulch for the soil and crops. In studies across Africa, the yield of maize, millet, groundnuts and sorghum has been seen to increase by 30-200% beneath F. albida canopies (C.C Rhoades, 1997). Though the number of trees per hectare depends on the canopy size of the tree, approximately 100 – 150 trees per ha, can provide maximum benefits in crop land.
- Leaves and pods are valuable feed for livestock and provides nutritious feed with high protein content. Trees also provide shade for animals reducing heat stress in the middle of the day
- Wood and branches can be collected through pruning or thinning techniques. The wood can be used for farm implements, firewood, construction of beehives from the bark and the thorny branches used for fencing.
- It gives flowers in the dry season, later than most plants, which is the most useful source of pollen and nectar for honey bees

Table 1 Effects of planting *F. albida* trees on yields of maize in Zambia



***Faidherbia* Trial Results in Zambia**

Maize yield - Zero fertiliser

	2008	2009	2010
	----- Tons/ha -------		
With Faidherbia	4.1	5.1	5.6
Without Faidherbia	1.3	2.6	2.6
Number of trials	15	40	40

Source: Garrity, 2013

Figure 2: Scattered trees of *F. albida as parkland agroforestry system, Ethiopia*

Propagation techniques

Establishment and promotion of *F. albida* in Ethiopian farms through planting, assisted natural regeneration are the two main propagation methods for*F. albida*.

Raising seedlings in the nursery

Nursery operation starts from getting quality seeds. Seeds can be obtained from local collection and seed supplying organizations.

Seed collection from local area begins from Mother tree selection: Seeds from more branchy and vigorous trees will most likely produce more branchy and vigorous trees

Seed collection and timing: The best time for seed collection is when the seed coat is still pale in color and relatively soft and the swollen pods are just beginning to turn brown. In this way insect damage is minimized and germination is good even without pre-sowing treatment.

Seeds can be collected through different techniques, so that the seeds get fall down: Shaking the branches or Beating the tree with a long slender pole, or throwing sticks at the branches, or Climbing to the tree. The best way of collecting seeds is to harvest the pod when they are ripe but before they open and the seeds dispersed.

Figure 3: pod collection and pods before seeds dispersed and quality seed from the pod

To extract the seeds correctly, pods can be dried in the sun until they split open(see fig 3 above).

Seeds are best stored in dry and cool conditions out of reach of insects, rodents and birds. Before storage the seeds must be properly dried otherwise they will become decaying. Airtight containers, tins or bottles, are good for storage of most seeds, and are essential for storage of seeds that are easily attacked by insects.

Seeds should be pre-treated in 3 ways for better germination:

Mechanical scarification works best for small lots or covering the seed with boiling water then allowing cooling for 24 hours or Put in cold water for 24 hours and sow immediately. Studies indicated that air pruning are recommended than the common practice of root pruning during raising seedlings in Nursery for 6-7 months before planting. Seedling can be raised in nursery by direct sowing to polyethylene tubes transplant from the bed to polyethylene tube filed with the 2:1:1 forest soil: compost: sand soil composition supported with regular watering in the early morning and late afternoon.

Figure 4: F. albidaseedlings raising using air pruned technique

Direct seeding:

This practice is especially good in relatively moist areas but needs further testing in dryland areas. Direct seeding of 1-2 seeds to the pits should be under taken early in the rainy season, to allow as much time as possible for the plants to establish before the dry season. A few weeks after the seedlings appear, thin them out leaving one strong and healthy seedling and also do replanting in the furrow/basin where there is no seedling germination. Seeds passes through digetsion process of livestock are best preferable for direct sowing. Farmers' in Abreha we Atsbehavillage, Tigray, are well experinced in feeding their animals with F. albida pods and collect their manaure and then put in their farm lands to get successful establishmnet of F. albida seeds.

The treated F. albida seed should be sown to the soil at a depth of two or three times of the seed size (10-15mm). Direct sown seedlings should get water at about five-day interval for two or three times or till it get well established.

Fencing/protecting from livestock and human interference is important using thorny acacia and wooden materials immediately after sawing and enlarge the fence together with the height of the seedling.

Farmer Managed Natural Regeneration (FMNR)

FMNR is a very rapid, low cost, easily replicable and sustainable method of degraded landscape restoration which can be easily managed by the whole family of a given household. It involves selective thinning and pruning of re-growth from stumps, roots or seeds of F. albida coming out from the ground. This practice is easily applicable using locally available materials (sickle, sharp axe, machete, harvesting knife). This method can complement and/or replace in some cases the need to establish trees using seedlings raised in nurseries which is costly and time consuming and often failures during planting out operations.

Figure 5: Young F. albida being grown through FMNR techniques

Figure 6: Pruning up to 2/3 of the total length of F. albida saplings grown naturally in any land use system

Management

There are certain management techniques which are applied to F. albida agroforestry trees.**Pruning**: it is the removal of branches from the lower part of the tree crown with the main objectives of Reduction of shade for crops near the tree; early harvest of branch wood for fuel or other use and to reduce competition & enhancing the growth of selected ones. Pruning to develop a single stem can be begin when F. albida saplings/trees are 2-years and an old ones can be pruned starting from the height of the crop under it. Usually the pruning should takes place in dry season when there is enough leaf biomass.

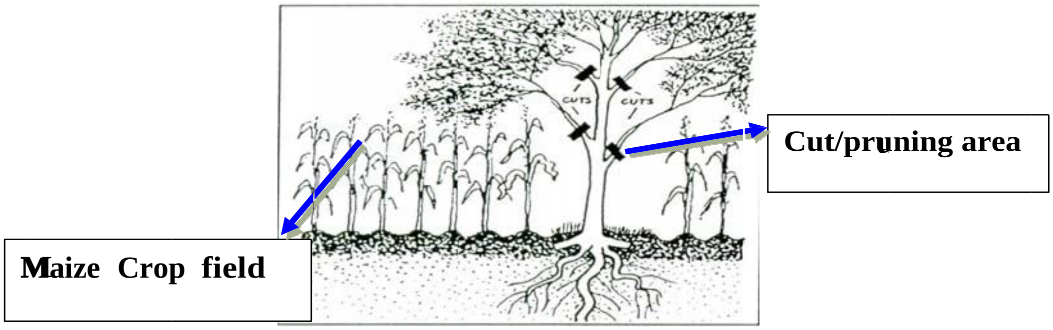


Figure 7: How to prune branches of F. albida in crop fields to reduce computation & to use branches for other purposes

Regardless of age and size of the tree, generally we can follow the following three steps to prune F. albida trees:

Step 1: Remove any dead, broken, diseased or dying branch;

Step 2: Identify the main stem & any branches that will compete with it, & decide how much competing stems should be removed.

Step 3: Removal of lower limbs.

Further, there are three steps to prune large limbs that require the use of sow:

Step 1: Cut a notch about 1/3 of the diameter of the stem

Step 2: Remove most of the branch above the notch

Step 3: The final cut is perpendicular to the branch, following the outside edge of the branch collar

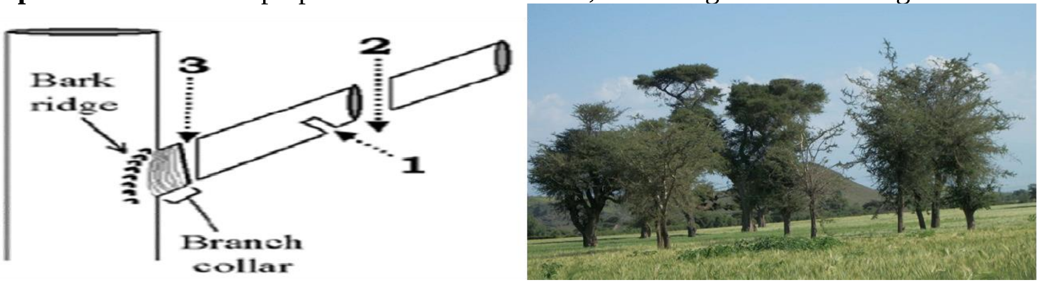


Figure 8: Three steps of large limb pruning of F. albida

Lopping: It is cutting of branches randomly from the leafy crown. Also lopping is not always done starting from the lower part of the tree but can be more haphazard. If any selection of branches is made, the main criteria are often a good green leafy biomass since the lopping is usually done to obtain branches of fodder. This is mostly common when F. albida are grown in rows in farmlands.

Figure 9: Lopping practice in row planted F. albida

Pollarding: It is the method of cutting of all the branches and the top part of the tree with a major objective of early harvest of wood and fodder production and reduction of shade for crops.

Figure 10: Pollarding of *Faidherbiaalbida* trees

GREVILLEA ROBUSTA

Grevillea robusta

A.cunn.ex R.Br.

DESCRIPTION

Grevillearobusta is a deciduous medium-sized to large tree 12-25 (max. 40) m tall; crown conical, dense, with branches projecting upwards. Bole straight, branchless for up to 15 m, up to 80 (max. 120) cm in diameter, usually without buttresses; bark fissured, sometimes pustulate, dark grey to dark brown, inner bark reddish-brown.

Leaves alternate, fernlike, pinnately (almost bipinnately) compound, 15-30 cm long, exstipulate; 11-21 pairs side axes (pinnae), 4-9 cm long, deeply divided into narrow, long, pointed lobes 6-12 mm wide, upper surfaces shiny dark green and hairless, underneath silky with whitish or ash-coloured hairs.

Flowers showy, yellowish, numerous, paired, on long slender stalks 1-2 cm, composed of 4 narrow yellow or orange sepals 12 mm long.

Fruits pod like, broad, slightly flattened (boat shaped), 2 cm long, black with long slender stalk and long, threadlike, curved style; 1 or 2 seeds, 10-13 mm long, elliptical, brown, flattened with wing all around a coriaceous to woody follicle, usually oblique and opening along the ventral margin

The name commemorates Charles F. Greville (1749-1809), one of the founders of the Royal Horticultural Society of London.

ECOLOGY

G. Robusta grows well in climates with a winter maximum or a bimodal rainfall regime. In temperate areas, it can survive moderate winter frosts. It is not resistant to persistent strong winds. In its natural range, the species is semi-deciduous, shedding most of its leaves in the dry season, and can stand up to 6 months of drought. In Ethiopia, it does well in Dry, Moist and Wet WeynaDega and Degaagroclimatic zones, 1,500–2,700 m.

BIOPHYSICAL LIMITS

Altitude: 0-2300 m, Mean annual temperature: 14-23 to 25-31 deg. C, Mean annual rainfall: 600-1700 mm

Soil type: Establishes well in riverine habitats, on alluvial soils that are free of waterlogging and mildly acid to neutral. Loam soil is preferred. It also occurs on clay loam and sand.

DOCUMENTED SPECIES DISTRIBUTION

Native: Australia

Exotic: China, Eritrea, Ethiopia, India, Indonesia, Jamaica, Kenya, Laos, Malawi, Malaysia, Mauritius,Nepal, Pakistan, Philippines, South Africa, Sri Lanka, Tanzania, Uganda, United States of America,Vietnam, Zambia, Zimbabwe

PRODUCTS

Apiculture: The golden flowers are attractive to bees, making it an important honey plant. G. robusta honey is dark amber, of high density with a pronounced flavour.

Fuel: G. robusta is popular for firewood and charcoal. It is also used to fuel locomotives and river steamers, power boilers and small industries. The calorific value of sapwood is about 4800 kcal/kg, while that of heartwood is 4950 kcal/kg.

Fibre: Mean fibre length is about 1.5 mm and width about 26 µm; the wood is suitable for pulping.

Timber: Grevillea yields a medium-weight hardwood with a density of 540-720 kg/cubic m at 15% moisture content. The timber has economic potential. Grain straight to wavy; texture medium to coarse and uneven; wood lustrous; prominent silver grain on radial surface

Gum or resin: By virtue of their solubility, viscosity and relatively high resistance to hydrolysis, G. robusta gums may have some industrial applications

Poison: The flower buds, fruit and seeds are cyanogenic. Through contact with the leaves, sensitive persons may develop contact dermatitis due to tridecylresorcinol, a chemical compound related to the allergen toxicodendron.

SERVICES

Shade or shelter: This is a well known shade tree in coffee and tea plantations. Its spreading branching system makes it ideal for windbreaks or shelterbelts against wind-induced mechanical damage, high rates of transpiration and surface evaporation.

Reclamation: G. robusta is a pioneering colonizer of disturbed sites.

Soil improver: G. robusta provides abundant quantities of leaf mulch, which may accumulate to a depth of 30-40 cm. This thick layer protects the soil and maintains soil temperature. The leaves and twigs are apparently rich in aluminium.

Ornamental: Its majestic height, attractive shape and beautiful foliage make G. robusta an ideal tree for landscaping of private and public gardens. The cut leaves are used in flower arrangements, and young plants are grown as indoor pot plants in Europe.

Intercropping: A deep rooting system causes little interference with shallow-rooted crops, and it can be successfully intercropped with banana, tomato and other agricultural crops.

TREE MANAGEMENT

Moderate to fast growing. When climate and soil are suitable and weed competition is not severe, annual height and diameter increments of at least 2 m and 2 cm, respectively, are usually achieved for the 1st few years in row planting on farms. Annual height increments of 3 m have been observed at the most favourable sites. G. robusta regrows well after complete defoliation following pruning and pollarding, which can be carried out repeatedly to yield wood and to regulate shading and competition with adjacent crops. It is characterized by root suckering, hence it is a good candidate for management under coppice rotation; it responds well to pollarding, lopping and pruning.

A plant density of 800-1200 trees/ha is recommended for plantations. Some control of competing vegetation is required for the 1st 1-2 years after planting. Seedlings are normally planted at a spacing of 2.5-3 x 3-4 m. The relatively open canopy of G. robusta makes it less suitable for areas with erosional hazard. It also easily regenerates naturally, especially in agricultural fields.

GERMPLASM MANAGEMENT

Collection of seeds from mature trees is very difficult because the seeds are borne on thin and inaccessible branches at great heights and are easily lost during collection. Seed storage behaviour is orthodox; whole seed have 28.5% mc; 60-70% germination following 2 years of hermetic storage at -7 deg. C with 10% mc; 35% germination following 12 months of open storage. Seeds were maintained for 4 years in commercial storage conditions; viability was maintained for 2 years in hermetic air-dry storage at 3 deg. C. There are between 24 000 and 105 000 seeds/kg.

- Treatment: Not necessary for fresh seed.
- Storage: Seed can be stored for up to three months, but this period can be extended if it is refrigerated. It is better to avoid storage.

PROPAGATION;

Wildings, seedlings

PESTS AND DISEASES

In humid regions, G. robusta is vulnerable to attack by fungal diseases such as Corticiumsalmoniclor. Fungi such as Amphichaeta grevilleae, Cercospora spp. and Phyllostica spp. have been observed to cause considerable damage to leaves and stems of young plants in Sri Lanka, particularly if they are overwatered in the nursery. Under lowland conditions in the Caribbean, it is severely attacked by the scale insect Asterolecaniumpustulans. Attack by termites can be a problem when planted on dry sites in Africa. The wood is susceptible to marine borer and pinhole borer. Sapwood is susceptible to Lyctus.

REMARK

It can be an important dry-season fodder although not top-quality. The leaf litter can be used as bedding material in livestock zero-grazing units. A mixture of manure and *Grevillea* leaves make a very good addition to the soil. The tree grows well with food crops if managed to reduce shade. The timber is hard and has an attractive grain — the red-brown colour and silky surface like that of the true oak, *Quercus*.

MORINGA *(MORINGA OLEIFERA)*

DESCRIPTION:

Moringaoleifera is a fast-growing, deciduous tree that can reach a height of 10–12 m (32-40 ft) and the trunk can reach a diameter of 45 cm (1.5 ft). The bark has a whitish-grey colour and is surrounded by thick cork. Young shoots have purplish or greenish-white, hairy bark. The tree has an open crown of drooping, fragile branches and the leaves build up feathery foliage of tripinnate leaves.

The flowers are fragrant and bisexual, surrounded by five unequal, thinly veined, yellowish-white petals. The flowers are about 1.0-1.5 cm (1/2") long and 2.0 cm (3/4") broad. They grow on slender, hairy stalks in spreading or drooping later flower clusters which have a length of 10–25 cm.

Flowering begins within the first six months after planting. In seasonally cool regions, flowering only occurs once a year between April and June. In more constant seasonal temperatures and with constant rainfall, flowering can happen twice or even all year-round.

The fruit is a hanging, three-sided brown capsule of 20–45 cm size which holds dark brown, globular seeds with a diameter around 1 cm. The seeds have three whitish papery wings and are dispersed by wind and water.

With regard to cultivation practice, the moringa tree is grown mainly in **semiarid, tropical,** and **subtropical**areas, It tolerates a wide range of soil conditions, but prefers a neutral to slightly acidic (**pH** 6.3 to 7.0), well-drained sandy or loamy soil. In waterlogged soil the roots have a tendency to rot. Moringa is particularly suitable for dry regions, as it can be grown using rainwater without expensive irrigation techniques.

Parameter	**Requirement/range**
Climate	Grows best in tropical or subtropical
Altitude	0 – 2000 m
Rainfall	

	250 – 3000 mm Irrigation needed for leaf production if rainfall < 800 mm
Soil Type	Loamy, sandy, or sandy-loam
Soil pH	pH 5 – 9

In respective of its uses**,** *Moringaoleifera* can be cultivated for its leaves, pods, and/or its kernels for oil extraction and water purification. The yields vary widely, depending on season, variety, fertilization, and irrigation regimen. Moringa yields best under warm, dry conditions with some supplemental fertilizer and irrigation. Harvest is done manually with knives, sickles, and stabs with hooks attached. **Pollarding, coppicing** and lopping or **pruning** are recommended to promote branching, increase production and facilitate harvesting.

TECHNICAL STANDARDS

Establishment

Cultivation practice: Moringa can be grown as an annual or perennial plant. In the first year, all pods are edible, later years bear inedible bitter pods and moringa is often commercially cultivated as an annual. On less favorable locations, perennial cultivation has big advantages as erosion is much smaller with perennial cultivation. Perennial cultivation of moringa is practiced in agroforestry.

Soil preparations: as soil erosion is a major problemin tropical cultivation, soil treatment has to be as shallow as possible. Plowing is required only for high planting densities. In low planting densities, it is better to dig pits (30 to 50 cm deep, and 20 to 40 cm wide) and refill them with the soil so as to ensure good root system penetration without causing too much land erosion.

Propagation: Moringa can be propagated from **seed** or **cuttings**. Direct seeding is possible because the germination rate of *Moringa oleifera* is high, (the germination rate is about 85% After 12 days). Production in **seedbeds** or **containers** is very time-consuming whereas the plants can be better protected from insects and other pests and these techniques are more useful in areas where soil erosion is a problem.

Cuttings of 1 m length and a diameter of at least 4 cm can be also used for propagation. At least one third of the cutting must be buried in the soil. It can also be propagated by seeds, which are planted an inch below the surface and can be germinated year-round in well-draining soil.

Plant Density/Spacing during Planting

For intensive leaf production, the spacing of plants should be 15 x 15 cm or 20 x 10 cm, with conveniently spaced alleys (for example: every 4 m) to facilitate plantation management and harvests. Another option is to space the seeding lines 45 cm apart and to sow every 5 cm on those lines. One can also space the lines only 30 cm apart and sow at a larger distance on the lines (10 to 20 cm)". **Weeding** and **disease prevention** are difficult because of the high density. In a semi-intensive production, the plants are spaced 50 cm to 1 m apart. This gives good results with less maintenance.

Moringa trees can also be cultivated in alleys, as natural fences and associated with other crops. The distance between moringa rows in an **agroforestry** cultivation are usually between 2 and 4 meters.

Types of Applicable Agroforestry Systems

In crop lands: Moringa tree is planted as an alley cropping with a spacing of 2.5-3 meters between plants and 10 meters between rows. The total tree population per ha ranges between 330 and 400.

In homestead: Moringa can be planted around homestead for intensive production. Depending on the available land size, interest of the farmers and water and soil types, the tree can be planted every 2-5 meters between rows and 0.5 – 2 meters between plants.

On hillsides: in low moisture conditions, planting should be complemented by water harvesting structures such as micro-basin and water collection pits. Spacing between plants and row is 3-5*3-5 meters.

Management Practices after Planting

Protection from **pests and diseases**, and **livestock** (fencing) is important**.**

Pollarding, coppicing and **lopping** or **pruning** are recommended to promote branching, increase production and facilitate harvesting.

PERSEA AMERICANA (AVOCADO)

DESCRIPTION

Avocado (***Perseaamericana***) is native to Mexico and Central America, subtropical and tropical origin. It is adaptable to a wide range of climatic conditions, mainly between latitude of 40^0 N and S; very humid and hot to humid and cool conditions. Avocado is almost evergreen plant, except for very limited period of dry seasons particularly at blooming time when it slightly shed its leaves.

Avocado trees are partially self- pollinating and often are propagated through grafting to maintain a predictable and quality of fruit. In Ethiopia, three races of avocado varieties have been identified namely Mexican, Guatemala and West Indies. Each race shows its own specific characteristics (See table 1).

Table 1: Main characteristics among avocado races

Race	Leaf Scent	Fruit				Seed		Tolerance	
		Size	Skin	Oil%	Month to ripen	Size	Cavity	Cold	Salt
Mexican	Anise	Small	Thin	High	6	Big	Loose	Yes	No
Guatemalan	None	Vary	Watery	Medium	9	Small	Tight	Medium	No
West Indians	None	Vary	Leathery	Medium	6	Big	Loose	No	Yes

Avocado growth requirement (distribution and potential niche)

Temperature: Avocado is a tropical to subtropical tree which requires average temperature of 12-30oc during day time and 5-10oc during night time. The three best races of avocado require specific climate as a result of adapting to original environment. West Indian races are adapted to hot, humid conditions with higher summer rainfall. Guatemalan races require a cool, tropical climate without any extreme temperature or humidity. Mexican races require low temperature than other races and withstand temperature of -3 up to -4oC and can grow up to 3600m.a.s.l. South western Ethiopia was found to be ideal area for production of avocado.

Soil type: Avocado trees can grow on a wide range of soil types from light sands through to well-drained clays soils, provided suitable management practices are put in place. The soil for avocado growth should be free of any drainage problems, has to have good depth with 1-2m. Soil with drainage problem makes the avocado tree high susceptible to root rot pathogens. Generally, avocado trees grow well on a rich sandy loam soil.

Altitudinal range: Basically, avocado trees can grow within wide range of agro-ecologies varying from 1800m.a.s.l. up to 3000m.a.s.l. Under Ethiopian condition, it can grow effectively on an altitudinal range of 1000-1800 m.a.s.l. Within this altitudinal range, each race can show its own specific climate requirement (See table 2).

Table : showing Specific climate requirement of each avocado race

No	Types of avocado	Climate requirement of each races
1	West Indian	Requires hot, humid conditions with higher summer rainfall
2	Guatemalan	Require a cool, tropical climate without any extreme temperature or humidity. Some are sensitive to frost
3	Mexican	Require low temperature than other races and withstand temperature of -3 up to -4oC and can grow up to 3600m.a.s.l.

Rainfall: Avocado trees are sensitive to water stress. An annual rainfall exceeding 1100mm is desirable, and it should be well distributed within a year. The production of avocado within moisture deficit areas should be supplemented by adequate irrigation. Beside rainfall, area with high winds is undesirable for avocado production. High winds reduce the humidity; dehydrate the flowers, and affect pollination.

Benefits and environmental services as potential drivers to increase or upscale Avocado

The unique characteristics of avocado trees are its wider distribution, available local knowledge and information, and multipurpose benefits and services make it one of the best climate smart agroforestry tree.It is widely planted as homestead multi story trees.Besides, farmers can plant avocado trees as farm boundary. It also improves soil organic matter from fallen leaves and debris.

Avocado fruits are the most nutritious fruit in the world. It has high protein content, fats (mono and polyunsaturated), several minerals and vitamins. It is suitable for infants through the elderly and does not contain any cholesterol. Therefore, in terms of building resilience at farmers level it has dual function, use as food and income generation values improving the livelihoods.

In terms of emission reduction, avocado trees are evergreen in its nature that it has high potential in reducing greenhouse gasses (carbon sequestration).

Description of the technology and steps to cultivate

Avocado Cultivars

The ‘local’ avocado lines produced conventionally originally introduced from unknown areas. They are however characterized by small fruit sized fruits and believed to be are mostly Mexican race that adapt to medium to high altitudes. Larger fruit size trees are either Guatemalan or West Indian races. In Ethiopia segregated types are found due to long period of crossing and traditional way of propagation seedling and grown trees. Some commercial varieties under production are Furete, Hass, Nabal, Bacoan, Pinkerton, and Ettinger. They were mainly introduced from Israel. The main qualities of these improved avocado varieties are:

- Good and regular yield of high quality,
- Fruit of medium weight with small seed in a well-filled cavity,
- Holding well on the tree,
- Good storage life,
- Small- or medium-sized tree, spreading habit
- Less fiber content of the fruit

Figure 1.1: Major avocado varieties' fruits external features (Source: Lemma A. Melkassa Agricultural Research Center (November 2012, Butajira)

Table1.3: Avocado cultivars and their properties

Cultivar	**Flower type**	**Race**	**Oil content (%)**	**Cold resistance**	**Maturity season**
Furete	B	Mexican x Guatemalan	18	-2 to -3	Mar - may
Hass	A	Gute	25	-2 to -3	Oct - April
Bacon	B	Mex x Gute	18	Very sensitive	May - Oct
Nabal	A	Gut	16	-1 to -2	Dec - May
Pinkerton			24	-1 to -2	-
Ettinger					April - May

Planting material propagation

Usually fruit planting material is prepared from two cultivars: the rootstock (the lower part) and the scion (the upper or fruiting part). Rootstocks, in general have a characteristics of well adapting to the soil environment including resisting/tolerating soil born diseases, well distributing and vigorous root system, optimizing trees height and canopy, and for better precocity whereas scion material is identified for its high yield and better fruit quality. In most cases the grafted/budded trees have also better fruit yield and quality than individual scion variety. Some rootstock can be raised from seeds e.g. Citrus, mango, avocado, peach, whereas others propagated vegetative (apple, plum, pear etc). Under natural conditions the daughter plants produced from a seed cannot be exact replica of the mother plants. Vegetative propagation (stem cuttings, rooted suckers) produces plants with the same characteristics as the parent plant.

Avocado Nursery Site Selection

Nursery site varies with the type of fruit trees planned to produce. But in general, nursery sites for avocado trees expected in areas with dependable and quality water resources for the dry weather, fertile soil otherwise manured, well-drained soil with optimum depth (>1.5m), good slope (5%), relatively near to other infrastructures. It also requires wise plan and design for adequate number of avocado planting material seedlings preparations and their managements. Successful avocado fruit growing needs a reliable source of healthy planting material of the right cultivar. Therefore, the first step towards improving avocado fruit growing is to establish a proper avocado fruit tree nursery under the management of avocado tree nursery expert with professional knowledge based on practical experience and a sense of responsibility.

Windbreaks around the periphery as protection against strong winds as well as fencing against livestock and wild animals are absolutely essential. Ensure availability of avocado scion materials nearby the nursery or establish scion mother trees in the nursery so that you easily prepare adequate grafted planting materials annually.

Rootstock Seed Collection and Planting

There are rootstock varieties identified for its disease resistance/tolerance, better anchorage, precocity, etc characteristics when grafted with identified improved scions. But usually, the choice of rootstock is largely depends on their resistance to three factors: Cold, salt and root rot. Mexican stocks are cold resistant; West Indians are not; and the Gutemalan are intermediate. Salt resistance order is reverse to the cold resistance. Malkassa Agricultural Research Center has already introduced different varieties of these rootstock varieties. One can thus use the seeds of varieties as initial materials for raising rootstocks.

In time of unavailable identified rootstock varieties, seeds of local but known history of avocado tree can be used as source of rootstock seeds. First identify the history of the tree you intended to use for rootstock material. Make a label/tag to the tree so that you can retrieve for the coming production years. In identifying trees for rootstock seeds, be sure that the tree is disease free, vigorous, and the seeds to be collected are true to type i.e. seeds are similar morphology.

Fruits should be mature to get viable seeds. The pulp of fruits should be removed within few days after fruit collection. Before sowing, the extracted seeds need to be treated in hot water (40 – 52^{o}C) for 30 minutes to prevent infection with Phytophthoracinnamoni. The seeds then planted on beds deep enough to cover the tips. Soon after germination, young seedlings are transplanted to grafting block or pot (see figure 2.1 below). After about five months the seedlings are cleft grafted with appropriate scion cultivars.

Figure 2.1: Rootstock transplanted to pot and now ready for grafting, GudeyBilla (Oromia)

Scion Preparation

Grafting/budding of different fruit types vary in time. Most avocado scion woods are selected and grafted when the mother trees are in dormant or just before breaking dormancy. The buds of the scion avocado woods are expected to be mature and ready to break dormancy. Scions are selected taking in consideration the size and other physical appearance of the rootstock prepared. Equal or nearly equal diameter of rootstock and scion will be grafted together to keep cambiums of both parts intact. Scion should be true to type, clean of any damage, diseases or pests, and should not be stunted shoots. Usually previous season grown shoots are selected as for scion woods. The most scion avocado wood has to have the following characteristics:

- Selected and disease free mother trees
- At dormancy period
- Use sterilized tools
- Collect in poly bags and put in ice box
- Both rootstock seedlings and scion trees be irrigated
- Cleft or wedge or fix in place grafting

Grafting and Post Grafting handling

Grafting is a technique of joining different varieties (but usually of the same species) of the rootstock and scion together. The rootstock will be grafted at the size when it reaches pencil size diameter. Grafting took place at 20-30cm height of the rootstock. Budding is applied when the rootstock and the bud of the scion is slippery (easily taken out from the bud stick). On the other hand, budding is recommended if the technician can easily implement the budding technique and could arrive better bud heal percentage. The scion for grafting should be of known variety, true to type and free of any disease and pest. Scion can be a single bud (for budding) or a cutting usually having three buds (for grafting) of the avocado tree.

After grafting, firmly tie the union from bottom to upwards using budding tape or locally prepared transparent plastic tape. Cover the scion along the point of grafting by use of transparent plastic sheet to increase Relative humidity and temperature of the union (see figure 2.2 below). Check the recovery of the union after two weeks by looking through the cover whether the scion starts sprouting or not. If it starts sprouting new shoots carefully remove the cover. Similarly don’t for get to keep the soil moist after grafting. Over water is equally dangerous to the plant.

Figure 2.2: Grafted avocado at GudeyaBilla (Oromia)

2.3 ***Figure 2.2:*** Cleft or Wedge grafting (source Girma L. BOA. November 12/2012 Butajira)

Figure 2.4: Grafting tools Pruning shear, Grafting knife, Plastic tape, Sharpener, Sterilizer (source Girma L. BOA. November 12/2012 Butajira).

Avocado Orchard Establishment and Management

Production Site Selection

Many fruit crops stay on the same place for many decades. Production site selection is one of the primary activities that keep the profitability of the avocado fruit farm. The site should be suitable for the selected avocado cultivar in climate and other requirements. It should be an area that provides moisture especially during the critical stages, seedling growing period, flowering, fruit setting and fruit growing periods. The soil should not be heavy or could be well drained soil. Other important considerations like roads, proximity to marketing place, etc results in better profitability of the avocado orchard.

Spacing is dependent on the variety, growth habit, soil, and others. However, 4-6 meter between rows and 4-6 meter between plants are recommended in general. In many countries 400 – 800 tress/ha avocado grafted trees are planted. Irrigation, fertilization and other routine activities are common.

Site Preparation and Layout

Layout and spacing: The layout is preferred if the varieties are mixed. If a farmer receives 10 grafted seedlings, advise him/her to plant the seedlings in two or three rows so that the plot looks good. It also makes simple for cultural practices like fencing and irrigation. The layout spacing considered six meter for both between rows and within plants

Pits Preparation: Pits will be prepared with the diameter size and depth 70cm. The 30cm upper soil will be dug out and placed separately to be mixed with decomposed manure/compost to be used for planting later. If there is no adequate decomposed manure/compost, the whole pit will be filled with fertile soil from backyard or forest soil.

Avocado Tree Planting

Be sure to buy trees from a reputable means trust worthy source, poorly raised trees can lead to disaster. Use trees that have been grafted to a recommended variety. Seedling of avocado trees has irregular cropping habits with unpredictable fruit quality and tree size. Take care when planting avocado seedlings. Dig holes large enough to take the root system comfortably; very large holes are unnecessary. Potted avocado trees can usually be planted without disturbing their root systems only some light root pruning may be necessary.

Do not place fertilizers in the planting hole, as burning of sensitive roots can occur! Place the tree in the center of pit so that the potting mix mark is slightly higher than ground level. Half fill the hole with soil and press it gently towards the root ball. Newly-planted trees should be staked for support and most require shading during the first several months.

Note the following important points while planting avocado seedlings or trees.

- Be sure that farmers have handled the grafted materials or avocado seedlings properly. There should not be damage to seedlings. Keep the seedlings under shade and ensure not to be damaged by direct sun light before planting.
- Ensure that planting to be taken place within one day after they transported the grafted materials/seedlings.
- During planting mix the upper soil with decomposed manure or compost. If decomposed manure or compost is not found around, the pits should be filled with the fertile soil, which soil can be taken from the backyard. The bottom soil of the pits will not be used for planting
- Keep the level of the seedlings crown on the same level of the land or up to 5cm deeper than it was.
- Place the seedlings in the center of the pit.
- Support the seedlings with stake in case it loses its balance.
- Ensure that soil is properly filled the pits. And mounding around the trees trunk is also not advised i.e. keep the level flat.

Post Planting Farmers Advice

- Advise the farmers to protect from animals

- Tell them brief physiology of the trees that the grafted plant can flower even within the season
- Tell them to pinch the flowers which will rise immediately after planting
- Tell them that they can have good quality fruits within the coming three years provided that they treat them well as expert's advice
- Inform them that these varieties and source from which it purchased was different from those varieties that was distributed before.
- Inform farmers that they will receive intensive training on avocado tree managements/cultural practices/ in the future.
- Advise them to communicate with the respective experts if some unusual things may be seen or observed.

Irrigation of Avocado Plantation

Avocado requires 665-1475mm of water for its annual growth. Avocado trees may not need irrigation during rainy season. Over irrigation can induce root rot which is the most common cause of avocado failure. If the soil is moist (holds together), do not irrigate; if it crumbles/deteriorate in the hand, it may be watered. Watch soil moisture carefully at the end of the irrigating season. Never enter winter or coldness with wet soil. Avocado should be irrigated slowly, deeply and thoroughly. Avoid wasting water to runoff and do not allow water to stand around the tree for more than a few hours. Deep irrigation will leach salt accumulation.

Fertilization

Commence feeding of young trees after one year of growth, using a balanced fertilizer (compost), 2-4 times yearly. Older trees benefit from feeding with nitrogenous fertilizer. Yellowed leaves (chlorosis) indicate iron deficiency. Mature trees often also show zinc deficiency.

Pruning

Pruning is not necessary common to grafted avocado trees, but damaged wood should be cut out in the spring (March, April and May). If only limb damage occurs, wait until re-growth commences and cut back to live tissue. Sometimes water sprout may grow upwards from the center of the canopy which competes for sinks and radiation. Such branched intended to be removed. If the tree is failed and killed to the ground, cut it off at ground level, the regenerated tree will be naturally multi-trunked or the excess sprouts can be removed to permit only one to reform the tree. The roots are highly competitive and will choke out nearby plants.

Pest and Disease Management

In most areas avocado seedlings grow healthy and fruit with good yield and quality fruits for longer time without showing significant damage by pests and diseases. But some fungal diseases especially phythophtra commonly attacks avocado trees, flowers and fruits.

Harvesting and Post-harvest Handling

Avocado fruits are hard while on the trees and only become soft and edible after they have been harvested. It is difficult to decide fruits maturity by only observing skin colour. Fruits become smooth at the end when mature. Keeping fruits on the trees beyond its physiological maturity time can reduce next season production and can be seen as one factor for the alternative bearing. Mexican races mature after 6 months, Guatemalan matures after 10 months and West Indians mature in between two months.

Avocado fruit will mature on the tree but will not ripen until harvested. There is a short delay from harvest until ripening begins, usually 3 to 10 days. This period is influenced by the variety, the temperature (both at time of harvest and during storage) and how long the fruit is left to hang on the tree. The presence of ethylene during storage will also speed up the ripening process. Avocado fruit generally do not ripen satisfactorily with an acceptable flavour if the fruit is not allowed to mature on the tree to about 21 per cent dry matter. Note that some varieties attain a better flavour if allowed
to mature to a higher dry matter percentage, for example, Hass 23 per cent plus. Avocado trees should start to yield small crops in year three and increase to near full production by year seven. Tree spacing affects the time to full production and yield per tree. Avocado fruits collected when mature and stored for ripening. Ripening requires heat and keeping fruits in cold areas reduces the quality of fruits and extends time for ripening. It takes 7 – 10 days for ripening.

Table 2: Selected AF technologies, Species type and number of trees/hafor each AEZ

Aspects	AF technology/ practice	Proposed species	spacing	Trees/ha	Agro-ecological zone of Ethiopian Highlands					
					HPP		HPC		LPC	
					<2500	>2500	<2500	>2500	<2500	>2500
Enhancing land productivity	Scattered trees on farmland	*F. albida, Cordia africana, Croton macrostachys, Ziziphus spina-christi, Balanites aegyptica, A.abyssinica, A.tortlis, A.etbaica etc.*	10 x 10	100				x	xx	
	Planting selected shade trees in coffee and spice farming	Cordia africana, Millitia feruginea, A.gummifera, A.lebeck,*Polyscias fulva etc*	10 x 10	100	xx		xx		xx	
Shelterbelt andwindbreak	Trees for farm boundary, shelter belt and live fence	C. cajan, Callliandra calostrosis, Tree lucern etc, by Combining tall spps like Gravillea, Cordia, Croton & others	0.5 x 0.5	40,000	x		x		xx	
Agroforestry for Soil and water conservation	Trees on bunds, terraces and raisers with or without grass	C. cajan, Caliandra, Tree lucern, Sesbania sesban, desmodium, Gravillea robusta, etc	1 x 10	1,000			x		x	
Food and income diversification	Promotion of improved highland fruits	Apple, Mango, papaya, Bananna, Avocado etc	4 x 4	625		x		x		x
	Domestication of underutilized wild fruits	Ziziphus mauritania, Ficus spp, Tamarindus indica	1 x 10	1,000			x		x	
	Expansion of Leafy trees and other vegetable trees	Moringa stenopylla, Moringa oliefera	4 x 4	625					xx	
Energy securing measures	Woodlot around homestead and riverbanks (Biomass	Gravillea robusta,, Acacia senegal, *Acacia polyacantha*, *Acacia melanoxylon* and other Acacia spp	1 x 1 2 x 2	10,000 2500	X	X	x	X	x	x

	production									
Promotion of fodder trees and shrubs	Establishment of fodder bank	Tree lucern, Callandria, Acacia spp. *Ficus thonningii*, *Dobera glabra*, *Optunia, ficus indica*	1 x 1	10,000	X	X	x	x	x	x
	Establishment of bee-forage	Acacia spps, Shiffelera abyssinica, *Leucas oligocephala*	1 x 1	10,000					x	
5. Trees/ shrubs on degraded land	Biological gully stabilization with bamboo and other woody material	Highalnd and lowland Bamboo, Acacia spp, A.saligna S. susban, improved grasses	1 x 8	1,250	X	X	x	x	x	x
	Reclamation of degraded sites	Fast growing tree/shrub spp, Optunia spp., Ficus-spp, Salt bush, Agave spps, grass spps, Acacia saligna, G. robusta etc	1 x 1	10,000						

Agro-ecological classification is based on Hoekstra et al. (1990)

HPP – High Potential Perennial zone (warmers and humid with >240 days growing period)

HPC – High Potential Cereal zone (intermediate with >180 days growing period)

LPC – Low Potential Cereal zone (high rainfall variability with 90-150 days growing per

References

- Introduction of Conservation Agriculture and Agro-forestry Technologies in to SLMP-II in Ethiopia, Final report, submitted by African Conservation Tillage Network (ACT) submitted to WB, Ethiopia Country Office, December 2013 (unpuplished)
- Training package for Agroforestry: Technical manual. developed by GIZ, Ministry of Agriculture, 2014
- Conservation Agriculture with trees: Principles and Practices: A simplified Guide for Extension staffs and farmers, ICRAF, Nairobi, Kenya, 2014, Technical Manual No 21

Technical information kit	**(1) Description**	**(2) period/ phase of implementation**
9.3Agro-biodiversity for enhancing crop production and food security	The recent concern over environmental quality of agricultural production has led to a renewed interest in crop–livestock systems, primarily because they provide opportunities for agro-bio diversification, nutrient cycling and greater energy efficiency. More generally system diversification is considered a viable option to manage climate related risks While agrobiodiversity encompasses the variety and variability of animals, plants and micro-organisms that are necessary for sustaining key functions of the agro-ecosystemin support of, food production and food security (including cultural and management practices), including its structure and processes for, and (FAO, 1999a), for ease of implementation we will only focus on crop genetic diversity in this chapter. Other components of agrobiodiversity are found in other infotechs, e.g. agroforestry, forage development, soil fertility and conservation agriculture infotechs,	Sustainable use of agrobiodiversity is a continuous process and varied among the agro-ecological zones and socio-economic settings of the local communities. There is no pre-defined crops/varieties/breeds that can be recommended before those conditions are known. The communities in different agro-ecological zones should be able to define their priorities and therefore set the objectives of which agrobiodiversity should be promoted. In many cases DAs will have already available manuals to manage the selected crops. However, whenever possible, it is advisable to test the crops and the varieties together with soil fertility management practices or conservation agriculture. This will maximize the overall agrobiodiversity in production systems.
(4) Suitability and adaptability to local knowledge		**(3) Main objectives**
The agrobiodiversity created and fostered with human intervention in the evolution of agriculture, holds useful materials that are time-tested well adapted and suit to the tastes and liking of local communities. The maintenance and use of agrobiodiversity relies on extensive indigenous knowledge systems, which address aspects such as cultivation practices, uses and genetic resources management of such plant species. Thus, it is expected that these resources have the necessary adaptive potential to climate change effect and can enhance resilience and reduce vulnerability.		Main purposes of sustainable use of agrobiodiversity are: • Enhance productivity and food security in watersheds; • Enhanceresilience of communities vis-à-vis climate change; • Foster continuing adaptation to climate change
Contribution of CSA/Climate Smartness		
The identification and use of well adapted agrobiodiversity in production systems has a very significant role in enhancing resilience of the watersheds. As a matter of fact, a wisely selected portfolio of crops and varieties can provide good yield under different inter-annual climatic conditions, which Ethiopia experienced often in the past years. In addition, productivity can increase as varieties are selected among those with higher productivity. When this approach is used together with CA or other approaches it can also contribute to mitigation.		
(6) Potential to increase/sustain productivity and		**(5) Main land use and agro-**

environmental protection (impacts)	ecology
Genetic diversity is important for three main reasons: (a) The combination of various crops and animals in agro-ecosystems permits locally available nutrients for human diets or improves household income, allowing the purchase of alternative food items on the market. Different breeds and species make different contributions to livelihoods through provision of food, fibre, fertilizer, cash income, draught power and transportation. (b) It provides insurance against fluctuating weather conditions. For example, resistance to new diseases, or adaptability to changed climatic condition. Generally, the more complex, diverse and risk-prone peasant livelihood systems are, the more they will need animal and crop genetic resources that are flexible, resistant and diverse in order to perform the required functions. (c) It provides opportunities that are potentially valuable, but not yet exploited. The characteristics found in the largely untapped wealth of undomesticated plants or farmers' varieties can provide a basis for enhanced food availability in future by their use in improvement of crop varieties.	Agrobiodiversity is applicable to all agricultural landscapes though the types of crops and varieties may vary, e.g. we expect more options to be available in the middle altitude than the lowland and highland.i

(7) Description of steps

Sustainable management of agrobiodiversity should follow the next steps:

(a) Identification of suitable crops and varieties that matches farmer's needs. This will require participatory work with farmers. The involvement of the national gene bank at EBI will ensure that farmers' are exposed to greater level of diversity and most suitable varieties can be identified. In addition they will provide support in selection of best animal breeds;
(b) Test the varieties through trials in farmers' training centres, ask farmers to evaluate the varieties;
(c) Distribute the most preferred varieties using a crowdsourcing approach;
(d) Enhance availability through community based approaches (community seed bank/seed producing cooperatives);
(e) Document the use of diversity in order to be able to monitor trends and fine tune best varieties
(f) Sensitize community about the importance of agricultural biodiversity.

Steps a to c are essential for implementation of agrobiodiversity infotech while steps d to f are supporting ones and necessary for strengthening and enhance sustainability of the infotech.

NOTE: Detailed information on implementation of each of the above steps is provided in separate infotechs.

(8) Integration opportunities/requirements

Adoption of agrobiodiversity can be an added option to be tested alongside integrated soil fertility management, conservation agriculture, agroforestry and forage development.

All of the above are clearly linked to improving crop production and system diversification and are therefore sharing the same objectives of this module. Testing farmers' varieties and crops alongside with integrated soil fertility management or in the crop rotation element of conservation agriculture can create an additional benefit for the infotechs. Elements of this infotech can also be used to identify best options for fodder development as well as for prioritization of agroforestry species. Finally, it also recognize the value and will strongly build on existing traditional knowledge.

(9) Challenges

This infotech may face a couple of challenges:

1. There may be a tendency to promote mono-culture in agricultural systems rather than a diversified approach. It may require demonstration to convince farmers, DAs and other relevant stakeholders about the potential benefits of this approach.
2. Farmers may be risk advert and may be reluctant to test the approach on their own fields.

(10) References

<table>
<tr><th>Technical information kit</th><th>(1) Components and phases forimplementation</th><th>(2) Main purp</th></tr>
<tr><td>9.3.1. Agro-biodiversity for enhancing crop production and food security – step 1</td><td>Identify suitable crops and their varieties for any given production system in watersheds using a participatory approach.</td><td rowspan="5">The assessmen of:
Identifying vari that enhance pr
Give attention with potential t generate incom
The target cro major staple c the watershed a tested using the

General inform including prod wild (fruits, v minor cultivate trees, vegetable collected as it r income generat</td></tr>
<tr><td colspan="2">(3) Suitability and adaptability to local knowledge</td></tr>
<tr><td colspan="2">Genetic diversity in agriculture enables crops to adapt to different environments and growing conditions. The ability of a particular variety to withstand drought or inundation, grow in poor or rich soil, resist insect pests or diseases, give higher protein yields or produce a better-tasting food are traits passed on naturally. Without this diversity we would lose the ability to adapt to ever-changing needs and weather conditions. The immense genetic diversity of traditional farming systems is the product of human innovation and experimentation-both historic indigenous knowledge and on-going change in biodiversity. Using superior farmers’ varieties and traditional crops is therefore very suitable to local knowledge. When farmers, extension and development agents and scientists join forces they can maximize the benefits deriving from this diversity and they can co-learn the importance of it. Farmers have their knowledge about crops and varieties that may have been under-researched. Development agent can help popularizing those crops and varieties and scientists can gain knowledge on crops which were not fully researched before.</td></tr>
<tr><td colspan="2">(4) Main land use and agro ecology</td></tr>
<tr><td colspan="2">Each watershed and each agro-ecology has its own set of crops and varieties with potential to be used to enhance productivity and resilience as well as provide new livelihood options.</td></tr>
<tr><td colspan="3">(5) Potential to increase/sustain productivity and environmental protection (impacts)</td></tr>
<tr><td colspan="3">This assessment will allow to put the basis for two possible impact: 1. Identification of best varieties f productivity and resilience and 2. To identify crops and species with potential to enhance nutrition and hea livelihood opportunities. For example if a traditional fruit or vegetable is found with good nutritional qualiti a new income generation activity (in addition to provide important nutrients to the community). Same could high potential to add value. These aspects will not be treated in this series of infotechs and it is just to highl activity to generate relevant information.</td></tr>
<tr><td colspan="3">(6) Description of the technology and steps</td></tr>
<tr><td colspan="3">This technology aims at identifying crops and varieties with high potential to contribute to food secur technology also aims at providing development agents and extension workers with greater insights about d contribution to livelihood
The technology is very simple to apply but it requires some skills to allow the implementing team to p farmers and representative of the communities. It is important to understand that in this exercise the sc community which resources they have that may enhance food security and create additional opportunities for implies that the facilitator needs to have a disposition to be self-reflective, question his/her own assumption local knowledge and listen to local voices rather than trying to push a predetermined agenda. Hence, it is c establishes a relationship of trust and creates a space, which is inclusive and where people feel at ease to exp are some key principles for participatory approaches.</td></tr>
</table>

Seeking and valuing local knowledge

Local people have their own expert knowledge. Within the community there will be differing perspective
person has their own experiences and interpretations which add richness and value to a process.

Using a mixture of visual and verbal techniques

A mix of methods aims to make processes as inclusive as possible. Through diagrams, drawings and sharin
to involve as many people as possible. The process aims to be on an equal basis, regardless of age, race,
level, social or economic status. Methods should be used in ways that make people comfortable, and encou
opinions and be heard.

Actively seeking unheard voices

Participatory approaches involve trying to ensure that people who are normally silent are granted safe spaces
participatory approaches means actively trying to find out who wants to participate but is currently exclu
include them. The approach also respects that some people may not want to take part! Care needs to be
relations will affect those who are often suppressed or silent when the project and outsiders have left.

Handing over the stick (or pen, or chalk)

This phrase came from early participatory work and is essentially about letting others “do it”. It involves th
powerful or of higher status sitting back, keeping quiet and letting the community get on with it. The terms “
often used in the context of participatory approaches: thinking about the relationships between them and thei
power, willingness to speak etc. is an important consideration.

Based on these principles, we are ready to start with the exercise.

In order to understand the diversity it is necessary to engage with a group of 6 to 8 male farmers and 6 to 8
(preferably) or together but with equal representation of gender.

NOTE: The facilitators need to come with big piece of paper, pens, post-its, board, flipchart.

When farmers are coming together, the facilitator will:

1. Introducing the exercise

The facilitator introduces him/herself and explains the objective of the exercise. If there are two facilitator
people is divided into a group of men and a group of women, who will ideally be in separate rooms. The foll
for the two groups.

2. Brainstorming about different components of agricultural biodiversity

The facilitator lists in a flipchart the crops (including fruit trees and vegetables as they are mentioned by the f
the wild) and asks participants for what reason they are used locally. It is important to also use the local nam
them. The participants are asked to rank the species/crop based on the importance for food security/nutriti
positive as well as negative feature for each crop. The facilitators also asks whether the crops are common
are cultivated or found from the wild.

3. Identify varieties for major staple crops (max for 2 crops)

On a separate flipchart the facilitators the 2/3 most important crops in the area and ask participants to indic
crop and whether they are improved or traditional. The facilitator will generate a table as the one below.

Crop: Wheat	
Name of Variety	Type of variety
A	Improved
B	Traditional
C	Improved
D	Traditional

<table>
<tr><th>Technical information kit</th><th>(1) Components and phases forimplementation</th><th>(2) Main purpose/ core deliverables</th></tr>
<tr><td>9.3.2.Diversified Agriculture for food and nutrition security (step 2)</td><td>Test the identified varieties with farmers using diversity blocks. Following the identification of suitable crops and varieties, a field is prepared with a maximum of 30 varieties for field evaluation by farmers and scientists. It is advised that this activity is conducted in collaboration with the closest research centre to benefit from the skills of researchers and technicians.</td><td>Diversity block is an experimental block of varieties managed by local institution for research and development purposes (e.g. farmers' training centres). The block is not only used for measuring and analysing agro-morphological characteristics but also used to allow farmers to evaluate the varieties and assess their preferences. Diversity block has the additional advantage of raising public awareness. Planting materials can be multiplied for further distribution to farmers who may request some specific varieties. In case material from other areas or from the national genebank is also tested in diversity blocks, than the diversity block is also a way to expose farmers to this new set of diverse material with traits for potential adaptation to climate change. Finally, the diversity blocks can serve to sensitise local community on the value of community managed biodiversity and create ownership of diversity.</td></tr>
<tr><td colspan="3">(3) Suitability and adaptability to local knowledge</td></tr>
<tr><td colspan="3">This step is required in order identify superior varieties of identified crop(s) for further use in the watersheds. Choice of crop(s) to be tested using this approach will depend on the previous exercise.</td></tr>
<tr><td colspan="3">(4) Main land use and agro ecology</td></tr>
<tr><td colspan="3">Diversified agriculture can be implemented in all agro-ecologies where there are agricultural practices and is one key climate smart activity. Selection and promotion of superior varieties of any given crop can be enabled under any climatic or soil conditions. In addition, it can be fully integrated with any other climate smart practices related to soil fertility management and most likely it will enhance productivity under those management practices compared to conventional varieties. Evidences from Ethiopia show that productivity can be enhanced twofold under marginal conditions in Tigray and Amhara when using superior and well adapted varieties to local environmental and soil conditions. In addition, these superior varieties tend to have greater resistance to major diseases and therefore contribute to minimize losses from pests and diseases. When grown in mixtures this effect can be further emphasized.
The identification of such superior varieties, however, requires at the initial stage a strong collaboration between research and the extension systems. It is therefore essential, unless superior varieties are already identified, to engage with zonal research centers.</td></tr>
<tr><td colspan="3">(5) Potential to increase/sustain productivity and environmental protection (impacts)</td></tr>
<tr><td colspan="3">The diversity blocks are an essential part of the biodiversity based approach as they are the way through which new varieties with better performance can be delivered to the farmers. It is therefore through diversity blocks that the performance of varieties can be assessed and farmers can become familiar with them. In addition, they will allow testing adaptation of different varieties to different environmental and climatic conditions.</td></tr>
<tr><td colspan="3">(6) Description of the steps</td></tr>
<tr><td colspan="3">The following steps and processes are required to establish a functional Diversity Block.
Step 1
Collect seed samples (50-200g seed per variety depending upon crop) during a community meeting. The collected varieties will be based upon the diversity assessment and should include passport data,</td></tr>
</table>

including the name of the variety, farmers' descriptor, names of farmers who provided the seeds, altitude, name of locality. The seeds shall include both modern and farmers' varieties. Additional varieties shall be collected from other sources such as the National Gene Bank in order to enhance the diversity available to the farmers.

Step 2

Complement the information acquired with additional number of varieties from the national gene bank. Ideally a total number of 20-30 varieties should compose a diversity block and therefore the number of additional varieties depend on the number of locally available varieties,

Step 3

Reiterate objectives and potential benefits from the diversity block and discuss in the community to identify interested local institutions to grow and maintain a diversity block at a strategic public place and representative domain. Ideally farmers' training centers are to be selected or, in alternative, the nearest research centre.

Step 4

Orient community members for simple field layout, planting and labelling and identify a focal person for management of the block. It is essential to provide conceptual and practical training to ensure proper management of the field. Collaboration with nearest research centre may be of great value.

Step 5

Grow available diversity of the crop under standard recommended management system for the crops. Make sure each variety is properly labeled to avoid confusion and mixing up of varieties. Ensure that standard agro-morphological traits (depending on the crop) are measured following standard procedure .

Step 6

Conduct a field day with interested and knowledgeable farmers, researchers and development agents in order to:

- promote proper farmers evaluation of the varieties displayed in the diversity block;
- collect demand for seed for future planting
- Make sure farmers' preferences are properly captured amd reasons for choice are properly noted, ideally male and female farmers' should evaluate varieties in separate groups.
- Reseachers may identify varieties useful for inclusion in breeding programs and can better understand farmers' preferences,

Step 7

Harvest seed and store seed in safe and proper environment, avoid seed contamination (harvest 1 block at a time) and prevent seeds attack by insects.

Step 8

Update the database of the community biodiversity register to encourage participants for on-farm conservation and to support landrace enhancement. Make sure all information are available to the community

Wheat						
Name of Variety	Type of variety	Trait 1	Trait 2	Trait 3	Trait 4	Overall
A	Improved	3	2	4	4	3
B	Traditional	2	4	3	5	4
C	Improved	1	5	4	2	4
D	Traditional	4	4	5	4	5

5. Identifying lost varieties

Finally the enumerators ask the farmers if they know other varieties that are no longer cultivated in the wat

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the names of these to be added at the bottom of the previous table and why they are no longer grown.
The final table will look like this:

Wheat						
Name of Variety	Type of variety	Trait 1	Trait 2	Trait 3	Trait 4	Overall
A	Improved	3	2	4	4	3
B	Traditional	2	4	3	5	4
C	Improved	1	5	4	2	4
D	Traditional	4	4	5	4	5
Lost Varieties						Reasons loosing
X	Traditional					Notes
Y	Traditional					Notes

This activity should be integrated as part of the watershed assessment. It will require a short training for necessary to select a small core number of watersheds representative of different agro-ecological zones in information for proper planning on maximizing the potential of diversity for the benefit of the farmers.

Technical information kit	**(1) Components and phases forimplementation**	**(2) Main purpose/ core deliverables**
9.3.3. Diversified Agriculture for food and nutrition security (step 3)	Validate varieties and enhance availability by distributing them through crowdsourcing approaches	Climate change affects agricultural productivity, making farmers unsecured and vulnerable. One feature of climate change is its unpredictability. Therefore diversifying agriculture at species/variety level will secure
(3) Suitability and adaptability to local knowledge		
The use of crowdsourcing approach is strongly linked		

to traditional knowledge. Farmers preferred varieties identified through previous steps are distributed to farmers in small quantities for them to test under their own management practices as well as soil conditions. The big advantage of this approach is that farmers can test the varieties throughout the growing season and they are not limited to a field day. They can therefore really appreciate the potential of the seeds for any use important to them. Quality traits, agronomic traits, fodder quality, nutritional properties are all important to farmers and with the crowdsourcing approach they are in better position to really appreciate them.

The approach allows to engage with a large number of farmers compared to conventional approaches and to have them fully involved in the evaluation. As the extension or research systems do not have to manage the trials by themselves the cost / farmer is much cheaper.

(4) Main land use and agro ecology

Each watershed and each agro-ecology has its own set of crops and varieties with potential to be used to enhance productivity and resilience as well as provide new livelihood options. All agroecologies and soil types are suitable for the crowdsourcing approach, although using different crops.

farmers from the total loss of harvest.

Crowdsourcing approach uses multiple superior varieties that are tested by the community themselves after selection from diversity block as best in bad season and others best in good season. Then since the climate is unpredictable, when the season is bad the farmer will harvest genotype that suits bad condition and if the season is good he/she will have a chance to get premium production from all genotypes. This tool will enable to reach large farmers in few resources in short period of time.

Using diversified genotypes and/or species is also help farmers to be resilient from sporadic outbreak of diseases and pests. Since the genetic makeup of different genotypes and species is different, they will not be attacked all at the same time.

Crowdsourcing can also be used to test combined technologies

(5) Potential to increase/sustain productivity and environmental protection (impacts)

Varieties distributed to farmers using a crowdsourcing approach have been pre-selected from diversity blocks and are therefore those with high productivity. As in the diversity blocks all varieties are included it is assumed that the one passing that stage are superior to the existing ones.

(6) Description of the technology and steps

Diversity agriculture can be integrally used with other technologies. As a way of demonstration and scaling up a crowdsourcing approach can be used to rich uncountable number of farmers in short period. The approach can be used also for dissemination of improved seeds or other technologies or a combination of technologies. The idea is that farmers should receive superior varieties and if farmers’ varieties are superior they need to be made available to farmers.

Steps in implementation of crowd sourcing

3. Component Identification

   Select varieties from diversity blocks.

   Select varieties/genotypes which are being produced by farmers and/or genotypes being produced in other localities that might be believed or identified to suite to such similar areas and farming system.

   The genotype components should have different genotypic makeup to react differently for the environment they will face within the watershed.

4. Identify farmers who are receiving different composition of varieties.

5. Seed preparation

   Seeds of three varieties or species can be prepared separately if the farmer plan to saw it in a separate plot of land.

   Case: from Bioversity international crowd sourcing experiment, farmers were provided three different random varieties from the total of 21 varieties distributed all over in the community.

6. Site selection and planting

   Crop rotation should be considered whenever a farmer need to select sites.

   It can be planted separately in the farmer field but it is preferred that they are planted together with the same crop for the farmer to appreciate the difference between the new and old varieties

7. Cultivation

   Apply cultural practice and local management practices of cultivation, fertilization (manure and compost) and weeding as recommended for that specific crop species in that specific locality.

8. Measurements

   Let farmers to take their own measurement and deep understanding about the varieties and the climate condition of that specific season, it will help farmers to select varieties for future.

9. Harvesting

   Harvesting can be done by hand using equipment. And let farmers to provide the seed at least for five other farmers in the next season to insure the availability of these varieties within the community and to change the diversity of varieties in that locality.

It is important that development agents follow the farmers throughout the process and advise them as part of their regular activities. In this way they can co-learn with farmers how varieties perform in different soils and micro-ecologies.

<table>
<tr><th>Technical information kit</th><th>(1) Components and phases forimplementation</th><th>(2) Main purpose/ core deliverables</th></tr>
<tr><td>9.3.4. Diversified Agriculture for food and nutrition security (Step 4)</td><td>Enhance social capital by establishing community seed bank.
.</td><td rowspan="5">Once farmers' preferred varieties are identified through diversity assessment and tested in diversity blocks as well as in crowdsourcing, it is important to make them available to the farmers alongside other crops and varieties that are important for that specific locality. Generally farmers varieties are not in the market, they are rarely registered and therefore they are difficult to multiply and make available through seed companies. While registering is considered an important step, it takes time and resources under current regulations. Community seed banks (CSB) are collections of seeds of local farmers' varieties that are maintained and administered by the communities.
By establishing a seed bank in a community, it is possible to:
Minimize loss of crop genetic diversity and local seed varieties
Generate locally adapted seeds that perform well in the local condition
Educate the community on how to produce quality seeds
Create linkage between farmers and national genebanks
Strengthen local seed system which contributes to sustainable agricultural production and food security.</td></tr>
<tr><td colspan="2">(3) Suitability and adaptability to local knowledge</td></tr>
<tr><td colspan="2">Community seed banks is a form of community based management and therefore relies on local knowledge to a significant extent. Farmers have knowledge about diversity of different crops and varieties and how to grow them. This body of knowledge is very important to establish the community seed bank.</td></tr>
<tr><td colspan="2">(4) Main use and objectives</td></tr>
<tr><td colspan="2">The main objective of establishing a community seed bank is to ensure that:
1. Farmers varieties will be conserved under a dynamic evolutionary system (on-farm) and extinction of local seed varieties prevented
2. Farmers livelihood enhanced through diversification of local varieties
3. Immediate and secure source of seeds for the farmers in the target areas will be established (informal seed system will be strengthened)
4. Farmers resilience enhanced
5. Productivity in watersheds is enhanced
6. Farmers are less vulnerable to natural disasters
Clearly a community seed bank can be established in all sites as they build and depend on local resources.</td></tr>
<tr><td colspan="3">(5) Potential to increase/sustain productivity and environmental protection (impacts)</td></tr>
<tr><td colspan="3">Community seed banks provide the seeds of farmers' preferred varieties with higher productivity.</td></tr>
<tr><td colspan="3">(6) Description of the technology and steps</td></tr>
<tr><td colspan="3">While these are key principles for good management of community seed banks there are steps and procedures to be followed for their establishment as follows (Adopted from Malik et al, 2013).
1. Selection of suitable site which is convenient and safe for storage of seeds. Location of seed bank should be accessible to most of the farmers of the target area and have the consent of most of the farmers of the watershed.
2. Development of infrastructure such as clean, dry and elevated space, storage bins of different sizes, weighing balance, documentation registers, display containers, metal/wooden shelves, cloth bags/sacks for supply of seeds</td></tr>
</table>

3. Formation of farmer groups having knowledge of local seed varieties and willingness to participate in conservation of local seed varieties and definition of by-laws
4. Nominating committee members to follow up the overall operation of the CSB.
5. Indentifying the responsible person (CSB manager) to look after the seed bank, day-to-day operation and maintenance, and motivate the farmers to associate with this system to derive maximum advantage of the seed bank.
6. Conduct awareness programs regularly and motivate the community for participatory seed management process and conservation of their heritage for future generations.
7. Design seed loan system (quantity, quality)
8. Periodical interaction and training of associated farmer families and farmer members of Seed Bank Committee members to make them aware of latest innovations in informal seed system and to get their input to improve on going system.
9. Assess potential demand and value of such varieties in the local market and promote these varieties to improve their price.
10. Link the seed banks with market to extend financial support to the farmers and seed banks.

NB: This activity should be implemented by Ethiopian Biodiversity Institute. Standards for constructing and managing CSB are available at EBI.

<table>
<tr><th>Technical information kit</th><th>(1) Components and phases forimplementation</th><th>(2) Main purpose/ core deliverables</th></tr>
<tr><td>9.3.5. Diversified Agriculture for food and nutrition security (Step 5)</td><td>Document community based management of diversity through community biodiversity registry. It can be applied to both animals and crops as a way to maintain the information about them.</td><td rowspan="3">Traditional knowledge and skills of farmers and indigenous people can make a significant contribution to sustainable development. Empowering community and local institutions to document and use information of their traditional knowledge and biodiversity helps to foster bioprospecting and check biopiracy. Community Biodiversity Registries can be used by diverse types of institutions for different purposes and, consequently, methodologies for CBR have different variants. In our case the main goal is to strengthening the capacity of local communities to document important genetic</td></tr>
<tr><td colspan="2">(3) Suitability and adaptability to local knowledge</td></tr>
<tr><td colspan="2">CBR is a participatory method developed by the project team to address a range of objectives, such as protection of traditional knowledge and genetic materials from biopiracy, promoting bioprospecting, monitoring genetic erosion, developing local ownership for development and conservation actions. Basically, through the CBR process, the on farm conservation project aims to empower local communities and institutions to develop better understanding for their own biodiversity assets and their value so that they play an important role in research, development and conservation strategies at the local level.
It is, therefore, a very powerful way to document traditional</td></tr>
</table>

<table>
<tr><td>knowledge and to share broadly with relevant stakeholders.</td><td rowspan="3">resources and traditional knowledge for developing conservation as well as development plans. However, the information collected and documented through the CBR is very useful also for the research system, for conservation purposes and for the extension agents.</td></tr>
<tr><td>(4) Main land use and agro ecology</td></tr>
<tr><td>CBR can be implemented in each watershed although they require building social capital in the form of managing the registry and collect information from other farmers. Ideally, the can be linked to community seed banks as the committee are knowledgeable about diversity and can therefore provide quality documentation.</td></tr>
<tr><td colspan="2">(5) Potential to increase/sustain productivity and environmental protection (impacts)</td></tr>
<tr><td colspan="2">Having community biodiversity in place is important as it will generate iterative knowledge whereby the potential of different crop varieties can be fully recorded year after year, thus contributing to fine tuning agronomic practices for each variety, their performance in different years and different climatic conditions as well as other benefits provided by the varieties such as resistance to pests and diseases, cooking qualities, nutritional properties, biomass and fodder quality when relevant, market value and potential for commercialization or value addition. Overall, that incremental knowledge will boost productivity by allowing farmers to select the most appropriate varieties for their conditions.</td></tr>
<tr><td colspan="2">(6) Description of the technology and steps</td></tr>
<tr><td colspan="2">Community Biodiversity registries are database with information collected by extension agents. The capacity needed is therefore linked to the identification of the information that the community (together with development agents and researchers) need to deliver to extension agents. Example of information can include the following:
1. Local, scientific and ethnic names of varieties/breed
2. Existence history at a given location (year of introduction, address of locality)
3. Where the variety came from (original place, source of knowledge and materials)
4. Nature of the species (e.g. annual, perennial, ever green, deciduous, herb, shrub, tree, etc.)
5. Mode of reproduction (e.g. means of propagation are described: seed, clones, sapling, stem, leaf)
6. Natural habitats (as defined by farmers)
7. Extent and distribution of genetic diversity ((R) rare, (M) medium, (W) widely grown)
8. Local techniques/traditional knowledge (practices that describe processing of products linked to specific variety and its management)
9. Uses (good and services of cultivar direct use, option and exploration values)
10. Useful parts, stages and times
In addition, if the community seed bank manages the registry it would be very important to ask questions to members about their preferences and options each year.
At the point a community registry has been established farmers are already quite familiar with the concept of diversity. The only requirement is therefore a community meeting to</td></tr>
</table>

discuss the type of information that needs to go into the registry and a specific training for the managers of the registry on how to handle the information.

NB: this activity should engage EBI because the information collected in the CBR is relevant to the mandate of the Institute.

<table>
<tr><th>Technical information kit</th><th>(1) Components and phases forimplementation</th><th>(2) Main purpose/ core deliverables</th></tr>
<tr><td>9.3.6. Diversified Agriculture for food and nutrition security (Step 6)</td><td>Popularize and share diversity within the community through diversity fairs.</td><td rowspan="3">The diversity fair helps to locate the area of high diversity and most productive landraces. It also recognises real custodians of rich genetic diversity and traditional knowledge. The diversity fair provides a good forum that over time and space maintains, enhances and creates crop genetic diversity and ensures its availability to and from farmers and other actors for improved livelihoods on a sustainable basis. Participation</td></tr>
<tr><td colspan="2">(3) Suitability and adaptability to local knowledge</td></tr>
<tr><td colspan="2">Diversity fair is a participatory tool for raising public awareness on the value of local landraces, bringing the farmers from different part of the watershed together to exhibit the range of diversity, so that traditional systems of seed and knowledge transmission continue to conserve. Traditionally, local seed markets and fairs constituted an important part of the community seed exchange network in the villages of many developing countries.</td></tr>
</table>

One of the aims of diversity fairs is to encourage farmers to share information and exchange seeds within the locality, giving them access to a wider choice of varieties and maintaining a higher level of biodiversity. It is often organized as a competitive event so that local communities are encouraged to maintain high crop diversity and bring in rare and unique diversity for display. This is also a good opportunity for researchers and development professionals to identify the custodians and learn more about traditional knowledge. In essence it is where traditional knowledge is shared and discussed with participants of the fair.

(4) Potential to increase/sustain productivity and environmental protection (impacts)

Diversity fairs is where seeds and knowledge are shared between farmers from different communities within a watershed. It is therefore an opportunity to get seeds of better adapted varieties from fellow farmers from a different village and a chance to test them under different conditions. I addition, extension agent and researcher can attend the fair and can provide additional inputs to farmers on how to better manage individual varieties. All this make the diversity fair an opportunity to further learning how to increase productivity

in diversity fairs generate self confidence in individual farmers and farmingcommunities as they display their rich crop genetic resources and indigenous knowledge to visitors and fellow farmers. It is one of the best forums to create awareness and interest, amongst diverse stakeholders on the importance and value of local plan genetic resources.

(5) Description of the technology and steps

Local institutions (e.g. community seed bank.) organize diversity fairs with technical facilitation from research and development professionals.

The steps to be followed while organizing a diversity fair are as follows:

Step 1: Participatory planning

In order to sensitize farming communities, development workers and researchers to the purpose of the diversity fair, a series of participatory planning meetings with grassroots institutions should be held, in which the detailed steps and procedures, including the options for the prizes, should be followed. In this phase, interaction with local community members, farmers' groups or CBOs is important to discuss the concept, purpose and financial support for the diversity fair. Identification and agreement with the focal local institution on the organizational modality of the diversity fair should be done. Wider sharing and community level planning of the diversity fair should be visualised. Guiding principles of the diversity fair and criteria for participating community selection should be formulated.

Selection of the venue and appropriate date should be finalised in consultation with local institutions. The organizing committee and sub-committees should be formed and roles and responsibilities for each committee should be defined.

Step 2: Preparation for setting norms and procedure for diversity fair

It is essential that norms and procedures should be made transparent due to the competitive nature of the activity. The information should be widely disseminated at different levels. Agro-ecological zones should be defined to determine the participants of diversity fair at the domain level. Different norms should be used in different sites to suit local conditions. Variety names, distinguishing traits and address of custodians, passport information of materials, specific reasons for cultivation and valuable traits should be provided for each sample. Seed or planting materials originating within the group members should be subjected to in situ verification, if contested/protested. An oral presentation on the value and importance of local varieties should be presented in front of a panel of judges. It is well advised that the dissemination of all the information to farmers about the date, venue and criteria of diversity fair using various means such as rural FM radio, newspapers, or posters in schools, etc. well before time. The potential competitors should understand the criteria for evaluation in different classes and the overall rules for display or competition. It is important to provide orientation training to participating group members on materials to be displayed, information to be shared, labelling the materials, number, and type of prizes and rules and regulations for the fair. Logistics information and supplies should be distributed to each farmers' committee with roles and responsibilities and practice sessions to fill out information sheets should be organized. Local communities should be encouraged to use local packaging materials so that the fair has an ethnic-cultural flavour. Press should be invited to visit stalls of the fair, along with local dignitaries, policy makers and district administrators, private entrepreneurs, neighbouring farming communities, pupils. An evaluation committee should be formed and should develop the criteria for evaluation.

Step 3: Implementation

Allocate space to each farmers' group along with the materials to decorate their stall. Field registration and registered materials should be verified, and inauguration of the fair should be instigated by the guest of honour.

Farmers and invitees should be guided to visit the stalls and facilitate in sharing the information and knowledge associated with the exhibited materials. Local institutions should be encouraged to integrate a light cultural show to attract more participants and share knowledge through songs, poems and dramas.

Step 4: Participatory evaluation

Evaluation of displayed materials by each group needs to be completed before the formal event, if possible a day in advance, and the winners should be notified according to the categories of prizes or award. The prize distribution ceremony should be commenced by the guest of honour.

Evaluations of fairs are prepared by experts from outside the community as they are technically sound for improved technologies and new seeds. The compositions of judges should include at least one knowledgeable nodal farmer, PGR specialist, agricultural officer, NGO, merchant, site staff and scientist from the project. The evaluation team should also develop a set of criteria for award assessment. This can vary again according to local expertise and the situation. The major criteria to be considered are:

- Number of local landraces displayed by the group or farmer in the target crops (40%)
- Quality of information (value of PGR) and its authenticity (30%)
- Style of presentation and quality of knowledge (15%)
- Rarity of displayed variety (10%)
- Degree of women participation (5%)

The weight assigned for each criterion can be mutually agreed and the indicators for measurement for each criterion can also be developed by the panel. Prior to the event the information needs be shared with all participating groups at the time of orientation training on the diversity fair.

Technical information kit	(1) Brief Description	(2) Main objective/ purpose	(3)Period/ phases forimplementation
9.5 Climate Smart Forage Development	Forage development is an importpart to respond to current and future milk and meet demand and to improve the environmental footprint of feeding animals. This is because feed is one of the limiting factors in animal production. in order to improve feeding and primary productivity it is important to make better use of existing feed and forage resources and to test new species in potentially suitable environmental conditions. This includes consideration of forages, crop residues and rangelands. Where land is not a limiting factor, forages and rangeland are the best option, however in areas where land is a limiting factor crop	The main objective of this infotech is to increase and better manage forage crops as an essential element to increase animal productivity in a climate smart manner. It is also important to overcome some of the major obstacles to better forage management, including: Availability of quality seeds, high price of forage seeds, adoption of improved forage management practices and lack Institutional support	Before Starting: Understanding of the forage situation in different watersheds in order to identify those that are facing an urgent need to improve forage. During this phase it is also important to understand current practices and potential useful resources already available in the site. First Season: Try one of the new options following proper management practices by few model farmers or in farmers training centre. Some of the options using perennial and trees may require two years to observe

	residues become prominent. In this infotech we will present a number options that are available to development agents although we are aware that this is not exhaustive and that the whole component of crop residues is missing. Options range from grasses, to annual and perennial legumes and root and tubers.	and coordination This approach will also potentially reduce the emission from animals by providing fodder which is more digestible for the different breeds.	performance. Second and Following Seasons: Further distribute to other farmers or plant in communal land (establishing nursery in case of trees).

(4) Suitability and adaptability to local conditions and knowledge	**(5) Main land use and agro ecology**
It is important to select different options based suitability and adaptability to local conditions as well as prevalent animal breeds in the different watersheds. A period to test adaptability of these options is required to test productivity, palatability and management options.	Main land uses and agroecology are reported in the infotechs for each different proposed species.

(6)) Contribution of CSA/Climate Smartness

Adaptation and Mitigation Roles

While it is difficult to quantify the potential role of this infotech in improving adaptation and reducing GHG emission, there is certainly a positive effect on both, although the magnitude of the effect may be different in different localities and will largely depend on the baseline at each site.

One of the ultimate goal of the infotech is to provide better adaptive forage crops and species to local conditions. It is therefore implicit a positive adaptive result.

On the other hand increasing biomass and primary productivity if associated with better animal feed will reduce overall GHG emission.

(7) Implementation modality and steps

Details of implementation are specific for each proposed crops

GRASS SPECIES:-

1. *Rhodes grass(**chlorisgayanakunth)***
2. *Elephant, Napier grass(**Pennisetumpurpureum**)*
3. *Oats(**Avena sativa L.)***
4. *Desho grass*

BROWSE TREES:-

1. *Tree Lucerne **(Tagasaste)(Chamaecytisusprolifer)***
2. *Pigeon pea (Cajanuscajan)*
3. *Sesbania (Sesbaniasesbanscopoli)*
4. *Lucenia (Leucaenaleucocephala)*

LEGUMES:-

1. *Vetch (Viciadasycarpa L.)*
2. *Alfa alfa (Medicagosativa)*
3. *Green leaf (Desmodiumintortum)*
4. *White clover (Trifoliumrepens L.)*

ROOT CROPS:–*Fodder beet (Beta Vulgaris)*

References

<table>
<tr><th>Technical information kit</th><th>(1) Main objective/purpose and bene</th></tr>
<tr><td>Rhodes grass (chloris gayana kunth)
</td><td>❖ Provide adequate energy for maintenance and moderate level protein.
❖ It is effective in maintaining ground cover and preventing erosion through soil stabilization.
❖ It makes good hay if cut at or just before early flowering.</td></tr>
<tr><td colspan="2">(2) Description of the Rhodes grass and its potential suitability</td></tr>
<tr><td colspan="2">Rhodes grass (<i>Chloris gayana</i>Kunth) is broadly used grass widespread in tropical and subtropical countries. It is a useful forage for pasture and hay, it is drought-resistant and very productive, of high quality particularly when the grass is harvested during flowering time.Rhodes grass is best adapted to medium –high altitude with moderate amount of rainfall. The species produce a good amount of seeds so it can established from home grown seeds. Its vigorous root system makes it relatively drought tolerant. It is also tolerant to fire and it withstands heavy grazing.

Adaptation:
❖ Altitude range: 600-2000 m.a.s.l.
❖ Climate requirement: rain fall 650-1200 mm.
❖ Soil requirement: Versatile.
Productivity:Normal productivity under farm condition ranges between 5-8t/ha DM, however, with</td></tr>
</table>

high N application and variable cutting frequency the species has been reported to be able to yield up to 25t/ha DM reported. Crude protein is about 13% in young grass

It is effective for erosion control but should not be used to produce forage on contour since it can become a weed. It tolerates heavy grazing and cutting and so its erosion control attributes are best used for stock exclusion areas.

Cultivation: Well prepared seed bed.

- Propagation is by seed at the rate of 1-4 kg/ha depending on amount of rain fall.
- Seeding depth should not exceed 0.6-2cm.
- Fertilizer requirement: Responds well to increasing levels of N application if in balance with P.
- Companion species: *Sylosanthesguyanensis, Neonotoniawightii, Macroptiliumlathyroids, M. atropurpureum, Medicago sativa, Centrocemapubescens.*

Utilization: Good for grazing and haymaking

Reproduction: Cross-pollinated, isolation distance of 200 m is recommended in seed production. Seed yields 65-650 kg/ha, often it is possible to have two crops per year.

(3) management requirement	**(4) Target groups**
Establishment-can be propagated vegetatively or from seeds surface sown no deeper than 2 cm at seed rate 1 to 4 kg per hectare than rolled. **Fertilizer-** apply well prepared Compost manure during establishment and after every cut **Weeding-** weed twice after planting at monthly intervals during establishment **Harvesting–** cut latest at flowering about 6 months after planting and then every 2 months to maintain quality	Target groups are all communities who have livestock andorganized user groups both men and women on forage production who sell their product to livestock owners,

(5) Limitations

- Fluffy seed difficult to sow
- High levels of soil fertility needed
- Not adapted to acid, infertile soils
- Not tolerant of high exchangeable aluminium levels
- Quality drops rapidly with onset of seeding
- Low shade tolerance
- Tend to become a weed

Technical information kit	**(1) Main objective/purpose**
Elephant or Napier grass *(Pennisetum purpureum*)  Photo - Jim Holmes (FSP) ©	❖ Provide adequate energy for maintenance and moderate level protein. ❖ It is recognized for their effectiveness in maintaining ground cover and preventing erosion through soil stabilization The species has good potential to enhance soil stability and as a wind break. The Napier grasscan be a very tallperennial grass which tends to become coarse as it matures; for this reason it has to be cut often and at early growth stage to ensure good palatability. Its vigorous deep root system makes the species tolerant to limited dry spells and poor drainage. It is useful for cut and carry, hay or silage.

(2) Description and characteristics

Adaptation:

- Best-adapted to high-rainfall areas, particularly to establish it.
- Altitude range: from sea level up to 2000 m.a.s.l.
- Climate requirement: Rainfall 1480-1620 mm/y; optimum temperature 25-40°C; resists drought if successfully established. Susceptible to frost.
- Soil requirement: Prefers deep, friable fertile soils.

Cultivation: full land preparation.

- Propagation: The species is usually propagated by stem cuttings buried in 15 cm furrows, 2 nodes, one in soil and one exposed. One ha of grass can provide planting material for 15-20 ha.
- Fertilizer requirement: Responds well to fertilizers applied after every cut.
- Companion species: *C.pubescens*, *N.wightii*, *P.phaseoloides.*

Utilization: The best use is in a cut-and-carry system, although it can also made in to silageof high quality without additives. For grazing, it is preferable to be maintained in a lush vegetative form. It is best grazed when the new growth consists of 5 new leaves.

Productivity: Expect about 40 tons per hectare fresh forage for cut and carry. Protein content of the forage is about 9 %.(ILRI)

Reproduction: Cross-pollinated; erratic seeder.

Special merits: High DM yield; deep roots can be efficient for using moisture and N.

(3) Target groups	**(4) management requirement**
Target groups are all communities who have livestock and user groups organized (both men and women) on forage production who sell their product to livestock owners,	**Field preparation-** ploughed field but grows well with zero tillage **Establishment-**stem cuttings of 2 to 3 nodes planted at 50cm spacing **Fertilizer-**Urea at 100 kg/ha or manure after each cut **Weeding-** after establishment and every cut **Harvesting**– cut at 5cm 3 times per year, or every 3 months if good growth

(5) Limitations

- Not adapted to areas with frost
- Not suited to waterlogged areas
- Will not persist without fertilizer, even after good establishment
- Coarse, fibrous and sharp leaves if not cut frequently, which makes it not palatable for the animals

Technical information kit	**(1) Main objective/purpose**
Oats grass (Avenasp L.) 	❖ a widely adaptable forage or grain crop, ❖ high yielding and fast growing annual fodder crops ❖ becoming increasingly important in Ethiopia

(2) Description of the Oats grass and major chracteristics

It is considered one of the best annual fodder grass for high land areas. Oats grassestolerate acid soilsit is a tall annual cereal up to 1.5 meters high and widely used for fodder. It is very versatile and can be used for grazing, hay, cut and carry and silage. In addition, the grain is very nutritious and suitable for human consumption. In areas with limited land availability this is an important characteristics.

Adaptation: Commonly grown annual crop in cool areas for fodder and grain.

- ❖ Altitude range: 1700-3000 m.a.s.l.
- ❖ Climate requirement: 500-800 mm mean annual rain fall, cold- and frost-tolerant.
- ❖ Soil requirement: Fairly tolerant to water logging.

Cultivation:

- Companion species: *Trifoliumalexandrinum, viciadasycarpa, viciavillosa, Lathyrussativus*.

Utilization: Fodder crop as green feed or conserved as hay.

Productivity: Yields of up 10-52 t/ha of fresh grasses have been reported. **Reproduction:** Seed yield up to 10 quintals/ha or more (1 quintal = 100kg).	
(3) Target groups	**(4) management requirement**
Target groups are all communities who have livestock, Organized user groups both men and women on forage production who sell their product to livestock owners. .	**Field preparation-** a clean, well prepared seed bed is required. **Establishment-**seed can be broadcast or row planted at a depth of 4 cm using 70-80 kg per hectare seed rate in pure stand. It can be grown in mixture with vetch (60 kg/ha of oat + 15-20kg/ha of vetch) or peas (60 kg/ha of oat + 20 kg/ha of pea) **Fertilizer-**100 kg/ha DAP at establishment and 50 kg/ha urea or manure during rapid growth **Weeding-** usually hand weeded once during early establishment. **Harvesting –** graze or cut for hay at 50% flowering to ensure quality unless grain harvest is also of interest.
(5) Limitations	
• Does not tolerate water-logging • It is not tolerant to drought or hot, dry weather • Declines in yield at low soil fertility	

Technical information kit	**(1) Main objective/purpose**
Desho grass	❖ A highly palatable, nutritious and fast growing grass characterized by high leaf/stem ratio ❖ To improve grazing land management, combat declining productivity and carrying capacity of the grazing land, even in degraded soils with lowfertility ❖ To stabilize the physical soil and water conservation structure.
(2) Description of desho grass and its major characteristics	
Desho is an indigenous grass of Ethiopia belonging to the family of Pocaceae • It is a perennial grass with an extensive root system that makes it a good candidate to stabilize soils. • It has a high biomassproduction capacity ranging from 30–109 t/hadepending on the conditions • It grows upright with the potential of reaching 90–120 cm based on soil fertility It can grow anywhere from 1500–2800 masl with optimum elevation over 1700 masl on medium to low soil fertility	
(3) Target groups	**(4) management requirement**
Target groups are all communities who have livestock organized user groups both men	**Planting**: • Recommended to plant at 10 cm by 10 cm intervals along bunds for SWC • Recommended to plant at 50 cm by 50 cm intervals for grazing land management (ILRI forage unit experience) • Remove the leafy part before planting to reduce competition before it establishes well

and women on forage production who sell their product to livestock owners,	• Open the soil with hoes and place the split in the soil before pressing the basal soil around the seedling **Fertilization:** • Compost/manure of about 4500 kg/ha for establishment and 1000 kg for maintenance **Land preparation**: • Desho needs very good land preparation **Weeding:** • Needs continuous weeding and gap filling **Harvesting:** • Cut and carry system is encouraged to maximize the potential of the species • Should be harvested at 8 cm high from ground level • Highest yield can be obtained if first harvested at 4 months after planting (Gohl 1981)
(5) Limitations	
• Shortage of inputs (planting material) and the establishment and maintenance of is labour intensive	

Technical information kit	**(2) Main objective/purpose**
 **Treelucern**	❖ Often used to overcome feed gaps at times of feed shortage. ❖ provide green forage rich in protein, minerals and vitamins during the dry season or during drought ❖ because of its deep root system it can use moisture very efficiently and continue to grow during droughts ❖ It is a perennial legumes which grow tall ❖ Provide high dry matter yield per year ❖ Can be planted with other forage crops and food crops ❖ It is multipurpose, its uses include: ✓Provide supplementary feed in drought season ✓Have high nutritive values ✓ Improve soil fertility ✓Can be used for fence, wind break, fuel, house construction
(3) Description of the **TreeLucerne**and its major characteristics	
Wide range of adaptation from lowland to 3200 m.a.s.l altitude. It is the only browse legume adapted to higher altitude highlands of Ethiopia. It tolerates infertile and acid soils and droughts once established. Needs good drainage.Useful as multipurpose fodder tree for cut- and- carry fodder, ornamental, wind beak, bee forage, fuel wood and biogas. **Cultivation:**	

- Propagation is by seed sown directly or by transplanting. Spacing 30-50 cm between plants. - Seed treatment necessary. Dip in boiling water for 5-10 minutes. - Inoculate if possible. **Utilization:** Establishment is low. Commence cutting in the second year. Cut at 1 meter height every 6-8 weeks. Use as a supplement to crop residues. **Reproduction:**Seed yield up to 0.5 kg/tree.	
(10) Target groups	**(11) management requirement**
Target groups are all communities who have livestock organized user groups both men and women on forage production who sell their product to livestock owners,	2. How to prepare your land 1. Secure the perimeter with 20% shade cloth attached to your fences.This will keep rabbits, buck, and other animals from entering your new lands. 2. Ripor double-plough the tree rows about 5 meters apart.Create mound for each row. 3. Place compost and about 50g of super phosphate in the rows where every tree will be planted. 4. Wet your soil. 5. Now you are ready to plant your trees. Management of your newly planted trees is vital! • Water regularly for the first 18 months. • Check regularly for snails, insects and other critters who may eat your young trees and take action! • Prune regularly to encourage side branches and denser foliage as well as keeping the trees 1 to 1.5 meters high.
(12) Limitations	
It takes 2 years before it can be harvested, Labour and investment intensive and Lack of basic forage seed.	

<table>
<tr><th>Technical information kit</th><th>(1) Main objective/purpose</th></tr>
<tr><td>Pigeon pea (Cajanuscajan)
</td><td>❖ provide green forage rich in protein, minerals and vitamins during the dry season or in times of drought
❖ Leaves and beans are also suitable for human consumption and provide significant contribution to nutrition.
❖ continue to grow in areas and periods of moisture shortage because they can exploit moisture at depth using their deep -root system
❖ Provide high dry matter yield per year
❖ Can be planted with other forage and food crops
❖ Are multipurpose:
✓ Provide supplementary feed in drought season due to their deep roots
✓ Have high nutritive values
❖ Improve soil fertility
❖ Special merits:Dual purpose crop; tolerant to soil acidity. Can be used as semi-permanent, perennial component in alley cropping systems. Grown as hedgerow for wind beaks, and as ground cover or shade cover for establishing plantation crops, e.g., coffee. Good nitrogen fixation makes it a useful green manure.</td></tr>
<tr><th colspan="2">(2) Description of the Pigeon pea and its major characteristics</th></tr>
<tr><td colspan="2">Pigeon pea is adapted to arid and semi- arid environments, it favors warm climate, it is drought –resistant; it can grow at 500-800mm annual rain fall and it is tolerant to acid soils.Good for restoring soil fertility and intercropping with cereals (sorghum, millets) orother legumes (cowpea and groundnut).
Cultivation:
- Propagation: Established from seed sown at the rate of 4-6 kg/ha or 1-20 kg/ha broad casting.
- Spacing: about 1 meter between rows.
- Fertilizer requirement: Responds favorably to P fertilizer but negatively to N.
Utilization: Dual-purpose crop for food and forage. For forage: cut when the first pods begin to ripen at 80 cm height.
Productivity: Up to 12 t/ha DM.
Reproduction: Essentially self- pollinated and self-fertilized, but cross-fertilization by bees can occur.</td></tr>
<tr><th>(3) Target groups</th><th>(4) management requirement</th></tr>
<tr><td>Target groups are all communities who have livestock organized user groups both men and women on forage production who sell their product to livestock owners,</td><td>Field preparation- ploughed field or sown in holes in zero tillage
Establishment- direct sowing at 3 cm depth or transplant seedling in hedge rows at 1m spacing between plants and 2m spacing between rows
Fertilizer- DAP at 100 kg/ha or manure
Weeding- slow weeding establishment phase, weed once 4 weeks after establishment and at regular intervals throughout the first year
Harvesting – cut at 0.8 m after grain harvest</td></tr>
<tr><th colspan="2">(5) Limits of use</th></tr>
<tr><td colspan="2">▪ Not adapted to areas over 2000m.a.s.l. with frost
▪ Does not tolerate heavy grazing or low coppicing
▪ Not suited to waterlogged areas
▪ Not relished by cattle in the immature stage</td></tr>
</table>

Technical information kit	**(1) Main objective/purpose**
Sesbania (SesbaniasesbanScopoli)  	❖ Often used to overcome feed gaps due to seasonal fluctuations in feed production. ❖ provide green forage rich in protein, minerals and vitamins during the dry season or in times of drought ❖ It is a perennial legume which grow tall ❖ Provide high dry matter yield per year ❖ Can be planted with other forage crops and food crops ❖ Are multipurpose: ✓ Provide supplementary feed in drought season due to their deep roots ✓ Have high nutritive values ✓ Improve soil fertility ❖ Can be used for fence, wind break, back yard forage, alley farming, and forage strips.

(2) Description of the species

Sesbania has a wide range of adaptation, 200 - 2400 m.a.s.l. and it grows mainly under moisture -stress free conditions.Sesbania withstands acidic soils and waterlogging and it tolerates a wide range of soil conditions and salinity.

Cultivation:

- Propagation: by seed; seed must be scarified by putting the seeds in concentrated sulphuric acid for 30 minutes; also mechanically by using drum scarifiers. Plant seedling at the onset of first rains.
- Spacing: variable according to uses:
  - Continuous hedges: 50 seeds/m or 2-3 seeds /hole at 0.5 spacing.
  - Alley cropping: Up to 4 m or more between alleys.

Utilization: Cut at 0.5 - 1 meter height every 6-8 week; Use as a supplement (20-30%) with crop residues. There is no toxicity.

Productivity: Expect up to 20 tons DM/hectare per year. Protein content of the forage is about 25‰. **Reproduction:** Cross-pollinated; prolific seeder. **Botanical description:** Relatively short-lived (6-7 years) shrub or small tree up 6 m high.	
(3) Target groups	**(4) management requirement**
Target groups are all communities who have livestock organized user groups both men and women on forage production who sell their product to livestock owners,	**Field preparation-** ploughed field or sown in holes in zero tillage **Establishment-** direct sowing by broadcasting at 4 to 5kg per hectare 3cm depth or transplant seedlings in hedge rows at 1 to 2m apart with plants spaced 25 to 5ocm apart with in rows. **Fertilizer-**generally not applied. **Weeding-** resilient and hardly affected by weeds in its establishment phase. **Harvesting** – coppice at 50 to 75cm height 3 to 8 times per year depending on growth.
(5) Limitations	
• Not adapted to areas with frost • Easily damaged by grazing or poor cutting management	

Technical information kit

(1) Main objective/purpose

Leucaena (Leucaenaleucocephala)

- Often used to overcome feed gaps due to seasonal fluctuations in feed production.
- provide green forage rich in protein, minerals and vitamins during the dry season or in times of drought
- continue to grow in areas and periods of moisture shortage
- It is a perennial legumes
- Provide higher dry matter yield per year
- Are multipurpose:
    - ✓ Provide supplementary feed in drought season due to their deep roots
    - ✓ Have high nutritive values
    - ✓ Can be used for fence, wind break, back yard forage, alley farming, and forage strips.
- **Special merits:** vigorous plant of high yield and high quality protein; leaves and thin twigs well-accepted by livestock

(2) Description of the species and what makes it important

It performs betterin warm climate at altitudes less than 2000 m. It is sensitive to frost, but very drought –tolerant, as it can grow at 400 mm annual mean rainfall. It requires well-drained soils and it is not tolerant to acids soils.Leucaenacan be used to restore soil fertility. It is highly productive and can tolerate heavy cutting/coppicing and grazing. Useful for grazing or cut and carry. It can also provide fuel wood.

Cultivation: Light cultivation for direct sowing; dug holes for transplanting.

- Propagation: by seed sown at 4-7 kg/ha, but different rate or spacing can be used depending on utilization, soil depth: 2-3 cm.
- Spacing: when sown 2-2.5 m between rows to up to 4.0 m between rows/alleys. Usually planted by seedling.
- Treatment: Seed treatment necessary. Hot-water treatment 60-80°C; H2SO4 for 10 minutes.
- Inoculation with appropriate rhizobium strain is helpful.
- Companion species: May be planted to pasture grasses in inter-row spaces.

Utilization: Cut at 80-100 cm height every 6-8 week intervals; Use as a supplement ration 25-30%, beyond this level, animals develop enlarged thyroid gland or goiters because of mimosine (an alkaloid) preventing animals from using iodine efficiently.

Productivity: Considered the best fodder tree in the world. Multipurpose (for fodder, fuel, pulp, immature shoots and seeds for human consumption, shade and hedge). Yields of 50 t/ha (cut at ground level) and 40 t/ha (at 75cm) have been reported. Despite inconsistent figures 10-20 t/ha DM can be expected.*Protein content of the forage is about 22‰.*

Reproduction: Self-pollination prevails, although Cross-pollination is possible; prolific seeder.

Special merits: vigorous plant of high yield and high quality protein; leaves and thin twigs well-accepted by livestock.	
(3) Target groups	**(4) management requirement**
Target groups are all communities who have livestock organized user groups both men and women on forage production who sell their product to livestock owners,	**Field preparation-** ploughed field or sown on holes in zero tillage. **Establishment-** direct sowing at 3cm or transplant seedlings in hedgerows at 1m spacing between plants. **Inoculants-** specific Rhizobia needed. **Fertilizer-** DAP at 100kg per hectare or manure. **Weeding-** slow early growth, weed once 4 weeks after establishment and at regular intervals throughout the first year. **coppicing–** coppice at 75cm height and protect from grazing while young **Harvesting-** cut 3 times per year in Debrezeyt
(5) Limitations	
• Not adapted to areas over 2000m with heavy frost, Not suited to heavy dry areas	

Technical information kit	**(1) Main objective/purpose**
Alfalfa (Medicago sativa) 	❖ **Special merits:** Lucerne (alfalfa) is the most widely used fodder in the tropics and has special application in the dairy business. It is ideal for irrigated pasture. Under irrigated conditions at DebreZeit, harvests every 3-4 weeks (12 times a year) have been possible. ❖ Leader in livestock feeding in the world because of its: ✓high yield ✓palatability, ✓richness in protein, and ✓High content of calcium and vitamins. ❖ provide green forage rich in protein, minerals and vitamins during the dry season or in times of drought ❖ Provide higher dry matter yield per year ❖ Can be planted with other forage crops
(2) Description and what makes it important	
Wide range of adaptation from 500-3000 m.a.s.l altitude and above. It is best adapted to warm, temperate climate. Because of its deep-rooted habit, it can be grown in areas receiving as little as 550 mm annual rain fall. It is quite intolerant to water logging and it requires fertile, well drained soils. It prefers neutral or alkaline (lime-rich) soils and it is susceptible to acid soils. **Utilization:** Utilized as grazed mixed pastures, as hay or as green fodder. Cut or graze at 30-40 days interval or at 10% flowering. **Productivity:** Variable as according to moisture supply. Yields of 7-9 t/ha/yr. are expected is quite often achieved. **Performance:** Expect about 20 tons per hectare dry matter per year from about 6 to 8 cuts in well managed stands. Protein content of the forage is usually from 20-25% with digestibility of about 70%.(ILRI) **Reproduction:** Cross-fertilized; bees necessary for pollination. Seed yields 100-300 kg/ha.	

(3) Target groups	**(4) management requirement**
Target groups are all communities who have livestock organized user groups both men and women on forage production who sell their product to livestock owners,	**Field preparation-** well cultivated uniform and firm seed bed. **Establishment-**seeds broadcast or drilled in rows or on ridges 50 to 70cm apart at 12 to 20kg per hectare under irrigation or 10 to 12kg per hectare under rain fed conditions.(ILRI) **Fertilizer-** DAP at 100kg per hectare may be used. Phosphorus may be required for establishment. **Weeding-** weeding essential in establishment stage and crop requires frequent cultivation. **Harvesting** – harvested for hay by cutting at 5cm height at first flowering.

(5) Limits to use
• Not tolerant of continuous grazing • Poor drought tolerance and require water for year round production • Not very tolerant of acid soils and water logging • Bloat in livestock is the major limitation to grazing Lucerne • Lack of basic forage seed.

Technical information kit	**(1) Main objective/purpose**
Green leaf (Desmodium intortum) 	❖ No toxicity recorded and no bloat. ❖ Good early and late season vigour. ❖ Shade tolerant. ❖ Often used to overcome feed gaps due to seasonal fluctuations in feed production. ❖ provide green forage rich in protein, minerals and vitamins during the dry season or in times of drought ❖ Provide high dry matter yield per year ❖ Can be planted with other forage crops ❖ Improve soil fertility

(2) Description and its major characteristics
Greenleaf desmodiumis best adapted to high rainfall areas exceeding 900 mm, with altitude range 800-2500 m.a.s.l. Fast growing giving good ground cover in 4 to 5 months and it is adapted to a variety of soils including acid soils. Green leaf is highly specific in its Rhizobium requirement. **Utilization:** Utilized as grazed mixed pastures, as hay or as green fodder. Cut or graze at 30-40 days interval or at 10% flowering. **Reproduction:**Self-and cross-pollinated. Sensitive to photoperiod; it is a short-day plant. Seed yields 100-120 kg/ha. Yield potential: Varies widely from 3-20 t/ha DM in pure stands.

(3) Target groups	**(4) management requirement**
Target groups are all communities who have livestock organized user groups both men and women on forage	**Field preparation-** well prepared seed bed. **Establishment-** by seed sown at the rate of 1-2 kg/ha in rows 45 cm wide. Cuttings root may be used. **Fertilizer-**Reported to respond well to P and K application. **Weeding-** slow establisher, weed once after 4 weeks and again after 8

production who sell their product to livestock owners,	weeks, when well established will suppress weed. **Harvesting –** first time at flowering after about one year and then every six months. **Herbicide effects** Seedlings show good tolerance to the herbicide 2, 4-D; mature plants are reasonably tolerant of the desiccant diquat.
(5) Limits to use	
• Low seedling vigor, Poor persistence under heavy grazing, Susceptibility to pests, Poor tolerance of drought and No tolerance to salinity and Not adapted to areas with frost	

White clover (Trifoliumrepens L.)

- ❖ It is tolerant to free grazing as it can withstand animal movements.
- ❖ It is an ideal mulching crop
- ❖ Are multi-purpose:
  - ✓ It is a good soil protector
  - ✓ Have high nutritive values
  - ✓ Improve soil fertility

(2) Description

White clover (Trifoliumrepens L.) is a short-lived perennial that can reseed itself under favorable conditions. It grows rapidly and spreads via stolons. White clover has a shallow root system, which makes it intolerant of drought conditions. It grows best during cool, moist weather on well-drained, fertile soils with a pH between 6 and 7. Pure stands of white clover are not usually planted because of their low growth habit and associated low yield. However, they make high-quality pastures in mixture with other grasses and fix nitrogen for use by the grass.

Clovers (Trifolium spp.) constitute one of the major forage legumes widely grown for its rich protein content and capacity to improving soil fertility

Adaptation: Cool tropical highlands.

- Altitude range: 1800-3000 m.a.s.l.
- Climatic requirement: Mean annual rainfall 800-1500 mm.
- Soil requirement: Versatile.

Cultivation: Well-prepared seedbed.

- Propagation: By seed at 3-6 kg/ha.
- Fertilizer requirement: Responds well up to P and S application.

Utilization: Most suited for grazing.

Productivity: About 1.5-2.5 t/ha/DM.

Reproduction: Cross-pollinated.

(3) Target groups

Target groups are all communities who have livestock organized user groups both men and women on forage production who sell their product to livestock owners,

(4) management requirement

Harvest ManagementHarvesting white clover for hay or silage is generally based on the grass in mixture with the clover, since white clover constitutes a small proportion of the total forage and is of relatively high quality at maturity. Harvest should be dictated by the harvest schedule that maximizes grass performance.

(5) Limitations

Lack of basic forage seed.

Technical information kit

Fodder beet (*Beta vulgaris*)

(1) Main objective/purpose

- ❖ Often used to overcome feed gaps due to seasonal fluctuations in feed production.
- ❖ Are annual fodder crops which grow under the soil.
- ❖ Provide higher dry matter yield per year
- ❖ Are multipurpose:
  - ✓Provide supplementary feed in drought season due to their deep roots
- ❖ Have high nutritive values

(2) Descriptions

Adaptation: High land crop (1800-3000 m.a.s.l). Needs long growing season, 5-7 months of 750 mm rain or over.

- Soil: fertile sandy soil, avoid water logging.
- Yield potential: Under well-fertilized and irrigated conditions at DebreZeyt Research Center each tuber had a fresh weight of 37.5 kg in about 5-7 months growth period.

Cultivation:

- Propagation:
  - Direct seeding 5 kg/ha; sowing depth, 2 cm; plant in rows 40 cm apart and thin to 20-25 cm between plants when two real leaves have been developed.
  - Transplanting from nurseries planted 1-2 months ahead of planting time gives it a competitive advantage over weeds.
- Seed propagation is stimulated by cold, thus an altitude between 2500-2750 m.a.s.l. is suitable.
- Fertilizer: Fodder beet is a heavy feeder and thus it should be planted near an animal corral for easy application of manure.

Utilization: Used in intensive management systems in dairy or fattening enterprises beets must be chopped before feeding.

Reproduction: Seed yield is about 400-500 kg/ha.

Botanical description: Biennial tuberous herb

(3) Target groups	**(5) management requirement**
Target groups are all communities who have livestock organized user groups both men and women on forage production who sell their product to livestock owners,	- Weeding - Manure /fertilizer application - Land preparation

Glossary

Browse: The part of leaf and current twig growth of shrubs, woody vines, and trees available for animal consumption.

Concentrate: All feed low in fiber and high in total digestible nutrients (TDN) that supply primary nutrients (protein, carbohydrate, and fat).

Feed: Any non-injurious, edible material, including forage, having nutritive value for animals when ingested.

Forage: The part of the vegetation that is available and acceptable for animal consumption, whether considered for grazing or mechanical harvesting; includes herbaceous plants in mostly whole plant form, and browse.

Fodder: Any bulky green or dry plant material, which is used for stock feed.

Forage crop: Forage plants harvested before being fed to animals, e.g. hay, silage, green chop.

Green chop: Harvested forage fed to animals while still fresh.

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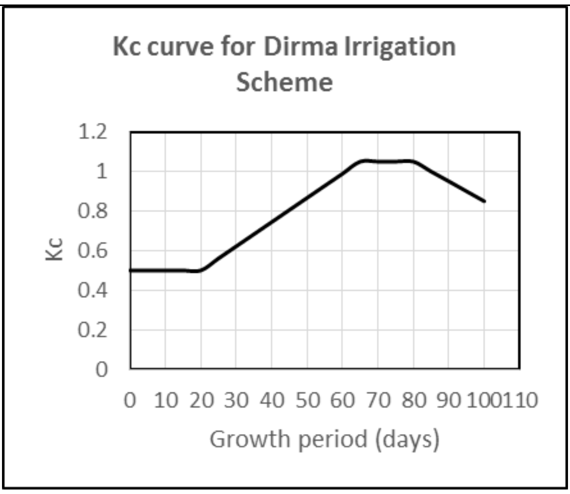
9.6 Agricultural Water Management

<table>
<tr><td>Technical Information Kit</td><td>1) Period/ phases for implementation</td><td>2) Main purpose/ core deliverables</td></tr>
<tr><td>9.6.1. Estimating Crop Water Requirement</td><td>Crop evapotranspiration or crop water requirement (ETc) is calculated both during the preparation of cropping plan and the crop growing season</td><td>To calculate ETc for each crop for the different stages of crop growth.
Deliverable: Daily, decadal, monthly or seasonal ETcto be taken from water sources</td></tr>
<tr><td>3) Data required for calculating ETc</td><td colspan="2">• Reference Evapotranspiration (ETo) for growing season or climate data for estimating ETo
If there is no local ETo data, refer to Annex 1
• Type of crop and planting date
• Crop factor or coefficient (Kc) for each growth stage of the selected crops
• Rainfall (P)/effective rainfall (Pe)
• Irrigation efficiency (if available)</td></tr>
<tr><td>4) Suitability and adaptability to local knowledge</td><td colspan="2">The knowledge of ETc is crucial for planning crop mixture and planting time especially during drought years to avoid water stress and yield reduction. Applying irrigation water as per crop’s need in each stage of crop growth will improve yield. If farmers are trained and demonstrated farmers on this, their traditional knowledge will improve and they will continue practicing it. Thus, sustainabilitydepends on the results and change of farmers’ attitude on application of irrigation according to crops needs.</td></tr>
<tr><td>5) Potential to increase/sustain productivity and environmental protection (impacts)</td><td colspan="2">Calculation of the ETc:
• helps to decide on crop mix, planting time and proportion of areas under the different crops in accordance with the available water
• enables uniform irrigation of crops to according water needs and thus increases crop yields
• saves water for irrigating additional area
• avoids excess water application and hence soil erosion and waterlogging</td></tr>
<tr><td>6) Description of the Method</td><td colspan="2">• The method is used to estimate ETo from climate data or taken form Annex 1
• ETc =Kc. ETo (mm)
• Net irrigation water requirement (IWRn) = ETc-Pe
<table>
<tr><td>For monthly rainfall</td><td>For decadal (10 day) rainfall</td></tr>
<tr><td>Pe=0.6Pm-10 for monthly Pm<70</td><td>Pe=0.8Pd-23 for Pd >23</td></tr>
<tr><td>Pe=0.8Pm-24 for monthly Pm>70</td><td>Pe=0.8Pd-23 for Pd >23</td></tr>
<tr><td></td><td></td></tr>
</table>
• Pd= decadal rainfall (mm)
• Pm= Monthly rainfall (mm)
• Gross Irrigation water requirement (IWRg)= IWRn/E (mm)</td></tr>
</table>

	• E= Irrigation efficiency
7) Calculation Steps with example	The steps for calculating ETc is given below with examples. **Step 1**: Select type of crop to be planted in a particular season **Crop**: Onion in Dirma Irrigation Scheme (Kalu Woreda) For more than one crops, determine the area to be covered by each crop. **Step 2**: Determine planting date of the selected crop **Planting date**: December 1 Planting of a crop can be staggered up to 3 weeks to avoid peak water demand during flowering and seed or fruit setting. **Step 3** Determine total growing period Total growing period of onion in this climate: 100 days **Step 4**: Determine length of growth stages Use local information, otherwise, use data from Annex 3. **Step 5**: Select Kc values for each growth stage Select Kc values for three of the growth stages - Kc_{in} for initial, Kc_{mid} for mid-season and Kc_{end} for late season from Annex 3 **Step 6:** Calculate Kc for different periods Prepare Kc curve by plotting Kc values at midpoints of growing periods and joining the points keeping the length of growth stages as shown in Annex 2, **Kc for development stage cannot be plotted**. Then read Kc values from the curve for a required date.



Kc values can also be calculated for different growth periods as follows.

Growth stages	**Duration (days**	**Dates**	**Kc**
Initial stage (Lgp_i)	20	Dec 1-20	0.5
Development stage (Lgp_d)	45	Dec 21-Feb 5	-
Mid-season stage (Lgp_m)	15	Feb 6-20	1.05
Late season stage (Lgp_l)	20	Feb 21-Mar 12	0.85
Total	**100**		

Calculate Kcs for every 10 days in each month

Variation of Kc during development stage per day

$$Kcd = \frac{(K_{cm} - K_{cin})}{Lgp_d} = \left(\frac{1.05 - 0.5}{45}\right) = 0.0122$$

Variation of Kc during late season stage per day

$$Kcl = \frac{(K_{cm} - K_{cin})}{Lgp_d} = \left(\frac{1.05 - 0.85}{20}\right) = 0.01$$

- To calculate ETc for any period up to Mid-season, multiply the number of days between initial stage and development stage by 0.0122 and add it to Kcin
- To calculate ETc for any period in late season, multiply the number of days between development stage and late season stage by 0.021and subtract it from Kcm of mid-season

Day	**Month**	**Stage**	**Calculation of Kc for different days**	**Kc**
10	Dec	Initial	Constant	0.50
20	Dec	Initial	Constant	0.50
30	Dec	Dev’t	0.5+0.0122*5	0.56
40	Jan	Dev’t	0.5+0.0122*15	0.68
50	Jan	Dev’t	0.5+0.0122*25	0.81
60	Jan	Dev’t	0.5+0.0122*35	0.93
70	Feb	Dev’t/Mid	(0.5+0.0122*42.5+1.05)/2	1.03
80	Feb	Mid	Constant	1.05
90	Feb	Late	1.05-.01*10	0.95

100	Mar	Late	End of the period	0.85

Step 7: Collect or select ETo values using one of the three options

a) Select from locally available data for the planting period.

b) Take indicative ETo values from Annex 1 for local condition

c) If you have computer and internet access, use FAO online Climate Info Tool to calculate ETo. Enterlatitude and longitude in degree decimal. (http://www.fao.org/nr/water/aquastat/quickwms/climate.htm)

Month	ETo (mm/day)	Monthly Rainfall (mm)
Dec	4.3	0
Jan	4.7	18.7
Feb	4.8	4.2
Mar		

Step 8: Calculate ETc for 10 days of each month

Consider 30 days for each month

Description	Decadal (10 days)									
	Dec	Dec	Dec	Jan	Jan	Jan	Feb	Feb	Feb	Mar
ETo (mm/day)	4.3	4.3	4.3	4.7	4.7	4.7	4.8	4.8	4.8	4.9
Kc	0.5	0.5	0.56	0.68	0.81	0.93	1.03	1.05	0.85	0.85
ETc=Kc x ETo (mm/day)	2.15	2.15	2.41	3.2	3.81	4.37	4.94	5.04	4.08	4.2

Step 9: Calculate Net Irrigation Water Requirement (IWRn)

IWRn can be calculated as follows:

Month	Monthly Rainfall (mm)	Effective rainfall Formula	Effective rainfall,(mm)
Dec	0	0.6 x 0-10 = -10	0
Jan	18.7	0.6 x 18.7-10 =1.22	1.22 (ignore it)
Feb	4.2	0.6 x 4.2-10= -7.48	0
Mar	0	0.6 x 10-10= -10.00	0

If the calculated Pe is negative, Pe is zero.

Alternatively, select Pe from Annex 4.

Step 10: Calculate gross irrigation water requirement (Dg)

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

Ea= irrigation application efficiency (decimal)

Irrigation application efficiency is different for different irrigation methods and ranges from 40-50% for surface, 80-90% for sprinkler and 90-95% for drip irrigation methods. It also different for furrow, border and basin surface irrigation methods.

Assume Ea= 60% or 0.6

	Decadal Values (mm)		Monthly Values (mm)	
Month	**IWRn**	**IWRg**	**IWRn**	**IWRg**
Dec	21.5	35.8	**67.1**	111.8
Dec	21.5	35.8		
Dec	24.1	40.2		
Jan	32.0	53.3	**113.8**	189.7
Jan	38.1	63.5		
Jan	43.7	72.8		
Feb	49.4	82.3	**140.6**	234.3
Feb	50.4	84.0		
Feb	40.8	68.0		
Mar	42.0	70.0	42.0	70
Total	**363.5**	**605.8**	**363.5**	**605.8**

IWRn (mm/10day) = 10 x IWRn (mm/day)

Total net irrigation water requirement for the growing season = **364 mm**
Total gross irrigation water requirement for the growing season = **606 mm**

8) Challenges and Constraints

- Availability of daily ETo data and converting monthly ETo data to a shorter period
- Preparation of appropriate cropping mix and calendar for the different farm plots with farmers in participatory way because it may be difficult to change farmers' planting needs
- Difficult to understand the unit of crop water requirement in terms of depth in mm per time (day)
- Difficulty in assuming or selecting an irrigation application efficiency to estimate gross irrigation water requirement
- Many calculations involved that require intensive training for the DAs

Technical Information Kit ; On-Farm Water Management

Technical Information Kit	**1) Description of the component**	**2) Main Purpose/deliverables**
9.6.2. Irrigation Scheduling	The preparation of irrigation scheduling is carried out during land preparation and refined during the entire crop growing season as required	To determine when and how much to apply irrigation water Deliverable: Irrigation interval and depth of water to be applied per irrigation
3) Data required for calculating irrigation scheduling	• Cropping program • Daily water requirements of the different crops during their growth stages (ETc) • Maximum root depth of a crop (if no local data, use Annex 6) • Crop root zone depth at different growth stages (Rzd) • Sol water holding capacity (Sa)- depth of water per meter of soil depth • Allowable soil moisture depletion level (p) • On-site monthly/daily rainfall to adjust irrigation interval	
4) Suitability and adaptability to local knowledge	Irrigation scheduling is applicable wherever irrigation is practiced and can be adapted to local conditions if tailor-made and practical training is provided to improve traditional irrigation practices	
5) Potential to increase/sustain productivity and environmental protection (impacts)	Irrigation scheduling: • Minimizes crop water stress • Ensures proper use of water and avoids over or under irrigation application • Minimizes water-logging and runoff problems • Reduces leaching and washing away of fertilizers • Increases net returns by increasing crop yields and crop quality	

6) Description of the Method	• **Irrigation interval**: The number of days between irrigation • **Total available water (TAW):** The amount of water held in the root zone • **Readily Available water (RAW)**: The amount of water in the root zone that can be easily extracted by crop and equals to net depth of irrigation. **Allowable soil water depletion level**: The proportion of RAW and TAW and depends on type of crop Timing and depth/amount of water to be applied are the main considerations in irrigation scheduling. The interval between irrigations and the amount of water to apply at each irrigation depend on how much water is held in the root zone and how fast it is used by the crop. Methods for irrigation scheduling can be classified into three: 7) Water budget or calculating evapotranspiration (ETc) 8) Visual observation of the plant and soil (requires experience) 9) Soil moisture monitoring (requires scientific equipment) **a) Water Budget** The water budget method accounts for the amount of water that is lost by ETc and the amount of water that enters the soil reservoir as effective rain or irrigation. The logic behind the water budget method is to apply irrigation with a net amount equivalent to the accumulated ETc losses since the last irrigation. The soil profile is thus recharged to full capacity, and the crops start to lose water and the cycle begins again. Irrigation interval (I) can be calculated using the following formulas: $TAW = Rzd.Sa$ $Dn = RAW = p.TAW$ $I = \frac{D_n}{ETc}$ (See Annex 5 for detail steps) Where, I = Irrigation interval (days) Dn = net irrigation depth (mm) TAW = Total available water in the root zone RAW = Readily available water (mm) p = Allowable soil moisture depletion level (decimal) from Annex 6 Rzd = Crop root zone depth (mm) Sa = Water holding capacity of soil (mm/m) given in Annex 7 ETc = Crop evapotranspiration (mm/day) The Rzd of each crop at the different stages of growth can be derived from local information or, in their absence, Annex 6 can be used.
	Maximum production can be obtained on most crops if allowable soil water depletionis not more than 50%. In other words, crops have to be irrigated when half of the total available soil moisture is removed from the soil during all the growing

stages.

The involvement of farmers is a very important role in the formulation, implementation, monitoring and testing of irrigation scheduling.

b) Visual observation of the plant and soil

i) Soil Indicators: Feel & appearance method

Soil water content can be judged by the feel and appearance of the soil

- Take soil samples with a probe or soil auger from each quarter of the root zone depth, form into a ball, toss into air and catch in one hand.
- Available moisture percentage is estimated for different textures of soils based on appearance and ball formation (Annex 9).
- Experience and judgment are necessary to estimate available soil moisture content in the sample within reasonable accuracy

ii) Plant indicators

- Cool leaf temperature during the hot part of the day means no water stress
- When partial or full stomatal closure occurs due to reduction of transpiration, there is a rise in leaf temperature
- Darkening of leaves (young leaves with light green to dark color or even to grayish and dull)
- Changing orientation (leaf angle) towards to or away from the sun

Visual observation is a quick and easy method but its accuracy depends on extensive experience.

c) Soil moisture

This requires measuring and monitoring soil moisture using scientific devices. Hence, it is not considered in this manual.

8) Calculation Steps

Step 1: Determine the effective root depth (Rzd) of a crop

Take the same crop used in calculating crop water requirement (onion)

Assume linear increase of root depth starting from planting depth to end of the development stage. Then the depth of root N day will be calculated with the following formula:

$$Rzdt = Rzdi + \frac{(Rzd_{\max} - Rzdi)}{EDS} Nday$$

EDS= End of development stage period (day)

Rzdi = Planting depth (m)

<u>Example: Depth of crop root 40 days after planting</u>

Maximum root depth of onion= 0.5 (Annex 6)

Planting depth = 0.2 m

$$Rzdt = 0.2 + \frac{(0.5 - 0.2)}{65} * 40 = 0.38m$$

Step 2: Determine water holding capacity (Sa) of the soil

Soil type: Loam

Sa = 150 mm/m (from Annex 7)

Step 3: Determine the depletion fraction (p)

Select allowable depletion level, p= 0.3

Step 4: Determine the readily available water (RAW)

TAW = Rzd x Sa = 0.38 m x 150 mm/m = 57 mm

RAW= pTAW = 0.3 x 57 = 17.1 mm

Step 5: Calculate the irrigation application depth (mm)

Dn= RAW

Step 6: Take daily ETc values calculated above

On the 40th day in January, ETc =3.2 mm/day

Step 7: Determine Irrigation Interval

$$I = \frac{Dn}{ETc} = \frac{17.1}{3.2} \text{ = 5.3, rounded to 5}$$

Use 5 days if there is adequate water, otherwise use 6 days.

If 5 days of irrigation interval is selected, the irrigation depth should be adjusted as follows:

Dn= 5 days x 3.2mm/day = 16 mm

Similarly, calculate the irrigation intervals for each of the decadal period as shown in the table below.

Month	Decade	ETc (mm/day)	Root Depth (m)	Depth of irrigation (mm)	Irrigation Interval (days)	No of Irrigations
A	**B**	**C**	**D**	**E**	**F**	**G**
Dec	1	2.15	0.1	4.5	2	4
Dec	2	2.15	0.18	8.1	4	2
Dec	3	2.41	0.26	11.7	5	2
Jan	4	3.20	0.34	15.3	5	2
Jan	5	3.81	0.42	18.9	5	2
Jan	6	4.37	0.5	22.5	5	1
Feb	7	4.94	0.5	22.5	5	2
Feb	8	5.04	0.5	22.5	4	2
Feb	9	4.08	0.5	22.5	6	1
Total						**18**

Note: E=p.Rzd.Sa F= E/B G= 10/E (number of irrigations in 10 days)

	Step 8: Adjust irrigation interval and depth of irrigation as appropriate with farmers taking into account crop water need and management ease. • 2 or 3 out of 4 irrigations may be needed during decade 1 • The last irrigation may not be required. • Irrigation interval of 5 or days can be adopted for decades 2 and 8 **Step 9**: Record daily rainfall during the growing season **Step 10**: Calculate the cumulative soil water deficit **Sept 11**: Adjust irrigation interval if the rain is adequate to refill the water deficit
10) Challenges and Constraints	Thefollowing difficulties are expected to constrain application of proper irrigation scheduling: • Irrigation scheduling becomes particularly sensitive under conditions of limited water resources, where water shortages require a refined timing of water applications in order to minimize yield reductions • Under saline conditions, water scheduling requires appropriate knowledge of salt tolerance levels • Variability of rainfall is often difficult to adequately accommodate in the planning of irrigation calendars • Lack of flow measuring system in irrigation canals poses difficulty in the application of known amount of water at each irrigation time • Changing farmers' attitude for applying more irrigation when there is adequate water
11) Reducing Risk of Water Shortage	• Prepare cropping plans • Calculate total water/irrigation needs of all crops • Estimate available water supply during peak irrigation • Consider operation needs or discharge for each tertiary unit • Adjust cropping plans if there is water shortage (set maximum area for crops that have high water needs) • Stagger the growing season within or between tertiary units • Relax irrigation interval in periods outside moisture sensitive period (Annex 8) • Irrigation must be given to these stages to avoid yield losses

12) Conversion of irrigation depth into discharge	Depth of irrigation water can be converted into flow or discharge as follows: $q = \frac{AD_n}{TE} = \frac{D_n}{8.64IE}$ (A= 1 ha) Where, Q= discharge in liters per select (l/s/ha) A= area in ha T= Time in seconds I = Irrigation interval (days) E= Irrigation efficiency 8.64 is conversion factor for 24 hrs of irrigation duration. <u>Example</u>: Consider the irrigation depth at decade 8 in the above table $q_{24} = \frac{1x16}{8.64x5x0.6}$ = 0.62 l/s/ha The discharge (Qt) for duration (t) other than 24 hrs of irrigation duration will be calculated as follows. Suppose irrigation duration is 14 hrs. $q_t = \frac{24}{t} q_{24} = \frac{24}{12} x0.62$ **=1.06 l/s/ha** To calculate the discharge for a tertiary canal, simply multiply this unit discharge by the tertiary area in ha**.** If a tertiary unit is 15 ha, the discharge will be Q =15 x1.06 = 15.9, say 16 lit/sec

13) Deficit Irrigation

Deficit irrigation (DI) is an optimization strategy in which limited irrigation either throughout the growing season or during drought-sensitive growth stages of a crop. Outside these periods, irrigation is limited or even unnecessary if rainfall provides a minimum supply of water. Water restriction is limited to drought-tolerant phonological stages, often the vegetative stages and the late ripening period. In short, DI is application of water below full crop-water requirements.

There are two types of deficit irrigation

- **Sustained deficit irrigation**: Applying below water requirements throughout the season
- **Regulated deficit Irrigation**: Applying below water requirements during specific growth periods mainly during vegetative growth and ripening.

In order to apply deficit irrigation strategy, we have to know the relationship between crop water requirement and crop yield as shown in the following equation.

$$1-\frac{Y_a}{Y_m}=K_y\left(1-\frac{ET_{ca}}{ET_c m}\right)$$

Where,
Y_m = Maximum expected yield
Y_a = Yield response factor (cropspecific and varies during the growing season)
ET_{cm} = ETc, for optimal water supply
ET_{ca} = Actual crop ET adjusted for water stress
K_y = Crop yield response factor (see Annex 10)

Steps for applying deficit irrigation
Step 1: Estimate Ym of an adapted crop variety
Step2: Calculate ETcm
Step 3: Decide on whether to apply sustained or regulated deficit irrigation
Step 4: Select level of yield reduction
Step 5: Calculate water deficit from CWR, yield reduction and Ky for specific period
Step 6: Adjust irrigation interval or amount of water to applied

Example

- Assume yield of onion to be reduced by 10% due to water shortage, that means Ya/Ym =100%-10%= 90% =0.9
- Consider the ETcm of onion calculated above = 3.2 mm/day
- Select crop yield response factor (Ky) for onion at development stage which is 0.45 (Annex 10)
- Calculate adjusted crop water requirement (ETcadj) using the following formula

$$ET_{c,adj} = ET_{cm}\left\{1-\frac{\left(1-\frac{Ya}{Ym}\right)}{Ky}\right\} = 3.2x\left\{1-\frac{(1-0.9)}{0.45}\right\}$$ = 2.49 mm/day

- Alternatively, read ETa/ETm in Annex 11 with Ky=0.45 and Ya/Ym =0.9
- The dotted line shows the value of ETa/ETm as 0.775.
- Then calculate reduced ETc as

  ETca= 0.775*3.2= 2.48 mm/day

- Adjust irrigation interval (Ir)as follows:

$$Ir = \frac{ETcm}{ETca} I = \frac{3.2}{2.49} x5 = 6.4$$, say 6 days.

Therefore, irrigate every 6 days instead of 5 days.

References

1. Andreas P. Savva and Karen Frenken (2002), Crop Water Requirements and Irrigation Scheduling, FAO Sub-Regional Office for East and Southern Africa, Harare
2. Field Guide on Irrigated Agriculture for Field Assistants, IPTRID (FAO), Report No.1, April 2001
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4. JossSwennenhuis(2009),Cropwat8.0, http://www.fao.org/nr/water/infores_databases_cropwat.html

Technical information Kit1	(1) Brief description ofbasin irrigation	(2) Main objective
9.6.3. Basin Irrigation	Basinirrigationis an irrigation methodthat involvesdividinga fieldintoseveral relativelysmall levelplotscalled checks or basinssurrounded bylowsoilbunds. Water isconveyed to checks byasystemosupply channel, lateralsandfield channels.Basinirrigationisthesimplestandmostwidely used surface irrigationmethod.	To increase crop productivity through the application of irrigation water to basins (level plots) separated by bunds.

(3) Implementation ofbasin irrigation

Basin irrigation can be implemented in a given areas by considering surface slope, soil and crop types, and water availability.

(3.1.) Suitability

Basin irrigation is mostsuitedon flatlandswithsoiltypeshavingmoderate toslow infiltrationrates. It can also beusedon slopingland providedthatthesoilsdeepenough toallowlevellingwithoutexposingthesubsurfacesoil.Basin irrigation can be used for most crop types and is suitable for most soils. The most suitable crops for basin irrigation include paddy rice, alfalfa, clover, citrus, banana, cereals(maize, wheat, and barley), etc. However, basin irrigation is generally not suitable for crops which cannot stand in wet or waterlogged conditions for a period more than 24 hours. These are usually root and tuber crops such as potatoes, cassava, beet root and carrots which require loose, well-drained soils. Basin irrigation is mostly suitable for flat topographies.

(3.2) Site selection

When you select a site for basin irrigation, you need to consider three major factors: (1) the slope of the land, (2) the soil texture, and (3) the water discharge or water flow rate. Basin irrigation is suitable for flat or gentle slopes. Higher water flow rate is required for clay soils than sandy soils.

(3.3) Basin layout and basin size

The basic structure of a basin irrigation is the **basin** which is formed by fencing an area by constructing bunds. The size of the basins depends on the slope of the area, the soil type and the available water flow to the basins. The relationship between slope and basin width is given in Table 1.

Table 1. Approximate values for the maximum basin width (m) at different surface slopes

Slope%	Width (m)	
	Average	Range
0.2	45	35-55
0.3	37	30-45
0.4	32	25-40
0.5	28	20-35
0.6	25	20-30
0.8	22	15-30
1	20	15-25
1.2	17	10-20
1.5	13	10-20
2	10	5-15

3	7	5-10
4	4	3-8

The relationship between stream size (water flow) and soil texture is given in Table 2 below.

Table 2. Suggested maximum basin areas(m^2) for various soil types and available stream size or flow rate (liter/second)

Stream size (liter/second)	Soil texture			
	Sand	Sandy loam	Clay loam	Clay
5	35	100	200	350
10	65	200	400	650
15	100	300	600	1000
30	200	600	120	2000
60	400	1200	2400	4000
90	600	1800	3600	6000

Basin layout not only refers to the shape (e.g., squares, rectangular or irregular) and size (e.g., 10, 100 or 1000 m^2) of the basin but also to the shape and height ((e.g., 10,50or100cm) of the bunds.

In general, one can determine the size of basins based on the following criteria.

The size of the basin should be small if:

1. he slope of land is steep
2. he soils is sandy
3. treams flow to the basin is small
4. required depth of the irrigation application is small
5. ield preparation is done by hand or animal traction

The size of the basin can be large if:

1. he slope of the land is gentle or flat
2. oil type is clay
3. tream size to the basin is large
4. equired depth of the irrigation application is large
5. Field preparation is mechanized

3.4. Size of bunds

Bunds are small earth embankment which contain irrigation water within basins. They are sometimes called dykes or levees. Bunds can have different sizes and shapes (width and height) and they can be either temporary or permanent.

- Temporary bunds can have 60-120cm at the base with a height of 15-30cm above the original ground surface, including a freeboard of 10cm
- Permanent bund can have 130-160cm at the base with a height of 60-90cm above the original ground surface,and asettling height of 40-50cm (see the pictures and diagrams at the end of this document).

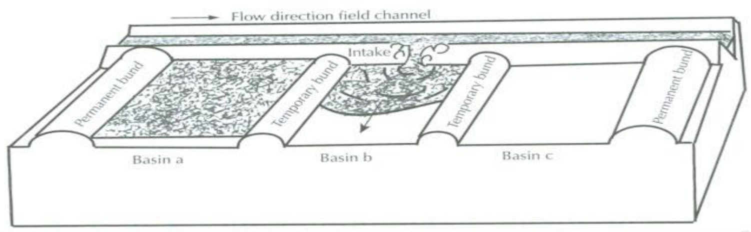
3.5. Steps in basin construction

There are three steps to be followed in the construction of basins:

1. **etting out contours:** Setting out contours is relatively simple and involves only straight lines. A terrace is set out by first locating a suitable contour lines across the land slope. This is the line along which the first bund is constructed. A second line is then set out along a contour further up the slope to mark the location of the next bund.
2. **uilding bunds**: **-** both temporary and permanent bunds can be formed by hand or by animal or tractor-powered equipment. The constructed bund should be properly compacted so the leakage cannot occur.
3. **and leveling:** Land leveling on flat land involves smoothing out the minor high and low spots so that the difference in leveling is less than 3cm within a basin. Although it could be difficult to check a 3cm high and low spots in a field using an eye, this can easily be checked by apply water across basin.
4. **ontract water supply furrows:** furrows that supply water from a water source to each basin need to be constructed. The width and depth of the water supply furrows depend on the flow rate and depth (amount) of irrigation required.

(4) Challenges and constraints (limitations)

Theprincipallimitationsof themethodinclude interferenceofthe ridgeswith otherfarm activities,considerableandiswasted to idgesandlateral fieldchannels construction,impedessurfacedrainage and causes soil crusting,preciselandgrading andLevel Ingarenecessary,labourrequirementsfor landpreparationandapplicationofirrigationwateraremuchhigher,highinitialcapitalinvestmentascompare dwith othersurfaceirrigation methodsandunsuitability forirrigatedcropssensitivetowetsoil conditions.



Layout of basin irrigation system

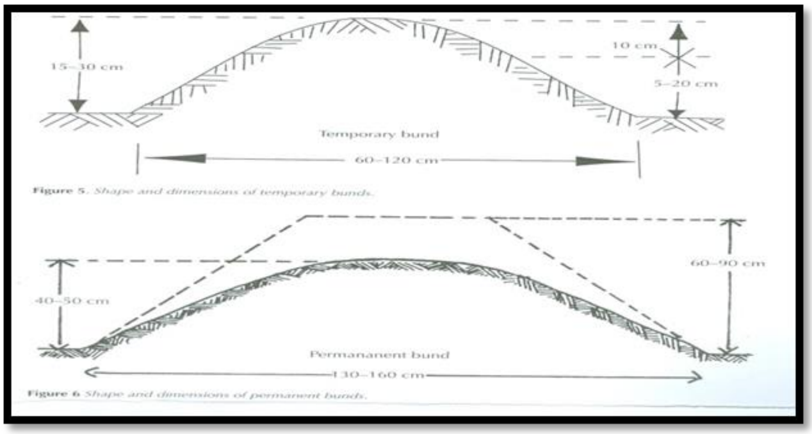


Figure 5 Shape and dimensions of temporary bunds.

Figure 6 Shape and dimensions of permanent bunds.

Références

Michael, A.M (1994). Irrigation Theory and Practice. Indian Agriculture Research Institute, New Delhi.

Surash R.,(2002) Soil and Water conservation Engineering. Bhargaveprinter,Delhi.

Technical information Kit --	**(1) Brief description**	**(2) Major objective**
9.6.4. Furrow Irrigation	Furrow irrigation refers to irrigating land by constructing furrows between two rows of crops or alternately after every two rows of crops, particularly for narrow spaced row crops such as onions, cabbage and pepper. It involves only wetting part of the surface of the soil so that water in the furrow moves laterally by capillaryaction to the un-watered areas below the ridge and also downward to wet the root zone soil.	to apply water through well prepared furrows to reduce evaporation losses and puddling of the soil surface,improve aeration of the root zone, and minimize accumulation of salts near the plant bases in areas where the problem exists.

(3) Implementation

Implementation of furrow irrigation requires preparation of rows with a careful selection of crops, surface slope, and soil type.

(3.1) Suitability

Furrow irrigation is well suited both to small and large farms. It is also suitable for many crops, and especially to row and tree crops, and it is the most widely used method for row crops such as vegetables, maize, groundnut, sugarcane, cotton, potatoes, etc. Fruit crops are also irrigated using furrow irrigation method. Crop type, farm equipment and row spacing are the factors that determine furrow size and shape.

(3.2) Design and layout

Furrow Layout

In furrowirrigation,waterisappliedtosmallchannels,knownasfurrowsthatarebetweentherowsofplants.Furrows are prepared by preparing long shallow trenches on the ground. The most important factor in the layout of furrows is determining the optimum furrow length.

Furrow Length

The most practical and efficient length of furrow is determined by considering the following factors:

- slope,
- soil type,
- stream size,
- irrigation depth,
- cultivation practice ,and
- field length.

Furrowlength can be as long as **500m** dependingonthe factors mentioned abovebutthefieldsizeandshape of fragmented fields, as is the case with smallholder farmers, put practical limits on furrow length. In principle, furrow lengths are shorter in coarse soils and longer in heavy clay soils. In this regard, furrow length is as short as 10 - 20 m long in vegetable gardens and long as 500 m in deep-rooted crops such as cotton in largemechanized irrigation schemes. Efficient furrow irrigation always involves run-off and surface drainage system, which is usually built at the end of the furrow perpendicular to the furrow, so that excess water from the is drained out. The recommended maximum furrow lengths for different soil types and slopes are given in Table 1.

Table 1.Recommendedfurrowlengthsfordifferentslopes,soil typesandnetdepthofwaterapplication (mm)

Furrow Slope (%)	Maximum flow of water per second	Furrowlength(m)							
		Soiltypeandavailablesoilmoistureinmm/mdepthofsoil							
		Clay			Loam		Sand		
		50	75	150	100)	150	50	75	100
0.05	3.0	120	300	400	270	400	60	90	150
0.10	3.0	180	340	440	340	440	90	120	190
0.20	2.5	220	370	470	370	470	120	190	250
0.30	2.0	280	400	500	400	500	150	220	280
0.50	1.2	280	400	500	370	470	120	190	250
1.00	0.6	250	280	400	300	370	90	150	190
1.50	0.5	220	250	340	280	340	80	120	190

2.00	0.3	180	220	270	250	300	60	90	150

Source:IrrigationAgronomyManual (1990),AddisAbaba

It can be understood from the table that furrow length decrease as slope increases or decreases depending on soil type. When the slope increases, run-off also increases, particularly on heavy clay soils with low infiltration rate, and when the slope is decreases, run-off is low increasing infiltration rate on coarse textured soils. Moreover, as the slope increases, the movement of water reaching the ridges will decreases resulting in water loss at the end ofthe furrow. In addition, higher velocities ofwater in the furrowlead to risks ofsoil erosion. Thus, in deciding a furrowsystem, careful consideration of slope length, soil texture and the other factors mentioned above isa must.

In order to control or at least minimize erosion, particularly in areas where there is heavy rainfall, furrow must have a limited slope and followingthe slope guidelines shown in Table 2 below is advisable.

Table2. Slope levels recommended for furrowirrigation on different soil types

Soiltype	**Maximumrecommended slope,%**
Sand	0.25
Sandyloam	0.40
Finesandyloam	0.50
Clay	2.50
Loam	6.25

In furrow irrigation, water is admitted to the head of each furrow, and the rate of flow is adjusted so that water flows from one end of the furrow to the other without overtopping. As the water reaches the end of the furrow, water infiltrates into the soil along the furrow to satisfy the water requirements of crops. The rate of flow into the furrow depends primarily on the intake rate of the soil and the length of the furrow. Infiltration rates for varioussoil textures and suitable furrow flow rates per 100 m length of furrow are given in Table3 below.

Table 3.SoilInfiltrationratesandsuitablefurrowinflowsper100moffurrowlength/furrowspacing1m/

Soil	Infiltration rate (mm/h)	Furrow inflow(liters/second/100m)length
Clay	1-5	0.03-0.15
Clayloam	5-10	0.15-0.30
Siltloam	10-20	0.30-0.50
Sandyloam	20-30	0.50-0.80
Sand	30-100	0.80-2.70

Source:Stern (1985).

Determination of the correct flow rateper furrow requires testing under field conditions. This can be done using a simple advance and recession test. If you plan to do this, please follow the following steps:

a) Markthree points along the furrow - a point near the beginning, the midway point, and a meter from the end of the furrow.
b) Directed water into the furrow at the desired operating flow rate
c) Record the time when the water passes the three markers
d) At the end of the irrigation, record the time that it takes the water to infiltrate and regress from the end of the furrow to the beginning.
e) With these two sets of data, plot the advance (c) and recession (d) curvesfor the flow rate in the furrow on x-y axis graph: x-axis is representing the length of furrow and corresponding marks; y-axis is the time on the same graph paper. If the two curves (i.e. advance and recession) are more or less parallel to each other, this indicates that the flow and time for the length of furrow being tested give a good water distribution. If this is not the case, the flow

rate and/or time of irrigation should be changed. This test should be done for each alteration until the desired results are achieved.

Furrow Spacing

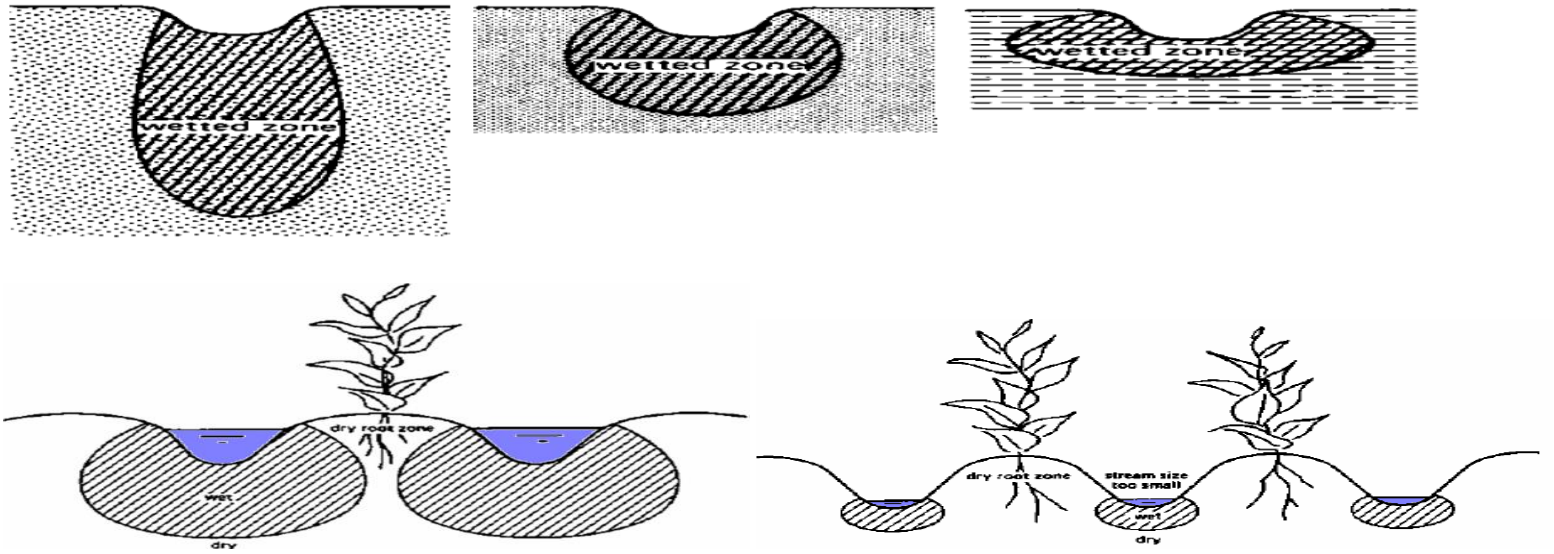
As mentioned above, furrow irrigation adapts better than any other method to crops that are grown in rows with more than 30 cm spacing, such as vegetables, maize, groundnut, sugarcane, cotton, and potatoes. Fruit crops are also irrigated by furrow method. Crop types, farm equipment to be used and planting distances between plants arethe factors that determine furrow size and shape. Furrowsareusually v-shaped in cross section, 25- 30 cm wide at the top, and 15- 20 cm deep, shallower in lightersoils and deeper in heavier soils. Wider, U-shaped furrows with a greater wetted area are sometimes used on soils with slower water intake rates. Usually, the spacing between furrows is narrower in sandy soils and wider in heavy soils. This is to ensure that water spreadslaterallyintothesoil belowridgesanddownwardsintheeffectiverootingdepth uniformly. Furrowspacinginsandy soilsis inarangeof60to80cm,whereasinclaysoils75to150cmandinloamsoilsit is between 60to90cm. Shallowrooted andtransplanted cropsusingseedlingsrequiresmallwidthandshallowdepth, while deeprootedcropshavewideanddeepfurrowdepth. Thereare3differenttypesoffurrow methods: straight level furrow, straight graded furrow and contour furrow (see Figure 1).

(4) Challenges and constraints (limitations)

The major problem in furrow irrigation is poor wetting pattern which can be caused by:

- Unfavorable natural condition. For example, compacted soil layers and uneven slope can result in uneven wetting along the furrow. This problem can be overcome by changing the land to a uniform slope.
- Poor layout- if furrow spacing is too wide, the root zone will not be adequately wetted.
- Poor management- a stream size that is too small will result in inadequate wetting of the ridges because of poor water distribution along the length of the furrow. Whilst overtopping of the ridge could also occur under high flow rate, stopping the inflow too soon is also a common management fault.

Figure 1. Spacing and wetting of furrows



a) Too wide furrow spacing **b) Too small flow**

Figure 2. Pictures of furrow irrigation

Technical information Kit--	(1) Brief description	(2) Major objective
9.6.5. Community pond	A community pond is a pond or reservoir constructed by a community during the dry period for the purpose of storing surface runoff from a catchment area.	To store water for use during the dry seasons for domestic and livestock use or for irrigating small gardens.

(3) Implementation

Implementation of border irrigation requires careful selection of surface slope, soils types, and catchment area.

(3.1) Suitability

Suitable in areas where scarcity of water is sever and there are no surface and/or underground water resources that are economical to develop. Therefore, community pods are mostly useful the arid and semiarid areas of Ethiopia. Community pods suitable in locations where there is enough catchment area that supply water to be stored in the ponds. Although pods needs to be constructed in lower catchment areas (farm, grass and communal lands)with a slope of less than 5% for protection or reducing erosion.

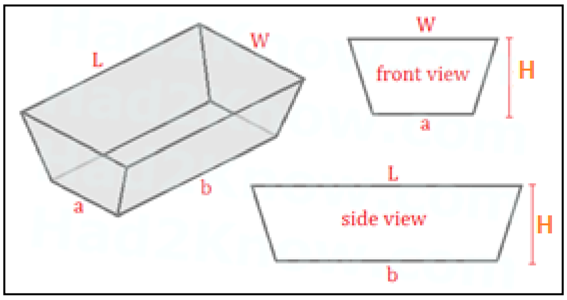
(3.2) Design and layout

The most common shapeof pond is a trapezoidal, mostly a frustum of cone with wider and narrower areas on the top and bottom parts of the trapezoid, respectively. The horizontal and vertical lengths ratiosare important in the construction of community ponds. The vertical to horizontal ratios have to be 1:2 (1 to 2) on stable soils and1:3 on unstable soils such as Vertisols (clay soils).

1. Determination of the volume of a trapezoidal community pond

The volume of trapezoidal prism pond can be calculated using the top and bottom areas of the trapezoid as follows:

$$V = \frac{H}{3}\left(A_t + A_b + \sqrt{A_t^2 + A_b^2}\right)$$



where V = storage capacity (m^3)
H = water storage depth or height (m)
A_t = top area of storage = L × W (m^2)
A_b = base area of storage = a × b (m^2)
W = width of top area (m)
L= length of top area (m)
a= width of bottom area (m)
b= length of bottom area (m)

Figure 1. Top and bottom sides of a trapezoid

The volume of trapezoidal pond can also be calculated using the top, middle and bottom areas of the trapezoid as follows:

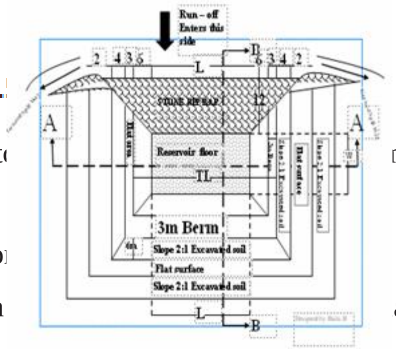
$$V = H \times \frac{[A + 4B + C]}{6}$$

where,
V = Volume of the pond (m^3)
H = Depth of the pond (m)
C = bottom area of pond (m^2)
A = top area of pond (m^2)
B = mid depth area (0.5*H) (m^2)

Figure 2. Dimension of a rectangular trapezoid community pond

2. Volume of a frustum of cone shape

The volume of a frustum of cone shape can be calculated using the following formula:



- V=1/3IIr3=Cone volume

$$V = \frac{\pi}{3}h(0.5R^2 + 0.5r^2 + (0.5R * 0.$$

whereV is volume of the pond (m^3), Ris t neter (m), and h is the depth of pond (m).

Ponds can be classifies in to three based o

- Type 1: 5504m^3 capacity with a ameter of 28m and depth of 6m
- Type 2: 2487m3 capacity with a top diameter of 30m , bottom diameter of 20m and depth of 5m
- Type 3: 1401 m3 capacity with a top diameter of 25 , bottom diameter of 17 and depth of 4m

You can calculate the volumes given for each type above using the formula provided above.
Example: Type 1: V = π/3*6*((40/2)^2+ (28/2)^2+ (40/2)*(28/2)) = 6.283*(400+196+280)= 5504m^3

The volume of the frustum of a cone (Vc) in m^3 is calculated as follows:

$$Vc = \frac{\pi}{3}\left(\frac{R}{2}\right)^2 - \frac{\pi}{3}\left(\frac{r}{2}\right)^3$$

(3.3) Construction and maintenance of community pond

The construction of a community pod is a step-wise process. The major steps are shown below.

Method 1:

1. Mark the top area of the pond on the ground with pegs
2. Mark the bottom area of the pond on the surface
3. Start excavating the bottom area to the required depth
4. Reshape the sloping side, triangle
5. Place the excavated soil 3maway from the border of the pond
6. Make stone steps or side steps along the side of the pond to allow people to fetch water

Method 2:

1. Mark the top area of the pond on the ground with pegs
2. Mark an area inside the top area maintaining the side slope
3. Consider point O (see Figure 3) as the center of the pond
4. If the side slopes are considered to be same in both sides, distances of points AC and BD are equal, and similarly, distances of points OA and OB are equal as well
5. Start excavating or digging AMNB first and then shape CAM and DBN
6. Place the excavated soil 3maway from the border of the pond
7. Make stone steps or side steps along the side of the pond to allow people to fetch water

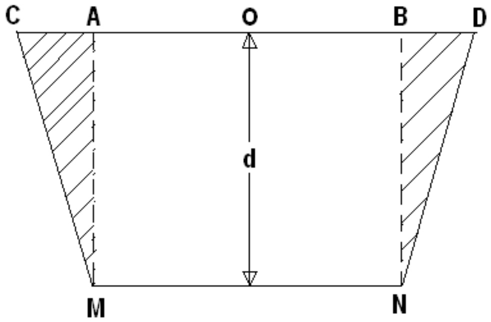


Figure 3. Marks for trapezoid construction

(3.4) Maintenance and management of community ponds

The pond has to be fenced for safety purpose, i.e., to protect animals and children from easily reaching to the water and get drowned. There is also a need to have appropriate water lifting technologies such as treadle pumps, pedal pumps, rope and washer pump etc., to abstract water from the pond.

(4) Challenges and Constraints (limitations)

Excavation is labor intensive, and it requires regular maintenance and management.

Figure 4. Pictures of a community pond. Photo: Hailu Hunde.

Reference

HailuHundie (2012) Soli Conservation Training Manual. KombolchaATVT College, Ethiopia.
Surash R.(2002) Soil and Water conservation Engineering . Bhargave printer,Delhi.

Technical information Kit-	**(1) Brief description ofbasin irrigation**	**(2) Main objective**

9.7. Climate/Weather information	Agriculture depends on weather/climate conditions that govern the growth and development of crops and animals, water availability to crops and animals, land use and agricultural decisions. Natural resource use and conservation is also highly influenced by climate. The Ethiopian climate is characterized by spatial and temporal variability and it is also influenced by global climate change. Adapting agriculture to both climate change and variability requires farm decisions that are based on pre-season, in-season and post-harvest climate information. This info-tech provides useful guidance in the use of climate information that guide farm level decisions under the changing climate.	The objective of this IFOTEC is to guide practitioners on the use of timely pre-season, in-season and harvest period climate/weather information for managing climate change and variability at farm and watershed levels

(3) Use of climate/weather information for agricultural decisions

1.1. Understanding terminologies

In order to use weather/climate information for practical decision making, first you need to understand the commonly used climate terminologies which are stated below.

Weather/climate information refers to a climate or weather forecast information obtained from climate service providers ahead of

- a season (e.g., Kiremt, Belg, Bega), known as seasonal forecast,
- a dekade (10 days), known as dekadal forecast,
- a month (30days), known as monthly forecast
- a week, known as weekly forecast, and/or
- a day, known as daily forecast

in order to guide seasonal, decadal, weekly and/or daily climate sensitive agricultural decisions.

The rainfall and temperature forecasts, particularly, the seasonal forecasts are provided by the climate providers in three categories as follows:

- **above-normal** when the forecast value is well above the median value of the previous 30 years (normal period) at a given site or region,
- **below-normal** when the forecast value is well below the median value of the previous 30 years (normal period) at a given site or region
- **near normal** when the forecast value is similar or close to the median value of the previous 30 years (normal period) at a given site or region.

1.2. Identify the stage of decision making

In order to use climate forecast information meaningfully, you need to look at the different stages of agricultural and natural resource conservation operations and the associated decisions needed: These include:

a) **Pre-season agricultural and natural resource decisions:** these are decisions to be made before the season starts based on seasonal climate forecast. The seasonal forecast information that you need to get for decision making are the mount of the expected rainfall in the coming season, start of the season and the length of the growing period. For example, if you receive a **below normal rainfall** and short growing season forecast for the *Kiremt* season rainfall, you need to prepare for constructing rain water harvesting structures, buy seeds of drought tolerant and short maturing crops for planting and decide on the type and amount of fertilizers that you need to buy from the market for a drier season. On the other hand, if the forecast is **above normal rainfall** for the *Kiremt* season, you need to consider constructing structures that control runoff and soil erosion on the steep slopes and drainage structures and ways to manage water logging on black clay soils, buy seeds of higher yielding crop varieties and higher fertilizer amounts. If the forecast is near normal rainfall for the *Kiremt* season, you follow the 'normal' or commonly used agricultural and natural resource conservation operations and decisions. Please note that the decisions and options that you need to make could vary based on agro-climatic conditions (*Dega, Woninda Dega or Kola*). For detail information on seasonal forecast and possible decisions, please see Table 1.

b) **In-season agricultural and natural resource decisions:** these are decisions to be made after the season starts (after planting) based on decadal or weekly and sometimes daily climate/weather forecasts. For example, if the forecast information is about dry weeks, you need to adjust your fertilizer application rates, consider water harvesting for supplemental irrigation, reduce your weeding frequency; and if the forecast shows additional dry weeks coming up, you may also consider thinning. If the forecast shows high rainfall in the coming weeks, you may need to apply your fertilizers, and consider soil erosion measures. See Table 2 for more details.

c) **End of season agricultural and natural resource decisions**: these are decisions to be made towards the end of the season (harvest time) based on weekly and sometimes daily climate/weather forecasts. End of the season is the time when crops mature and become ready for harvest. The forecasts that are given during these period are untimely rains, hail storms, floods, and heavy winds. Based on the forecast information, you are expected to harvest as early as possible or prepare for any protection that damage the crops. For example, if the forecast show heavy rainfall conditions that can cause flood towards the end of the season which can destroy the natural conservation structures that you built throughout the season, you need to make the necessary decisions to protect your conservation structures. For more details on the use of end of season climate/weather forecast, see Table 3.

(3.1) Suitability

Climate and weather information is applicable to all agro-ecologies and farming systems

(4) Implementation of climate information use for agricultural decisions

4.1. Pre-season climate information

➢ **Why is it needed?** Pre-season climate information is important to make early decisions like land preparation, crop/variety type choice, water management and labor requirement and need for credit services (See Table 1). These decisions are important to minimize risks and exploit opportunities in a given cropping season to enhance crop productivity, contribute to household food security and reduce greenhouse gas emissions by optimizing tillage and other land operations.

- **Where is it needed?** Pre-season climate info is needed across all ago-ecologies.
- **What type of climate information is needed?** Start of rainfall, length of growing season and seasonal rainfall distribution and amount.
- **Sources of information for pre-season climate information includes:**
  - ✓ National Meteorology Agency (NMA) seasonal forecast (http://www.ethiomet.gov.et/bulletins/bulletin_viewer/462/bulletins/Belg_Assessment&Kiremt_2016_Outlook/en)
  - ✓ Online weekly forecast (http://zw.freemeteo.com/weather/?language=englishandcountry=ethiopia
  - ✓ Medias (TV, Radio, bulletins, newspapers),
  - ✓ Interactive voice response , IVR (From Ethio-telecom),
  - ✓ Short message services (SMS) and
  - ✓ Minister of Agriculture (MOA) internal communication

4.2. In-season climate information

- **Why is it needed?** In-season climate information is important to make crop management decisions like proper fertilizer choice, amount and placement, supplementary irrigation requirement, cultivation and crop protection measures and reduce land degradation that may arises from low productivity.
- **Where is it needed?** In-season climate information is needed across all agro-ecologies.
- **What type of climate information is needed?** Dekadal, weekly and daily rainfall forecast.
- **Sources of information for in-season climate information:**
  - ✓ NMA dekadal, weekly and daily rainfall and temperature forecasts (http://www.ethiomet.gov.et/daily_weather; http://www.ethiomet.gov.et/forecasts/three_day_forecast)
  - ✓ Climate bulletins (http://www.ethiomet.gov.et/bulletins/bulletins)
  - ✓ Ethiopia Institute of Agricultural Research (EIAR)- 10 days rainfall forecast,
  - ✓ Online weekly forecast (http://zw.freemeteo.com/weather/?language=englishandcountry=ethiopia)
  - ✓ Medias (TV, Radio, newspapers),
  - ✓ Interactive voice response , IVR (Tele),
  - ✓ Short message services (SMS),
  - ✓ MOA internal communication.

4.3. Harvesting period climate information

- **Why is it needed?** Climate information during harvesting period is important to avoid/reduce damage from unexpected rain, hailstorm, flood, strong wind, and outbreak pests and diseases.
- **Where is it needed?** Harvesting period climate information is needed

across all ago-ecologies.

- **What type of climate information is needed?** Special climate warnings on unexpected heavy rain, hailstorm, flood, strong wind, unusual outbreak of pests and diseases.
- **Sources of information harvest period climate information**
  - ✓ NMA dekadal, weekly and daily rainfall and temperature forecasts (http://www.ethiomet.gov.et/daily_weather; http://www.ethiomet.gov.et/forecasts/three_day_forecast)
  - ✓ Ethiopia Institute of Agricultural Research (EIAR)- 10 days rainfall forecast,
  - ✓ Online weekly forecast (http://zw.freemeteo.com/weather/?language=englishandcountry=ethiopia)
  - ✓ Medias (TV, Radio, newspapers),
  - ✓ Interactive voice response (IVR) from Tele
  - ✓ Short message services (SMS),
  - ✓ MOA internal communication.

(4) Challenges and constraints (limitations)

The major limitations are availability of timely and location specific climate information. The users need to be aware of where the climate information can be reached and accessed.

Table: Possible crop management decisions based on pre-season climate information and Agro-ecology

Rainfall Onset forecast (N, E, L)	LGS* forecast (N, L, S)	Rainfall amount forecast (N, AN, BN)	Decision implications in different agro-ecologies			Remark
			Dega	**Weyena-dega**	**Kola**	
Normal	Normal	Normal	• Follow commonly practices of land preparation, sowing time, crop/variety choice and other water/ soil management practices			These decisions should take into account the soil type and water availability conditions of a given particular site under consideration
Normal	Normal	Above normal	• Use commonly grown crops • Soil erosion could be a major problem- prepare for soil conservation practices ahead of time	• Use commonly grown crops • Soil erosion is likely and prepare for soil conservation practices ahead of time	• Use common grown crops • Soil erosion could be a possibility based on soil type	
Normal	Normal	Below normal	• Consider water harvesting and storage for supplemental irrigation	• Prepare for water harvesting/storage structures for supplemental irrigation	• Practicing water harvesting/storage structures and supplemental irrigation is required for successful crop harvest • possibility of crop failure is likely	
Normal	Long	Normal	• Medium to late maturing crop types/varieties	• Medium to late maturing crop types/varieties	• Medium maturing crop types/varieties	
Normal	Long	Above normal	• Grow late maturing crop types/varieties • Soil erosion could be a major problem- prepare for soil conservati	• Grow late maturing crop types/varieties • Soil erosion is likely and prepare for soil conservation practices ahead of time	• Grow medium maturing crop types/varieties • Soil erosion could be a possibility based on soil type	

			on practices ahead of time			
Normal	Long	Below normal	• Grow medium to late maturing crop types/varieties • Consider water harvesting and storage for supplemental irrigation	• Medium maturing crop types/varieties • Prepare for water harvesting/storage structures for supplemental irrigation	• Grow early to medium maturing crop types/varieties • Practicing water harvesting/storage structures and supplemental irrigation is required for successful crop harvest • Possibility of crop failure is likely if not supplemented with irrigation	
Normal	Short	Normal	• Grow early to medium maturing crop types/varieties • Consider water harvesting in drier localities	• Grow early maturing crop types/varieties • Practice water harvesting	• Grow very early maturing crop types/varieties • Water harvesting is necessary for successful crop production	
Normal	Short	Above normal	• Medium maturing crop types/varieties • Soil erosion could be a major problem-prepare for soil conservation practices ahead of time	• Grow early maturing crop types/varieties • Soil erosion is likely and prepare for soil conservation practices ahead of time	• Grow very early maturing crop types/varieties • Soil erosion could be a possibility based on soil type • Water harvesting may help avert rainfall distribution problems	
Normal	Short	Below normal	• Grow early to medium maturing crop types/varieties • Consider water harvesting	• Grow early to very early maturing crop types/varieties • Prepare for water harvesting/storage structures for	• Grow extra early maturing crop types/varieties • Practicing water harvesting/storage structures and	

			and storage for supplemental irrigation	supplemental irrigation	supplemental irrigation is required for successful crop harvestpossibility of crop failure is likely	
Early	Normal	Normal	• Early land preparation • Early planting is required • Use commonly grown crop types/varieties	• Early land preparation • Early planting is required • Use commonly grown crop types/varieties	• Early land preparation • Early planting is required • Use commonly grown crop types/varieties	
Early	Normal	Above normal	• Early land preparation • Early planting • Use commonly grown crop types/varieties • Soil erosion could be a major problem- prepare for soil conservation practices ahead of time	• Early land preparation • Use commonly grown crop types/varieties • Early planting • Soil erosion is likely and prepare for soil conservation practices ahead of time	• Early land preparation • Use commonly grown crop types/varieties • Early planting • Soil erosion could be a possibility based on soil type • Water harvesting is beneficial	
Early	Normal	Below normal	• Early land preparation • Early planting • Medium maturing crop types/varieties • Consider water harvesting and storage for supplemental irrigation	• Early land preparation • Early planting • Grow early to medium maturing crop types/varieties • Prepare for water harvesting/storage structures for supplemental irrigation	• Early land preparation • Early planting • Grow early maturing crop varieties • Soil erosion could be a possibility based on soil type • Practicing water harvesting/storage structures and supplemental irrigation is required for successful crop harvest • Crop failure is likely if not irrigated	
Early	Long	Normal	• Early land preparation • Early planting	• Early land preparation • Early planting	• Early land preparation • Early planting	

			• Long maturing crop types/varieties	• Medium to late maturing crop types/varieties	• Medium maturing crop types/varieties • Water harvesting is beneficial	
Early	Long	Above normal	• Early land preparation • Early planting • |Late maturing crop types/varieties • Soil erosion could be a major problem- prepare for soil conservation practices ahead of time	• Early land preparation • Early planting • Late maturing crop types/varieties • Soil erosion is likely and prepare for soil conservation practices ahead of time	• Early land preparation • Early planting • Medium maturing crop types/varieties • Soil erosion could be a possibility based on soil type • Water harvesting may be required in some areas where rainfall distribution is poor	
Early	Long	Below normal	• Early land preparation • Early planting • Medium to late maturing crop types/varieties • Consider water harvesting and storage for supplemental irrigation	• Early land preparation • Early planting • Medium maturing crop types/varieties • Prepare for water harvesting/storage structures for supplemental irrigation	• Early land preparation • Early planting • Early maturing crop types/varieties with drought tolerant traits • Practicing water harvesting/storage structures and supplemental irrigation is required for successful crop harvest • Possibility of crop failure is likely	
Early	Short	Normal	• Early land preparation • Medium maturing crop types/varieties Early planting	• Early land preparation • Early maturing crop types/varieties Early planting	• Early land preparation • Very early maturing crop types/varieties Early planting Water harvesting is required	
Early	Short	Above normal	• Early land preparation • Medium maturing crop types/varietie	• Early land preparation • Medium maturing crop types/varieties • Early planting	• Early land preparation • Early maturing crop types/varieties • Early planting	

			s • Early planting • Soil erosion could be a major problem- prepare for soil conservation practices ahead of time	• Soil erosion is likely and prepare for soil conservation practices ahead of time	• Soil erosion could be a possibility based on soil type • Water harvesting may be required in some areas where rainfall distribution is poor	
Early	Short	Below normal	• Early land preparation • Medium maturing crop types/varieties • Early planting • Consider water harvesting and storage for supplemental irrigation	• Early land preparation • Early to medium maturing crop types/varieties • Early planting • Prepare for water harvesting/storage structures for supplemental irrigation	• Early land preparation • Very early maturing crop types/varieties • Early planting • Prepare for water harvesting/storage structures for supplemental irrigation	
Late	Normal	Normal	• Late land preparation • Use commonly grown crop types/varieties •	• Late land preparation • Use commonly grown crop types/varieties	• Late land preparation Early maturing crop types/varieties Water harvesting is beneficial	
Late	Normal	Above normal	• Late land preparation • Use commonly grown crop types/varieties • Soil erosion could be a major problem- prepare for soil conservation practices ahead of time	• Late land preparation • Use commonly grown crop types/varieties • Soil erosion is likely and prepare for soil conservation practices ahead of time	• Late land preparation • Earlyto medium maturing crop types/varieties • Soil erosion could be a possibility based on soil type Water harvesting may be required in some areas where rainfall distribution is poor	
Late	Normal	Below normal	• Late land preparation • Medium maturing crop types/varieties • Consider water harvesting and storage for supplemental irrigation	• Late land preparation • Early to medium maturing crop types/varieties • Prepare for water harvesting/storage structures for supplemental irrigation	• Late land preparation • Early maturing crop types/varieties • Practicing water harvesting/storage structures and supplemental irrigation is required for	

					successful crop harvest • Possibility of crop failure is likely distribution is poor	
Late	Long	Normal	• Late land preparation • Late planting • Use medium maturing crops/varieties	• Late land preparation • Late planting • Use medium maturing crops/varieties	• Late land preparation • Late planting • Grow early to medium maturing crops/varieties	
Late	Long	Above normal	• Late land preparation • Late planting • Use late maturing crops/varieties • Soil erosion could be a major problem- prepare for soil conservation practices ahead of time	• Late land preparation • Late planting • Use late maturing crops/varieties • Soil erosion is likely and prepare for soil conservation practices ahead of time	• Late land preparation • Late planting • Use of medium maturing crops/varieties is a must • Soil erosion could be a possibility based on soil type • Water harvesting may be required in some areas where rainfall distribution is poor	
Late	Long	Below normal	• Late land preparation • Late planting • Use medium to late maturing crops/varieties • Consider water harvesting and storage for supplemental irrigation	• Late land preparation • Late planting • Use medium maturing crops/varieties • Prepare for water harvesting/storage structures for supplemental irrigation	• Late land preparation • Late planting • Use early maturing crops/varieties Prepare for water harvesting/storage structures for supplemental irrigation	
Late	Short	Normal	• Late land preparation • Late planting Use early to medium maturing crops/varieties	• Late land preparation • Late planting Use early maturing crops/varieties	• Late land preparation • Late planting • Use of very early maturing crops/varieties is a must • Water harvesting is beneficial	
Late	Short	Above normal	Late land preparation Late planting Use early to medium short	Late land preparation Late planting Use early maturing crops/varieties	Late land preparation Late planting Use of very early maturing	

			maturing crops/varieties Soil erosion could be a major problem- prepare for soil conservation practices ahead of time	Soil erosion is likely and prepare for soil conservation practices ahead of time	crops/varieties is a must Soil erosion could be a possibility based on soil type Water harvesting may be required in some areas where rainfall distribution is poor	
Late	Short	Below normal	• Late land preparation • Late planting • Use early maturing crops/varieties • Consider water harvesting and storage for supplemental irrigation	• Late land preparation • Late planting Use very early to early maturing crops/varieties • Prepare for water harvesting/storage structures for supplemental irrigation	• Late land preparation • Grow very early maturing crop types/varieties • Practicing water harvesting/storage structures and supplemental irrigation is required for successful crop harvest • Possibility of crop failure is likely distribution is poor	

Table 1: Possible crop management decisions based on in-season climate information, Agro-ecology and Soil water holding capacity

Weekly rainfall forecast	**Soil water holding capacity**	**Decision implication based on Agro-ecology**			**Remark**
		Dega	**Weyena-dega**	**Kola**	
No-rain (dry)	Low (Sandy soil)	Normal crop growth expected	Drought sensitive crops may need attention (supplementary irrigation could be consider)	Crops may be affected by water stress ✓ Apply supplementary irrigation ✓ Mulching ✓ Consider thinning	If consecutive weeks are dry crops could be affected by water stress and decisions
	Medium(Loam soil)	Normal crop growth expected	Normal crop growth expected but drought sensitive crops may need attention	Crops may be affected by water stress ✓ Apply supplementary irrigation or consider other evaporation reducing measures	
	High (Clay soil)	Normal crop growth expected	Normal crop growth	Normal crop growth expected but drought	

				sensitive crops may need attention	should consider cumulative effects of weekly forecasts
Light rain	Low (Sandy soil)	Normal crop growth expected ✓ Apply recommended fertilizer rates,	Normal crop growth	Normal crop growth expected but drought sensitive crops may need attention	
	Medium(Loam soil)	Normal crop growth expected ✓ Apply recommended fertilizer rates, ✓ Practice weeding and other cultivation normally	Normal crop growth expected ✓ Apply recommended fertilizer rates,	✓ Drought sensitive crops may need attention (supplementary irrigation could be consider)	
	High (Clay soil)	Normal crop growth expected Water logging problem is likely	Normal crop growth expected ✓ Apply recommended fertilizer rates,	Normal crop growth expected but drought sensitive crops may need attention	
Heavy rain	Low (Sandy soil)	Normal crop growth expected ✓ Apply recommended crop management practices ✓ Expect nutrient leaching ✓ Soil erosion is more likely (take conservation measures)	Normal crop growth expected ✓ Apply recommended fertilizer rates ✓ Soil erosion is likely (take conservation measures)	Normal crop growth expected ✓ Apply recommended crop management practices	
	Medium(Loam soil)	Normal crop growth expected ✓ Apply recommended crop management practices ✓ Expect some waterlogged conditions ✓ Soil erosion is	Normal crop growth expected ✓ Apply recommended fertilizer rates ✓ Soil erosion is more likely (take conservation measures)	Normal crop growth expected ✓ Apply recommended crop management practices	

		likely (take conservation measures)			
	High (Clay soil)	Crops may be affected by water logged conditions ✓ Apply soil water drainage practices (e.g., BBM, BBF) ✓ Don’t apply fertilizers ✓ Soil erosion is highly likely (take conservation measures)	Normal crop crop growth expected but there could be water logged conditions for sensitive crops ✓ Consider drainage measures	Normal crop growth expected ✓ Apply recommended crop management practices ✓ Soil erosion is likely in some pocket areas	

Table 3: Possible crop harvest decisions based on harvest period climate extreme information

Climate extremes, pest and disease forecasts	**Decision implication based on Agro-ecology**			**Remark**
	Dega	**Weyena-dega**	**Kola**	
unexpected heavy rain, strong wind, hailstorm and flood	Ready for early harvest, be aware of possibilities of wind and water erosion	Ready for early harvest, be aware of possibilities of wind and water erosion	Ready for early harvest, be aware of possibilities of wind and water erosion	Early harvested crops may develop molds and wastage would be high and hence daily follow up is required to make sure that acceptable drying after harvest
unusual pest and disease outbreak	Early harvest, prepare for crop protection measures	Early harvest, prepare for crop protection measures	Early harvest, prepare for crop protection measures	
No climate extreme problem	Proper time for effective crop harvest			

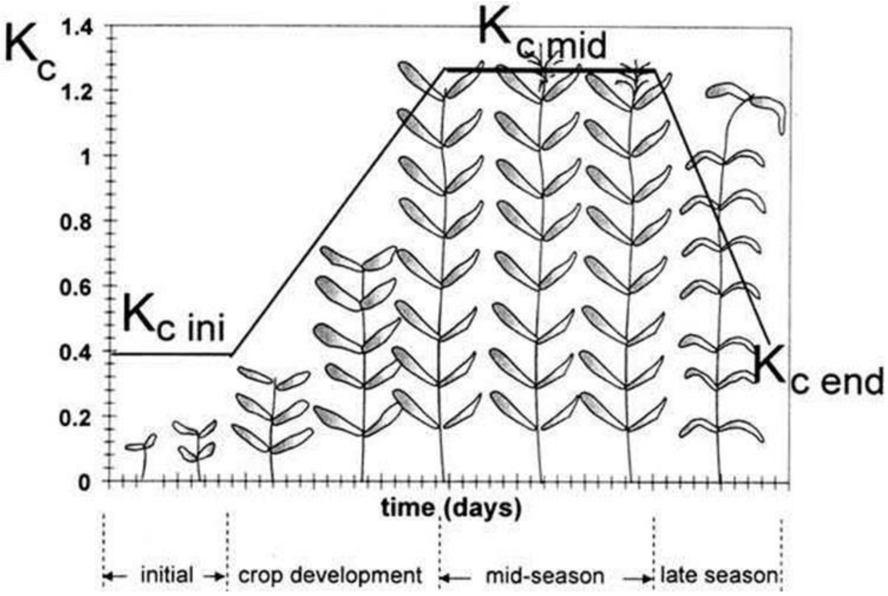
Annexes

Annex 1: Average daily water requirement of a standard grass (reference evapotranspiration)

Climatic Zone	Mean Daily Temperature		
	Low (<15 °C)	Medium (15-25° C)	High (>25° C)
Desert/arid	4-6	7-8	9-10
Semi-arid	4-5	6-7	8-9
Sub-humid	3-4	5-6	7-8
Humid	1-2	3-4	5-6

Source: Irrigation water management training manual no. 3 (FAO 1986)

Annex 2: Kc Curve



Source: Irrigation water management training manual no. 3 (FAO 1986)

Annex 3: Indicative duration of growth stages for various crops and crop factor (Kc)

Crop	Total Growing Period (days)	Initial stage		Crop Development stage		Mid-season stage		Late season stage	
		Days	Kc	Days	Kc	Days	Kc	Days	Kc
Banana (tropical)	390	120	0.5	90	0.85	120	1.1	60	0.85
Barley/Oats/Wheat	120-150	15	0.35	25-30	0.75	50-65	1.15	30-40	0.45
Bean/green	75-90	15-20	0.35	25-30	0.7	25-30	1.1	10	0.9
Bean/dry	95-110	15-20	0.35	25-30	0.7	35-40	1.1	20	0.3
Cabbage	120-140	20-25	0.45	25-30	0.75	60-65	1.05	15-20	0.9
Carrot	100-150	20-25	0.45	30-35	0.75	30-70	1.15	20	0.75
Cotton/Flax	180-195	30	0.45	50	0.7	55-65	0.9	45-50	0.75
Cucumber	105-130	20-25	0.45	30-35	0.75	40-50	1.15	15-20	0.8
Eggplant	130-140	30	0.35	40	0.75	40-45	1.1	20-25	0.65
Grain/small	150-165	20-25	0.45	30-35	0.75	60-65	1.1	40	0.5
Groundnut	50-100	20-25	0.45	35	0.75	50	1	20	0.4
Lentil	150-170	20-25	0.45	30-35	0.6	60-70	1	40	0.9
Lettuce	75-140	20-35	0.4	30-50	0.8	15-45	1.15	10	1
Maize, sweet	80-110	20	0.4	25-30	0.8	25-50	1.15	10	0.7
Maize, grain	125-180	20-30	0.45	35-50	0.75	40-60	1	30-40	0.75
Melon	120-160	25-30	0.35	35-45	0.7	40-65	1.1	20	0.65
Millet	105-140	15-20	0.5	25-30	0.7	40-55	1	25-35	1
Onion/green	70-95	25	0.5	30-40	0.75	10-20	1.05	5-10	0.85
Onion/dry	150-210	15-20	0.45	25-35	0.75	70-110	1.05	40-45	0.7
Peanut/Groundnut	130-140	25-30	0.45	35-40	0.8	45	1.15	25	1.05
Pea	90-100	15-20	0.35	25-30	0.7	35	1.05	15	0.9
Pepper	120-210	25-30	0.45	35-40	0.75	40-110	1.15	20-30	0.85
Potato	105-145	25-30	0.45	30-35	0.6	30-50	0.9	20-30	0.9
Radish	35-40	5-10	0.35	10	0.75	15	1.1	5	0.65
Sorghum	120-130	20	0.35	30-35	0.75	40-45	1.1	30	0.6
Soybean	135-150	20	0.45	30	0.8	60-70	1.15	25-30	0.8
Spinach	60-100	20	0.35	20-30	0.75	15-40	1.15	5-10	0.55
Squash	95-120	20-25	0.35	30-35	0.75	30-35	1.1	15-25	0.45
Sugarbeet	160-230	25-45	0.35	35-65	0.75	60-80	1.15	40	0.9
Sunflower	125-130	20-25	0.35	35	0.7	45	1.1	25	0.3
Tomato	135-180	30-35	0.35	40-45	0.7	40-70	1.1	25-30	0.9

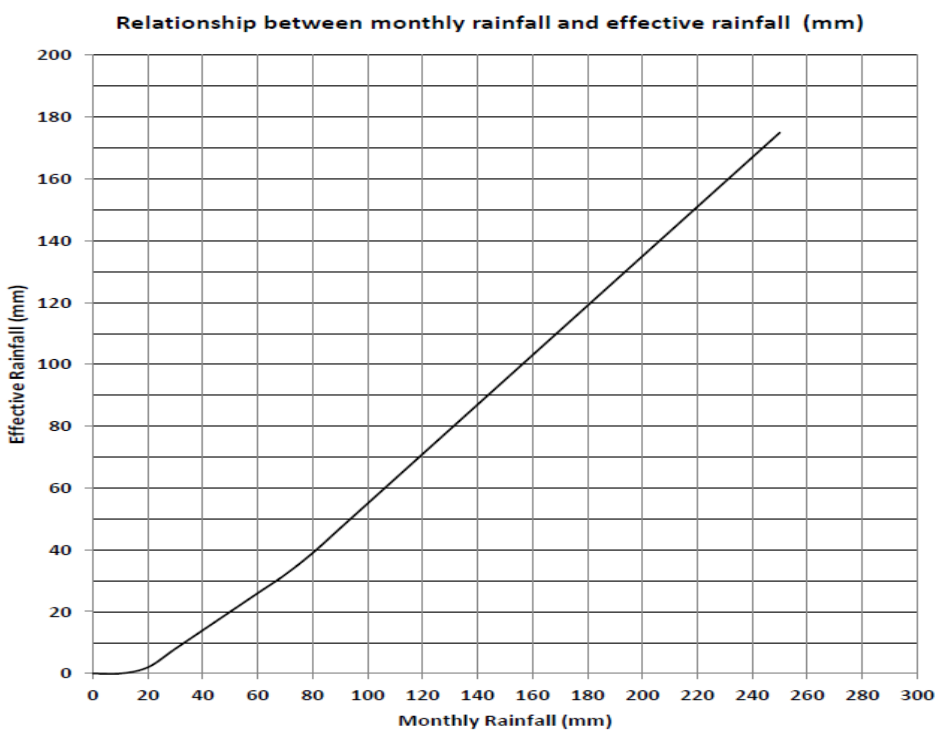
Source: Irrigation water management training manual No. 3 (FAO 1986)

Note

1. The table always refers to "sown" crops. When the crop is transplanted, the length of the initial stage should be reduced.
2. When a crop is harvested "green" or "fresh" the late season stage is shorter
3. The table above shows average Kc values for the various crops and growth stages. In fact, the Kc is also dependent on the climate and, in particular, on the relative humidity and the windspeed. The values indicated above should be reduced by 0.05 if the relative humidity is high (RH > 80%)

and the windspeed is low (u < 2 m/sec), e.g. Kc = 1.15 becomes Kc = 1.10. The values should be increased by 0.05 if the relative humidity is low (RH < 50%) and the windspeed is high (u > 5 m/sec), e.g. Kc = 1.05 becomes Kc = 1.10.

Annex 4: Monthly rainfall and effective rainfall



Monthly Rainfall (mm)	Effective Rainfall (mm)
0	0
10	0
20	2
30	8
40	14
50	20
60	26
70	32
80	39
90	47
100	55
110	63
120	71
130	79
140	87
150	95
160	103
170	111
180	119
190	127
200	135
210	143
220	151
230	159
240	167
250	175

Graph prepared from data source: Training manual onagricultural water management (IWMI, 2009)

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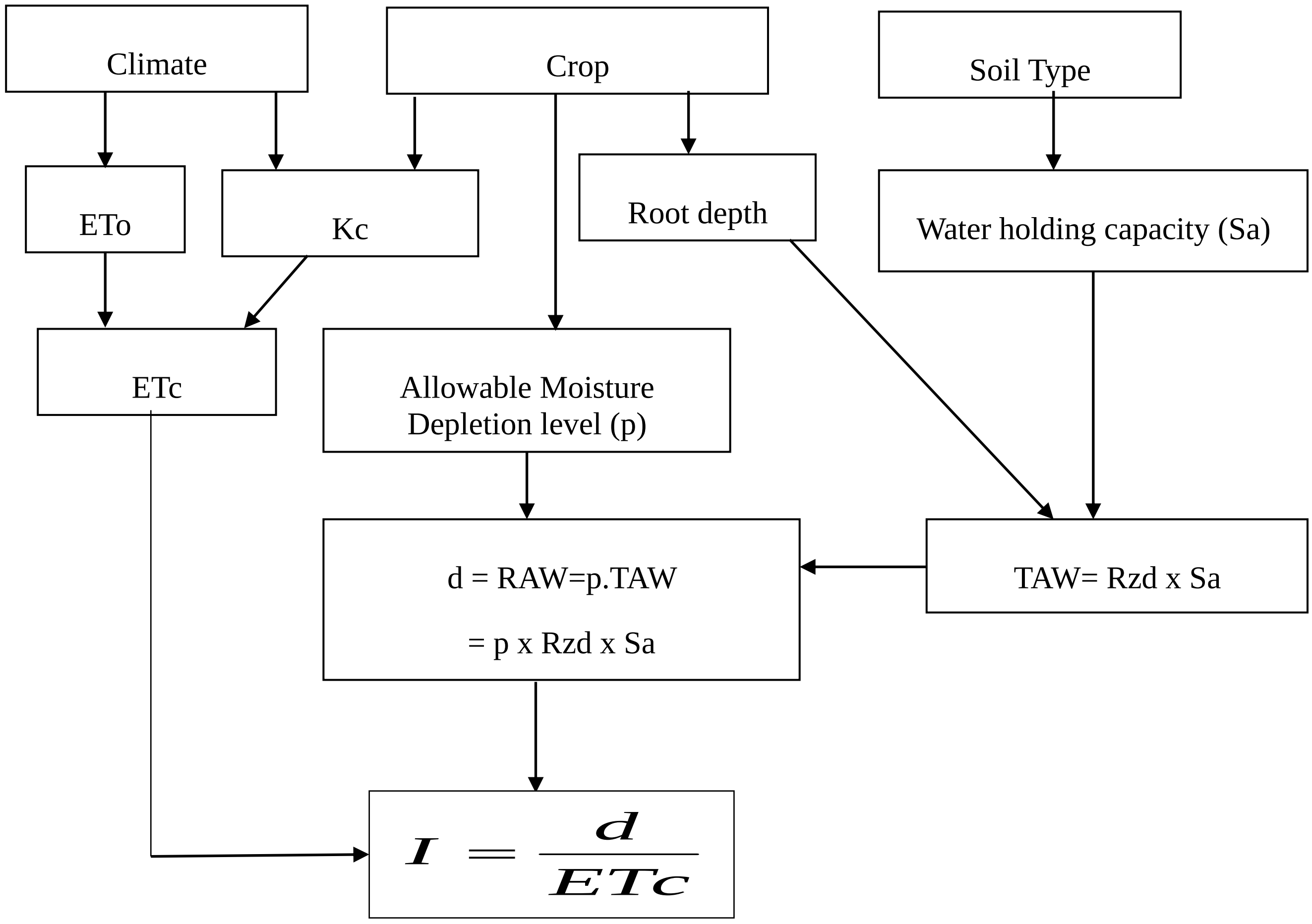
Annex 5: Steps for Calculating Irrigation Interval



Annex 6: Rooting depth, soil water holding capacity and readily available water

Crop	Root depth (m)	Management allowable depletion level (p[1])	Readily Available soil water (mm/m)		
			Clay	Loam	Sand
Alfalfa	1.0-2.0	0.55	110	75	35
Banana[2]	0.5-0.9	0.35	70	50	20
Barley	1.0-1.5	0.55	110	75	35
Beans[2]	0.5-0.7	0.45	90	65	30
Cabbage	0.4-0.5	0.45	90	65	30
Carrot	0.5-1.0	0.55	70	50	20
Citrus	1.2-1.5	0.50	100	70	30
Cotton	1.0-1.7	0.65	130	90	40
Cucumber	0.7-1.2	0.50	100	70	30
Dates	1.5-2.5	0.50	100	70	30
Flax2	1.0-1.5	0.50	100	70	30
Grapes	1.0-2.0	0.35	70	50	20
Grass	0.5-1.5	0.50	100	70	30
Groundnut	0.5-1.0	0.40	80	55	25
Lettuce	0.3-0.5	0.30	60	40	20
Maize[2]	1.0-1.7	0.60	120	80	30
Melons	1.0-1.5	0.35	70	50	25
Onion	0.3-0.5	0.25	50	35	15
Peas	0.5-1.0	0.35	70	50	25
Pepper	0.5-1.0	0.25	50	35	15
Pineapple	0.4-0.6	0.50	100	65	30
Potato	0.4-0.6	0.25	50	30	15
Safflower[2]	1.0-2.0	0.60	10	80	40
Sorghum	1.0-2.0	0.55	110	75	35
Soybeans	0.6-1.3	0.50	100	75	35
Spinach	0.3-0.5	0.20	40	30	15
Sugarcane[2]	1.2-2.0	0.65	130	90	40
Sunflower[2]	1.0-1.5	0.45	90	60	30
Sweet potato	1.0-1.5	0.65	130	90	40
Tomato	0.7-1.5	0.40	180	60	25
Vegetables	0.3-0.6	0.20	40	30	15
Wheat	1.0-15	0.55	105	70	35

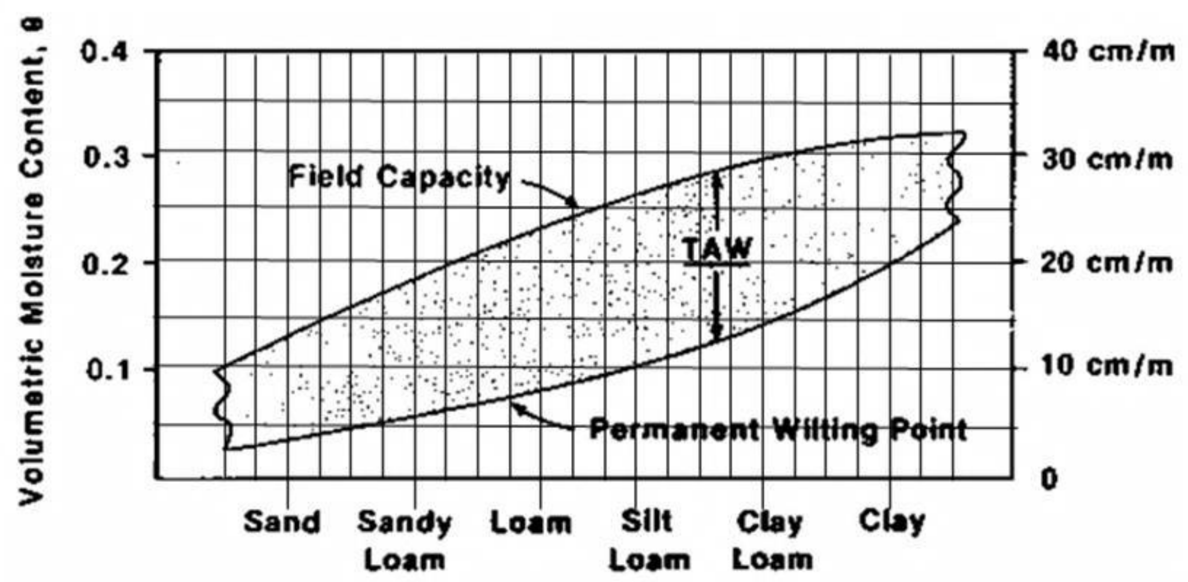
1. When ETc is 3 mm/day or smaller, increase the values by some 30%; when ETc is 8 mm/day or more, reduce the values by some 30%., assuming non-saline condition
2. Higher values than those shown can apply during ripening.

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

Annex 7: Water Holding Capacity of Selected Soil Texture

		Water holding capacity	
Soil Type	**Soil Texture**	**(mm/m)**	**%**
Heavy	Clay	120-200	12-20
	Silty clay	130-190	13-19
	Silty clay loam	130-180	13-18
Medium	Silty loam	130-190	13-19
	Loam	130-180	13-18
	Sandy loam	110-150	11-15
Light	Loamy sand	60-120	6-12
	Sand	50-110	5-11

Source: Field Guide on Irrigated Agriculture for Field Assistants, IPTRID (FAO), Report No.1, April 2001



Source: Guidelines for designing and evaluating surface irrigation systems FAO (1989); gridlines are added to simplify reading from the curve

Annex 8: Crop Sensitive Period

Crop	**Sensitive period**
Alfalfa	Just after cutting
Alfalfa (for seed prod.)	Flowering
Banana	Throughout
Bean	Flowering and pod filling
Cabbage	Head enlargement and ripening
Citrus	Flowering and fruit setting more than fruit enlargement
Cotton	Flowering and boll formation
Grape	Vegetative period and flowering more than fruit filling
Groundnut	Flowering and pod setting
Maize	Flowering and grain filling
Olive	Just prior to flowering and yield formation
Onion	Bulb enlargement
Onion (for seed prod.)	Flowering
Pea/fresh	Flowering and yield formation
Pea/dry	Ripening
Pepper	Throughout
Pineapple	Vegetative period
Potato	Stolonization and tuber initiation
Rice	Head development and flowering
Sorghum	Flowering and yield formation
Soybean	Flowering and yield formation
Sugarcane	Vegetative period (tillering and stem elongation)
Sunflower	Flowering more than yield formation
Tomato	Flowering more than yield formation
Wheat	Flowering more than yield formation

Source: Irrigation Water Management: Training Manual 4 (FAO, 1989)

Annex 9: Guide for judging the amount of available moisture in soil

Depletion of available soil moisture (%)	**Coarse/light Textured-soil**	**Moderately coarse Textured-soil**	**Medium Textured-soil**	**Fine Textured /Heavy soil**
0 (Field Capacity)	On squeezing, no free water appears on the soil ball but a wet outline is left on the hand	On squeezing, no free water appears on the soil ball but a wet outline is left on the hand		
0-25	Tends to stick together slightly and may form a weak ball under pressure	Forms a weak ball that easily breaks	Forms a ball and soil is pliable. Feels slippery if clay content is high	Easily rolls out into a ribbon
25-50	Feels dry and will not form a ball even under pressure	Will form a ball under pressure but it will not hold together	Will form a mouldable ball	Will form a ball and can be rolled into a ribbon
50-75	Feels dry and will not form a ball even under pressure	Feels dry and will not form a ball even under pressure	Somewhat crumbly but will hold together under pressure	Can be moulded and will form a ball under pressure
75-100	Dry, loose, soil grains run through fingers	Dry, easily crumbs through fingers	Powdery, dry, may be slightly crusted but easily powdered	Hard, baked and cracked with loose crumbs on surface

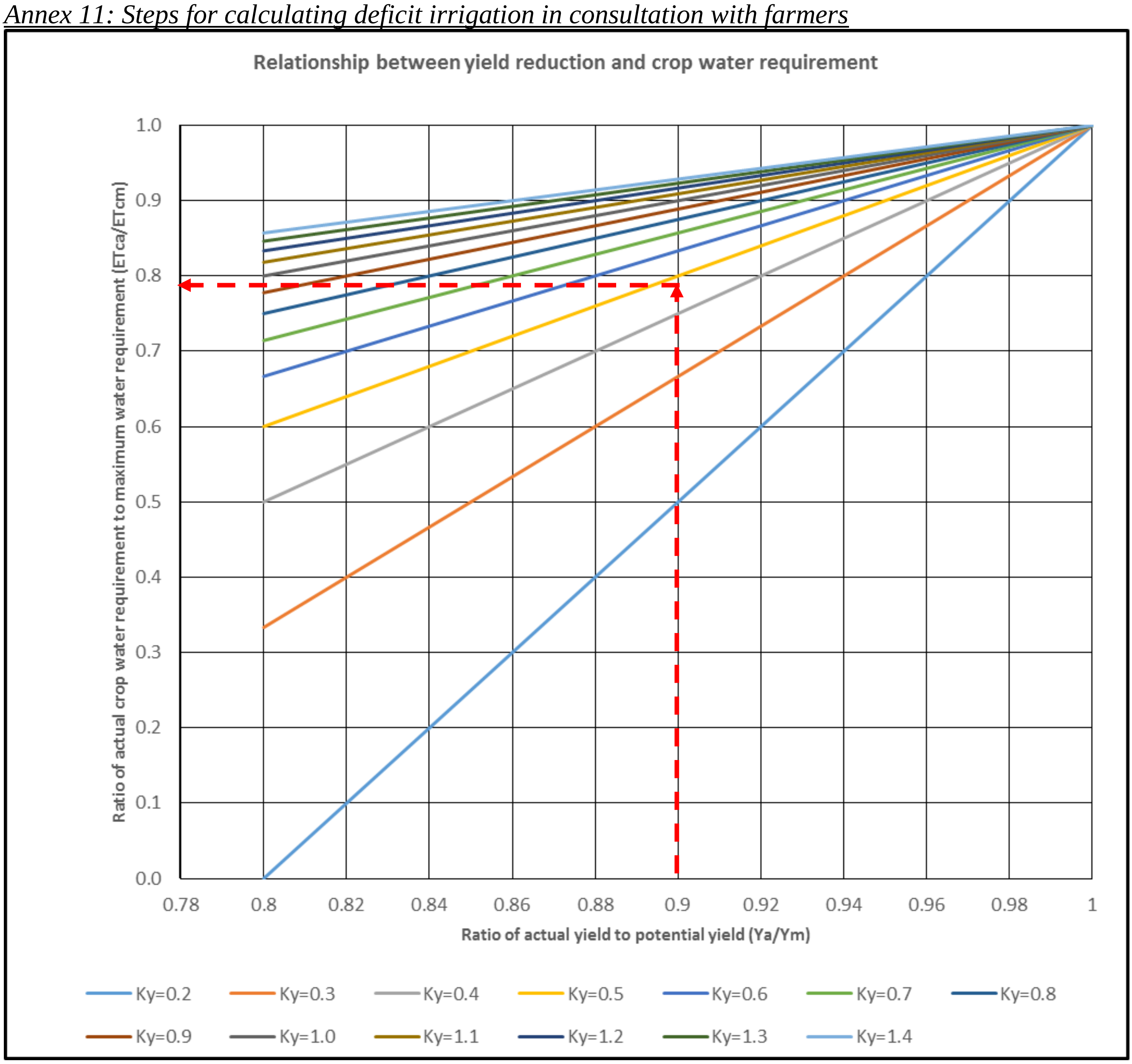
Source: Field Guide on Irrigated Agriculture for Field Assistants, IPTRID (FAO), Report No.1, April 2001

Annex 10: Annual/Seasonal Yield Response factor to water stress values (Ky) for crops

Crop	Avg. K_y	Growth periods				Crop	Ky	Growth periods			
		Initial	Vegetative	Mid-season	Late season			Initial	Vegetative	Mid-season	Late season
Alfalfa	1.1	1.1	1.1			Potato	1.1	0.6	0.33	0.7	0.2
Beans	1.2-1.35	0.2	1.1	0.75	0.2	Sorghum	0.9	0.2	0.55	0.45	0.2
Cabbage	0.95	0.2		0.45	0.6	Soybean	0.85	0.2	0.8	1.0	
Citrus	1.1-1.3					Wheat	1.15	0.2	0.65	0.55	0.25
Cotton	0.85	0.2	0.5	0.05		Sugar beet	1				
Grape	0.85					Sugarcane	1.2	0.75	1.2	0.5	0.1
Maize	1.25	0.4	1.5	0.5	0.2	Sunflower	0.95	0.4	1.0	0.8	
Onion	1.1	0.2	0.45	0.8	0.3	Tomato	1.05	0.4	0.4	1.1	0.8/0.4
Peas	1.15	0.2		0.9	0.7/0.2	Watermelon	1.1	0.45	0.7	0.8	0.3
Pepper	1.1					Potato	1.1	0.45	0.8	0.7	0.2

Source: FAO, 1998

Annex 11: Steps for calculating deficit irrigation in consultation with farmers



Annex 11: CSA Indicator

Input	Activities	output	Midterm outcomes	outcomes	Impacts and long term goals

ANNEX 12 – The Basket of Options Methodology

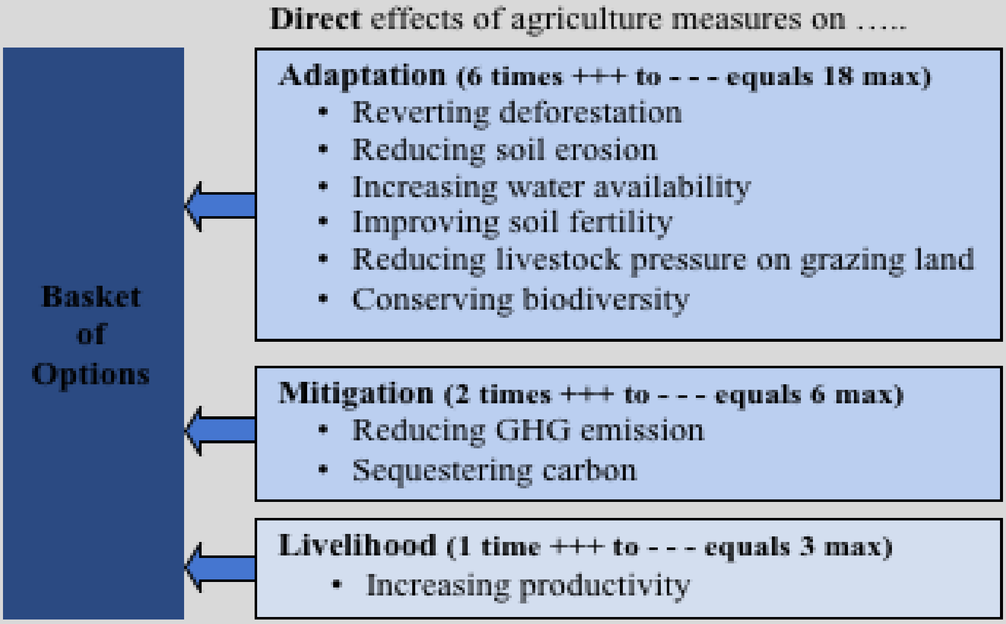
The Basket of Options (BoO)methodology can be used to conduct an assessment of the climate smartness of practices recommended in the infotechs, and subsequently as part of the training to be provided to CSA practitioners and advisors. Secondly, the DA can use the BoO to provide examplesof climate-smartness of interventions.In addition, the methodology of scoring points to individual practicescan be used as a selection tool to identify suitable CSA interventions or packages

Box: Basket of Options (BoO) for classifying climate-smartness of CSA activities

The BoO classifies agricultural interventions or practices and scores them according to their adaptation, mitigation and livelihood enhancement potentials. The interventions are grouped into 4 major land use types of the typical watershed and one livestock group. The following table gives an overview of the BoO matrix.

Measures by land-use type/livestock	**Adaptation**	**Mitigation**	**Livelihood**	**M&E**	**Remarks**
Degraded hillsides	Score and justification		Score and justification		
Farmland		Score and justification			
Homesteads	Score and justification		Score and justification		
Grazing land		Score and justification			
Livestock	Score and justification		Score and justification		

As one score for adaptation and mitigation cannot be easily attributed six and two sub-parameters respectively were introduced to describe the complexity of direct effects. These sub-parameters help to describe the **direct** effects of an intervention on the three components of CSA. The different sub-parameters are as follows.



Each intervention is being scored for each sub-parameter with a score ranging from -3 to +3 (or - - - ….. 0 ….. +++). The scores of the 6 adaptation sub-parameters, 2 mitigation sub-parameters and 1 livelihood sub-parameter together make the total score of climate-smartness. The total CSA rating being the summary of all 9 sub-parameter ratings automatically gives a very strong focus on adaptation because the adaptation component is made up of 6 sub-parameters compared to two and one sub-parameter for mitigation and livelihood respectively.

The different sub-parameters also allow focussing on interventions with maximum effects on mitigation for example by selecting respective activities from the BoO with the highest mitigation rating.

Thereafter the maximum score in the BoO for each intervention for adaptation, mitigation and livelihood is 6x3=18, 2x3=6 and 1x3=3 respectively; totalling to a **maximum climate-smart score of** 18+6+3=**27**

The following table presents the climate-smart scores for some single interventions on farmland. The table also proposes whether the intervention should be implemented in testing/demonstration mode or in the upscaling mode (to be updated).

Table - Selected interventions and their ratings by order of total rating

Direct effects on →	**Adaptation**							**Mitigation**			**Livelihood**		**CSA**
Measures by land use type	**Forest degradation**	**Soil degradation**	**Water availability**	**Soil fertility**	**Livestock pressure**	**Biodiversity**	**Subtotal**	**Reducing emission**	**Storing carbon**	**Subtotal**	**Increasing productivity**	**Subtotal**	**Total rating**
Farm land													
Agroforestry	NDR	++	++	++	+	+	8	++	++	4	++	2	**14**
Applying compost	NDR	++	++	+++	NDR	++	9	--	++	0	++	2	**11**
Mulching	NDR	++	+++	+	NDR	+	7	+	+	2	+	1	**10**
Forage production	NDR	+	+	+	++	+	6	+	+	2	+	1	**9**
Conservation Agriculture	NDR	++	+	++	+	+	7	+	0	1	+	1	**9**
Intercropping	NDR	++	++	+	NDR	+	6	NDR	NDR	0	++	2	**8**
Green manuring	NDR	+	++	++	NDR	+	6	0	+	1	+	1	**8**
Using bio-fertilizer	NDR	NDR	NDR	+++	NDR	+	4	+	NDR	1	++	2	**7**
Applying lime on acidic soils	NDR	+	+	+++	NDR	+	7	-	NDR	-1	+	1	**7**
Crop residue management	NDR	++	+	+	-	+	4	+	+	2	+	1	**7**
Crop rotation	NDR	+	+	+	NDR	+	4	NDR	NDR	0	++	2	**6**
Planting with space/row planting	NDR	+	+	0	NDR	0	2	NDR	NDR	0	++	2	**4**
Changing crop varieties	NDR	0	NDR	+	NDR	-	0	0	0	0	++	2	**2**

Note: (NDR=No Direct Relation)

The scoring of CSA interventions in the BoO has been done on the basis of single interventions. As a single intervention often doesn't include a triple win due to trade-offs between the CSA elements, a high degree of climate-smartness can be achieved by combining different single measures. For example, the rating of conservation agriculture is composed of the three single measures by which it is defined, that are minimum tillage, mulching and crop rotation. Combining single measures meaningfully can increase the degree of climate-smartness of interventions and helps to work towards climate-smart watersheds. Therefore, in order to overcome trade-offs between the three components within a single measure DAs should facilitate the planning to identify combination of measures within a land use type.

Each score in the BoO is underpinned with a justification. These justifications are very important to understand and possibly review the scores. The scores are most meaningful if an intervention is precisely defined, for example row planting compared to ISFM which entails a great number of activities with different degree of climate-smartness. While the scale effect is partially considered in the score, for example planting trees on degraded hill sides is stronger than planting few trees around the homestead, the time effect is normally not considered in the score. For example, the climate effects of planting trees occur usually much later than applying compost on the farm land. The following table is the example for justifications of the scores for applying compost on farmland.

Table 3 - Example of rating climate-smart measures and their justifications

Criteria	Direct effectson	Applying compost	
		Rating	**Justification**
Adaptation	Forest degradation	NDR	No Direct Relation
	Soil degradation	++	the organic matter soil nutrients are better maintained
	Water availability	++	enhances water holding capacity through improved soil structure
	Soil fertility	+++	adds soil organic matter (SOM)
	Livestock pressure	NDR	No Direct Relation
	Biodiversity	++	maintains & improves soil biota
	Subtotal	**9**	
Mitigation	Reducing emission	**- -**	increases GHG emissions if exposed
	Storing carbon	++	the absorption of compost directly increases soil organic matter
	Subtotal	**0**	
Productivity	Increasing productivity	++	directly increases crop yield depending on compost quality and amount applied
	Subtotal	**2**	
CSA	Total rating	**11**	

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