Preventing Forest Loss, Promoting Restoration and Integrating Sustainability into Ethiopia's Coffee Value Chains and Food Systems (FOLUR Ethiopia)

Climate Smart Natural Resources Management:
A Training Manual

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Abbreviations

CSF	Climate Smart Forestry
CSA	Climate Smart Agriculture
COP	Conferences of Parties
CRGE	Climate Resilient Green Economy
DA	Development Agent
GDP	Gross Domestic Product
GHG	Green House Gases
GoE	Government of Ethiopia
GTP	Growth and Transformation Plan
FAO	Food and Agricultural Organization
IK	Indigenous knowledge
IWRM	Integrated Water Resources Management
LT-LEDS	Long-Term Low Emission and Climate Resilient Development Strategy
MEFCC	Ministry of Environment Forest and Climate Change
MOA	Ministry of Agriculture
Mt CO2	Metric Tons of Carbon di Oxide
NAP	National Adaptation Plan
NFCS	National Framework for Climate Services
PFM	Participatory Forest Management
REDD	Reducing Emission from Deforestation and Forest Degradation
SCBD	Secretariat of the Convention on Biological Diversity
TVET	Technical Vocational and Education and Training

Objectives of the Manual

The general objective of this module is to familiarize Development Agents (DA) and practitioners with the application of climate-smart natural resource management within this changing climate and environmental resources so that they will able to apply in their local contexts. The specific objectives of the module include:

i To acquaint DAs and practitioners about concept and importance of climate smart natural resource management.

ii To ensure that DAs and practitioners acquire practical skills on physical soil and water conservation, water resource management, climate smart forestry and biodiversity conservation.

iii To enable DAs and practitioners to link them with the existing climate smart natural resource management related polices, case studies and best practices to scale them up to their operational contexts.

iv To dig on the existing indigenous knowledge regarding climate smart natural resource management so that DAs and practitioners will apply such knowledge to their working areas.

1 Introduction

The earth is bestowed with so much diversity in myriad forms of resources, which are important for our very existence. These resources are either in renewable or non-renewable forms. Renewable natural resources are those that can be replenished overtime, either through natural processes or through human interventions. Renewable resources include solar energy, wind energy, hydro power, timber, and fisheries. These kinds of resources could be restocked and could be used again and again over times. While the non-renewable natural resources, on the other hand, are finite and cannot be replenished once they are depleted and used. These resources could include fossil fuels (coal, oil and natural gas), minerals (iron, copper and gold), among others [Meier, 2020].

Natural resources are important for economic development and human well-being. They provide raw materials for industry, fuel for energy production, food for sustenance and are sources of timber, medicine and fiber. They also provide supporting functions, such as flood control, climate regulation, nutrient cycling, resilience to disturbance and environmental change, source of pollinators and pest control in agriculture, carbon storage and sequestration, economic, recreational, human health benefits and social contributions [Paul and Weinthal, 2019].

However, the exploitation of natural resources has negative impacts on the environment and local communities. Over-exploitation can lead to the depletion of resources, environmental degradation and conflicts over access and use of resources. As the population of the world is increasing at an alarming rate, the consumption of natural resources has also been increasing; and over-exploitation of these natural resources by growing population resulted in various severe problems such as land degradation, denudation, soil erosion, landslides, floods, drought, climate change and unbalanced ecosystems.

For developing countries like Ethiopia, where majority of the population depend on rain fed agriculture and natural resource, the consequences of over-exploitation and unwise utilization could result in more devastating and sustainability of these resources for the next generation could be questionable. Therefore, it is important to manage these natural resources to ensure their long-term availability and benefits for human health, food security and economic development as well as to the national and global security.

Like most developing countries, agriculture related sub-sectors in Ethiopia have the greatest share of Gross Domestic Product (GDP) and relatively have large share of Green House Gas (GHG) emissions. It is stated in the [Paul and Weinthal, 2019] that, the annual emission of GHGs (data 2010) in Ethiopia was 150 Mt CO2 equivalents and the agriculture sector represents an estimated 50 percent of total emissions followed by deforestation and forest degradation with (37 percent). The same document indicated that the emission from Ethiopia was less than 0.3 percent; and this was very insignificant compared to the global annual emission of other developed countries of the same year. However, as the impacts of climate change is global and its severity is high in developing countries, Ethiopia gave attention to climate change.

Since 2011, the Ethiopian government is addressing climate change through refining and developing polices and strategies that could reduce the impacts of climate change. For example, according to its CRGE strategy, Ethiopia intends to protect its economic development from the adverse impacts of climate change (resilience) in one hand and limit its net GHG emissions by 64 percent in 2030 as compared to a projected "business-as-usual" scenario on the other (carbon neutral or green development).

The Ethiopian forestry sector (one of the leading sectors in natural resources management) is argued to have the highest contribution of GHG emissions due to deforestation in one hand and carries the highest abatement potential through conservation and restoration on the other.

2 Climate Smart Natural Resource Management concepts and Practices

Climate change and food and nutrition insecurity pose two of the greatest development challenges of our time. Natural resources and their management form a critical interface between climate change and development. The impacts of climate change can affect the quality and reliability of many of the services natural resources provide. On the other hand, natural resources (specially the forests) play important roles in sequestration as well as absorption of greenhouse serve as a first line of defense against climate change.

Addressing growing threats by climate change requires fundamental shift in the practices of natural resource management. The historic restoration of natural resource through the "business as usual" is highly unlikely to be a viable and sustainable approach in the face of climate change. A range of climate smart natural resource management activities, over extended timescales and geographic scope, should therefore be practiced to ensure sustainable economic, social and ecological outcomes.

Being "climate-smart" is "the intentional and deliberate consideration of climate change in natural resource management, realized through adopting forward-looking goals and explicitly linking strategies to key climate impacts and vulnerabilities. That is intentionally making a transition from a paradigm of protection and restoration (resisting change) to one that anticipates and actively manages for uncertain yet plausible future conditions.

Integrating biological and physical soil and water management action in agricultural production systems and agroforestry are also integral components of climate smart natural resources management. Mainstreaming of these practices into agriculture and other economic sectors in the lens of climate change are considered as climate smart natural resources management.

2.1 Climate services for natural resources management

2.1.1 Climate service in forest management

Among the natural resources of Ethiopia, forests cover resource has a lot of uses, which provides ecosystem services like carbon sequestration, soil conservation, and wildlife habitat. This resource has been threatened by climate change and adverse weather conditions. For instance, the rising global temperatures make all kinds of extreme weather events more likely, leading to more extreme droughts, with drier forests that are more susceptible to wildfires. To handle the forest wildfire damage, early climate service needs to enable forest management.

Climate change has been a key factor in increasing the risk and extent of wildfires in Ethiopia. Wildfire risk depends on a number of factors, including temperature, soil moisture, and the presence of trees, shrubs, and other potential fuel. All these factors have strong direct or indirect ties to climate variability and climate change. Research shows that changes in climate create warmer, drier conditions. Increased drought and a longer fire season are boosting these increases in wildfire risk.

Wildfire in Ethiopia has been occurring in the driest seasons, which are during the end of Bega and the beginning of the Belg seasons' months. In those months, climatic elements determine the wildfire: rainfall (absence), temperature (rising), relative humidity (lowest), and wind (windy).

Rainfall is one of the elements of weather used to predict fire occurrences. If the length of the dry season extends, it is usually short and rainy in the lowland areas of forest areas in Ethiopia. The study of temperature characteristics during the dry season indicates that temperatures as high as their normal affect the drying factor of plants, soils, and animals. It affects the evapotranspiration process; it also speeds up the rate at which dry combustible plant matter is made available for ignition. Relative humidity generally follows the rainfall pattern: it is usually high during the rainy season and low during the dry period. Windy air conditions will speed up and indicate the direction of the wildfire's movement.

Climate service is necessary to manage forest resources affected by human and wildfire. Short- to long-term action plans, as well as a policy of using climate service for forest management, are essential.

2.1.2 Climate service in land use management

The other natural resource of Ethiopia is a large area of fertile land in the highlands, midlands, and lowlands, which are suitable for agriculture. Natural and human-induced factors (existences of poorly consolidated, easily erodible, saturated, and soft earth materials; high slope gradients; intensive or continuous precipitations with subsequent flooding and erosion; scarcity or absence of vegetation cover in sloppy terrains; ground vibrations or seismicity; and continuous growth of population with poor land-use practices) are among the key causes that exposed the country to land use problems and landslide risks. Risks associated with landslide are mainly influenced by heavy rainfall. Events that have been occurring in Ethiopia are evidence that they occurred during the highest rainy seasons. Most of the slides consequences are after frequent heavy rainfalls.

Undertaking landslide risk assessments therefore remains to be important to identify and prioritize areas based on their extent, frequency of occurrences, the severity of consequences, as well as the nature of different elements exposed to risk. Climate services have greater roles in this regard. For example, landslides caused by heavy rains in recent times have triggered successive landslides in the remote mountainous Gezei Gofa Woreda of the Gofa Zone in the Southern Ethiopian Region, causing significant loss of life and properly damages. The region's topography and vulnerability to extreme weather make it prone to floods and landslides [Ayele et al.,].

2.1.3 Climate service in water resource management

Water resources of Ethiopia are available as rivers, gorges, ground, and lakes, which are used for irrigation, hydroelectric power, habitat, and domestic water supply. Consequences after excessive and shortage of rainy seasons are these water resources are increasing and decreasing. Both events of the rainy seasons may have impacts on the socioeconomic development of the country. Flooding comes from excess rainy seasons, which have a positive impact on the replenishment of water resources (surface and ground) and provide very important soil supply for other places. In return, it has a negative impact in damaging crops, causing soil erosion, and causing the loss of cattle and human lives.

Early and accurate climate forecasting services are crucial in minimizing climate-associated hazards such as floods that cause life losses and damages to natural resource, infrastructure, and property. Hence, Climate services such as provision of weather information, irrigation scheduling, reservoir monitoring, and storing have roles in water resource management and disaster risk reduction.

2.2 Soil and Water Conservation

Soil and water are two important natural resources and the basic needs for agricultural production. Farmers depend on healthy soil and water to be able to produce healthy and safe food. During the last century, it has been observed that the pressure of increasing population has led to degradation of these natural resources. In other words increase in agricultural production to feed the increasing population is only possible if there sufficient fertile land and water are available for farming.

The uppermost weathered and disintegrated layer of the Earth's crust is called soil. The soil layer is composed of mineral and organic matter and is capable of sustaining plant life. The soil depth is less in some places and more at other places and may vary from practically nil to several metres. The soil layer is continuously exposed to actions of atmosphere. Wind and water in motion are two main agencies which act on the soil layer and dislodge the soil particles and transport them. The loosening of soil from its place and its transportation from one place to another is known as soil erosion.

Soil erosion is the process of removal of the top fertile soil from agricultural, grazing, forest or other land units. It is one form of soil degradation which refers to the decline in the soil's capacity to support life due to various reasons; e.g. salinity, soil erosion, fertility exhaustion, compaction, chemical pollution, etc. Soil erosion is often the effect of many natural causes, such as water and wind. There are also human factors which increase the rate of soil erosion such as construction, cultivation and other activities. Soil conservation is defined as the control of soil erosion in order to maintain agricultural productivity.

i. Agents of erosion

Soil erosion is the detachment of soil from its original location and transportation to a new location. Mainly water is responsible for this erosion although in many locations wind, glaciers are also the agents causing soil erosion. When the rain falls along the mountains and bare soil, the water detaches the soil particles, and takes away the silt and clay particles along with the flowing water. Similarly, when wind blows in the form of storms, its speed becomes too high to lift off the entire soil upper layer and causes soil erosion. Activities of human like forest cutting, increased agriculture, and clearing of land for different purposes are the other agents that cause erosion of the soil. Since erosion in many parts of our country is due to water and most of the participating Woredas are from highland areas, this manual focuses on erosion by water.

ii. Processes of erosion

Erosion is a process involving the detachment of individual soil article from soil mass, transporting it to another place and when sufficient energy is not available to transport a particle, a third phase known as deposition occurs. Hence soil erosion is defined as a process of detachment, transportation and deposition of soil particles (sediment). Soil erosion is initiated by detachment of soil particles due to action of rain. The detached particles are transported by erosion agents from one place to another and finally get settled at some place leading to soil erosion process.

iii. Types of erosion

Erosion by water can be classified into raindrop erosion/splash erosion, sheet erosion, rill erosion and gully erosion.

- Splash Erosion

This is the first stage in the erosion process that is caused by rain. Raindrops basically “bombard” the exposed and bare land, moving its particles and destroying the structure of the top layer. Eventually, it causes the formation of surface crusts, negatively affects soil infiltration ability, and eventually results in runoff formation.

Splash erosion is the initial stage of water erosion, where the impact of raindrops on bare soil dislodges and moves soil particles. This process breaks down soil aggregates, splashing particles upwards and outwards, and can lead to the formation of a soil crust that reduces water infiltration.

- Sheet Erosion

Sheet erosion is the uniform removal of soil in thin layers by raindrop impact and shallow surface flow. It often goes unnoticed because the soil loss is gradual, but the cumulative effect can be significant, especially on vulnerable, overgrazed, or cultivated land lacking vegetation.

This type of soil degradation by water occurs when the rainfall intensity is greater than the soil infiltration ability and results in the loss of the finest soil particles that contain nutrients and organic matter. It usually follows after crusting that is caused by the previous stage of soil damage by water. If not prevented timely, one of the most negative effects of sheet erosion will be the formation of rills.

- Rill Erosion

Rill erosion is a type of soil erosion where concentrated water flow creates small, yet distinct channels or rills on the land surface. These rills are typically shallow, a few centimeters deep, and are a stage between sheet erosion and gully erosion. They form as runoff water accumulates and begins to carve channels as it moves downslope. Rill erosion follows after, when the water concentrates deeper in the soil and starts forming faster-flowing channels. These channels can be up to 30cm deep and cause detachment and transportation of soil particles. Rill erosion can eventually evolve into gully erosion. That is when the rills become at least 0.3m deep.

- Gully erosion

Rills can deepen and widen into larger channels called gullies, which can be significant in size and depth. This is an advanced stage of land damage by water when the surface channels are eroded to the extent when even tillage operations wouldn't be of any help. Apart from causing huge soil losses and destroying farmland, it also results in reduction of water quality by increasing the sediment load in streams. It is a highly visible form of soil erosion that affects soil productivity, restricts land use and can threaten roads, fences and buildings. Gully erosion occurs when running water erodes soil to form channels deeper than 30cm.

2.2.1 Physical /mechanical or technical measures

Physical soil and water conservation refers to the use of physical structures and techniques to control soil and water erosion. They involve using structural measures to manage runoff and erosion, ultimately protecting soil and water resources. These methods are deigned to divide the long slope of lands into several shorter and thereby reducing amount of water and velocity of surface runoff and increase the time of concentration of runoff. This in turn slows down the movement of water on the land surface and improves water retention and infiltration and enhances land productivity. Here are some of the physical soils and water conservation structures implemented in many parts of the country.

A. Bunds and their design

A bund is a structural measure with an embankment of soil or stones, or soil and stones, constructed along the contour and stabilized with vegetative measures, such as grass and fodder trees. They are of engineering technique that divide slope of lands into several shorter slopes and constructed along the contour. Bunds are used for creating obstruction across the path of surface runoff to reduce the velocity of flowing water.

Bunds also help to retain water behind the bund, which can support water infiltration and groundwater recharge rather than flowing over surface. This slows down the flow of surface water runoff and at the same time helps to reduce soil erosion. It retains the running off water in the watershed and thus helps to control soil erosion.

i. Site selection

- Identify areas prone to erosion, particularly sloppy lands
- .Conduct survey to determine slope gradient and bund spacing

ii. Layout and alignment

Contour bund

When bunds are constructed following the same contour line, they are called contour (level) bunds, Contour bunds are recommended for areas with low annual rainfall (¡600 mm), agricultural fields permeable soil and having a land slope ¡6 percent. The major requirements in such areas are prevention of soil erosion and conservation of rain water in the soil for crop use.

For laying out a contour across a slope, the team begins at the edge of the field. The operator holding the pole at the field's edge remains stationery while the operator holding the other pole moves up and down the slope until the third operator is satisfied that the bubble is centered. The two points are then marked (with stones or pegs). The first person then moves to the second person and the second person moves forward and the process is repeated. This continues until the contour line reaches the far end of the field. Here is the procedure.

- Use line level (water level), two poles of each with 2M height and string with 11M long
- Starting from the upper of the catchment mark contour lines
- Tie the string at 1M of each poles so that the distance between the poles is 10M apart (for contour bund)

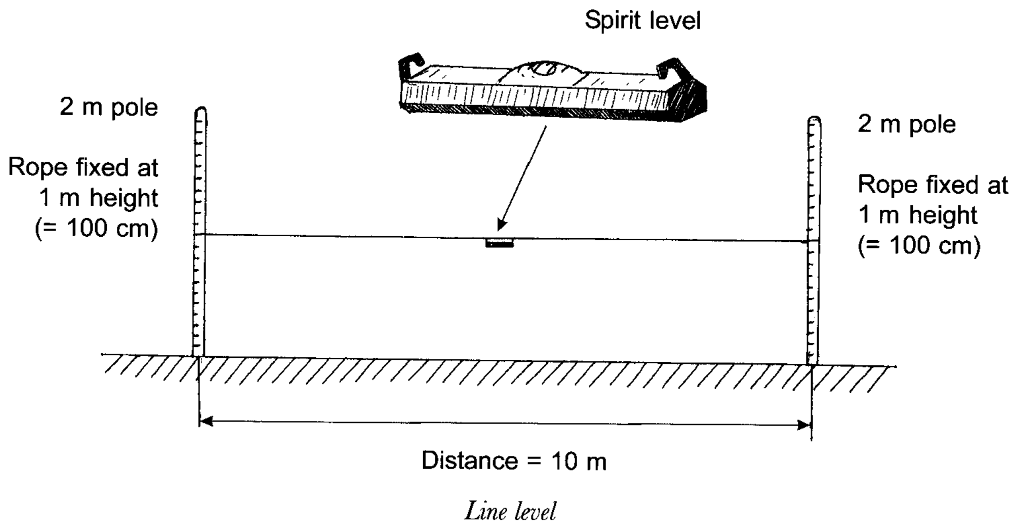

Figure 1: location of string and water table, source CBPWO, 2005 Guidline

- Tie the water level at the middle of the string (5M) and mark one pole at the starting edge of the upper catchment
- By moving the other pole either upward and downside and find a point where the bubble of water level becomes at the middle

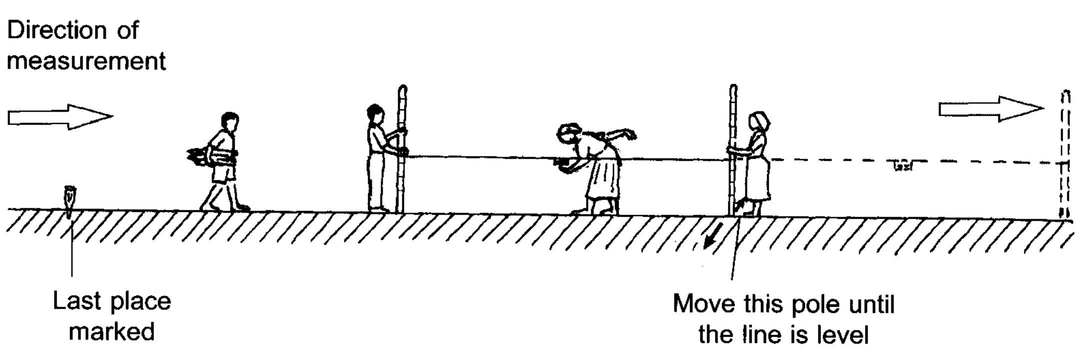

Figure 2: Marking contour bands,Source, CBPWO, 2005 Guideline

Once the two points are found, mark the two points with pegs and take the fixed pole and mark it at the movable pole and take the movable pole away and find the third point and continue repeatedly until the desired location is reached. in this case, the water retains in the bund.

Graded bunds

When a grade is provided along the bunds for safe disposal of run off water over the area between two consecutive bunds, they are called graded bunds. Graded bunds are adopted incase of high or medium annual rainfall (greater than 600 mm) and relatively less permeable soil. Graded bunds are designed to dispose excessive runoff from agricultural fields.

If the bund to be constructed is graded bund, it deviates slightly from the true contour and used to take off water from the catchment, a 1 percent difference is commonly used on the location of the string on the poles. So,

- Tie the string at 110 Cm of the pole that is to be marked at the edge of the catchment

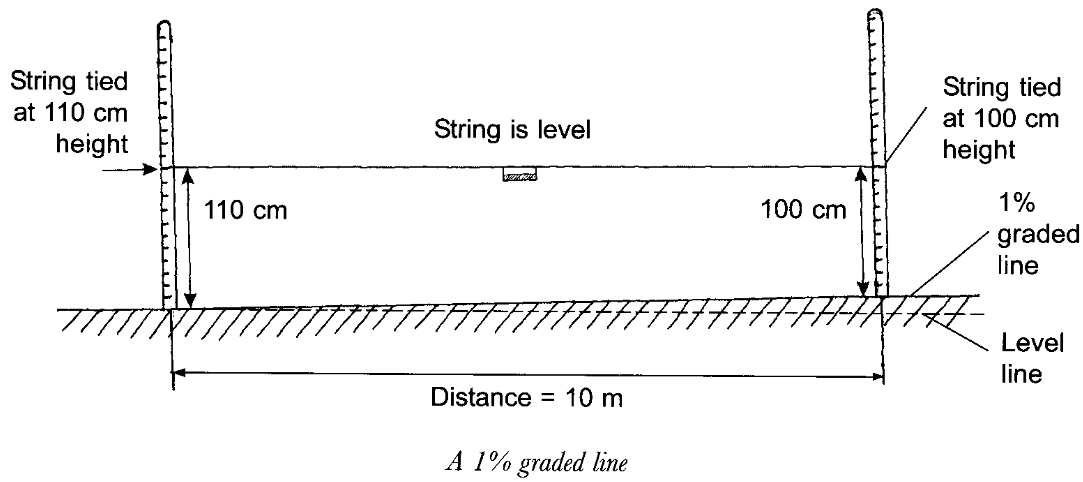

Figure 3: Marking 1 percent slope

- Mark the other side of the string at 100cm of the pole. Tie the water level at 5m in between of the two poles

- By fixing the first pole and moving the other pole either upwards or downwards until the bubble in the water table becomes the middle mark the location

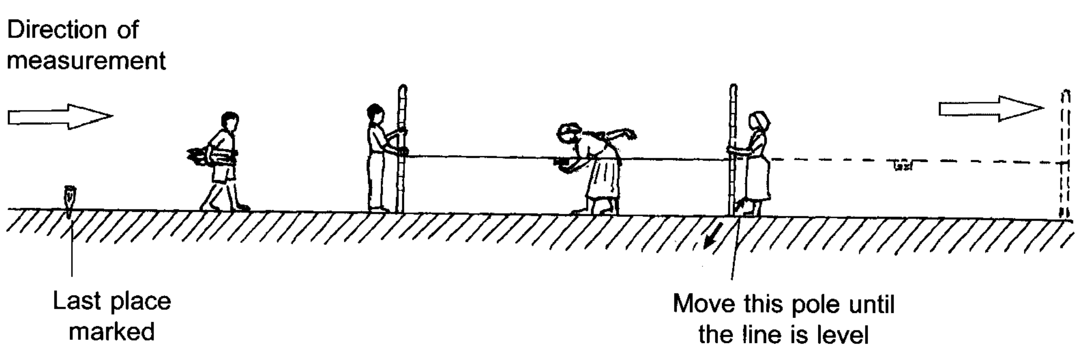

Figure 4: Marking graded bund, Source CBPWO, 2005 Guideline

- Once the two points are found, mark the two points with pegs and take the fixed pole and mark it at the movable pole and take the movable pole away and find the third point and continue repeatedly until the desired location

iii. Spacing between two consecutive bunds

The space between two consecutive bunds is commonly expressed in terms of vertical interval (VI). VI is defined as the difference in elevation between two similar points on two consecutive bunds. Vertical interval (m) is the difference in Meter between the poles when arranged in higher (above) and lower (below) elevation and string is stacked in the middle of them.

The spacing between consecutive bunds, depends on factors like slope, rainfall, and soil type, but a rule of thumb is that the vertical interval (difference in elevation) is often 1 meter for slopes under 15 percent, and it can be more closer for area with greater slopes. But some authors recommended to use spacing of 15 to 20 m for slopes between 2-5 percent, 10 to 15 m for slopes between 5 to 10 percent and 5 to 10 m for slopes greater than 10 percent.

Similarly, knowing the Horizontal Interval (Hi) and Slope (S) of the site help in advancing to calculate the vertical interval of the site.

Horizontal Interval (Hi) is the distance between two poles (points) measured in mater when measuring the vertical interval.

Slope gradient (percent) is the degree of inclination or steepness of the land feature. Slope gradient is also defined as the change in vertical distance or elevation over a given horizontal distance, or the change in horizontal distance over a given vertical distance; it is the vertical angle made by the sloping line and a horizontal line. Slope is measured either in percentage of length (percent) or in degree.

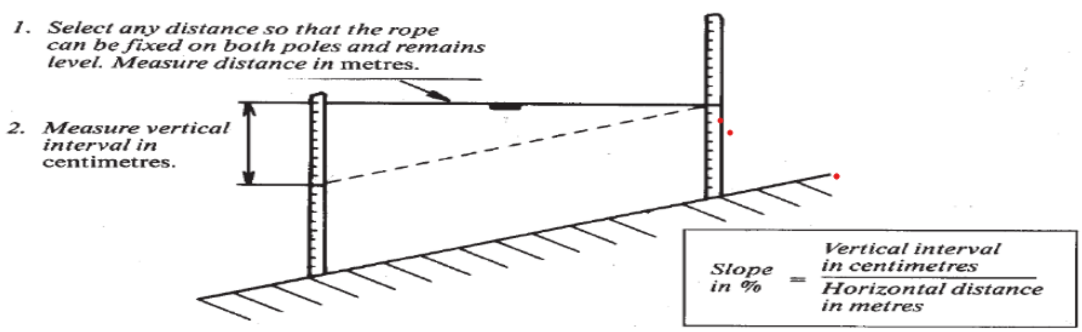

Figure 5: Calculating slope, source, CBPWO, 2005 Guideline

So, in order to determine spacing between two consecutive bunds,

- Decide the vertical interval of the site to be done (for example of 1M, 1.5M and so on),

- Tie one edge of the string (rope) at the lower pole the same distance on the upper pole below the decided distance (for example, if 1m vertical interval is decided, the lower string edge is tied at 1m level on the lower pole below the upper pole edge where the string is tied.

- Tie the water level on the string exactly at the middle of the two poles

- One person stands and holds one pole at the upper bund (where all the points were marked) and the other person holds the lower pole

- The third person adjusts the lower person and orders him to move upward or to extend downwards so that the length of the string is either lowered or extended untie the bubble of the water table is at the middle

- Once the bubble is at the middle, that exactly the location of the second bund.

- Now marking the location of the second bund can be extended based on the previous orders

- The third and other bunds are marked as done before untie the total area is covered.

The basic principles to be adopted for deciding the spacing of bunds are: (1) the seepage zone below the upper bund should meet the saturation zone of the lower bund; (2) the bunds should check the water at a point where the water attains erosive velocity and (3) the bund should not cause inconvenience to the agricultural operations. For determining the spacing of the bunds (Murthy, 1994), the formula used is:

$$Vi = \frac{s}{a} + b$$

where V.I. = vertical interval between consecutive bunds, S = land slope (percent) and a and b = constants, depend upon the soil and rainfall characteristics of the area.; a = 3 and b =2 for medium and heavy rainfall zones and a = 2 and b =2 for low rainfall zones.

Horizontal interval (spacing) - The bund spacing cannot be easily located on the ground on the basis of vertical interval; the horizontal interval should be added. The horizontal interval (spacing) can be easily measured on the land surface. For this purpose, the relationship between horizontal and vertical spacing is important and calculated as:

$$Hi = \frac{Vi}{s} * 100$$

where Hi=horizontal Interval of the bund (m) and Vi = vertical interval (m) and s= slope

Length of Bund: The length of bund is determined by calculating the horizontal interval of the bund formed. The length of bund per hectare area of land is given as:

$$L = \frac{10,000}{Hi}$$

where L is length of the bund in a hectare

Size of the Bund: The size of bund includes its height, top width, side slopes and bottom width. The height of bunds mainly depends upon the slope of the land, spacing of the bunds and the maximum intensity of rainfall expected in the area. Once the height of the bund is determined, other dimensions of the bund viz., base width, top width and side slopes are determined using the information on the nature of the soil. As much as possible, it should be wide and long as well as durable enough to hold the coming flooded water.

iv. Excavation and bund formation

The usual cross section of bund is symmetric trapezium. Dig a foundation of usually 30-40 cm deep and 40 cm wide along the marked contour line, excavate soil from the upslope side along the contour and pile on the lower side of 60 cm height, 1m to 1.2 m width base and 30 cm width of upper base and 50 cm of free board and compact the pile of the bund. The soil dug out of the bund is piled on the lower side of the embankment and the water drained from the upper catchment is collected and stored in the bund embankment.

Figure 6: Bund constructed in Oromia region at Kersa Woreda in East Harerge zone

B. Fanya Juu (Converse)

This physical SWC measure is constructed along contour by digging soil and forming embankment at upslope side of the trench. Fanya juu terraces are similar with bunds but in case of the Fanya juu, the soil is thrown uphill to form an embankment.

C. Terracing

Terracing is a soil and water conservation technique used to manage runoff and reduce erosion on sloping land. It involves creating level platforms or benches along a hillside, which helps to slow down water flow, increase infiltration, and reduce soil loss. Terracing involves the construction of embankment or ridge like structure, across the land slope to check the flow of surface runoff and to reduce the soil loss.

Terracing is a crucial soil and water conservation practice in Ethiopia, particularly on sloping lands, helping to prevent erosion and improve water management. This practice, often combined with other techniques like agroforestry, plays a vital role in maintaining agricultural productivity and mitigating the impacts of drought.

There are two main types of terracing techniques: graded terracing and level terracing. With graded terracing, the slope can vary along the length of the terrace to direct water in the desired direction; this is especially useful for less permeable land. With level terracing, the terraces follow a contour line and do not vary in slope along this line, this ensures that water is more evenly distributed along the terrace. Stone or wooden walls are often used to hold terraces in place, although a simple earth wall without supporting material can be used with slopes and terraces on the smaller side. In many parts of our country, the farmers practiced bench terraces.

Bench terraces are a series of level or virtually level strips running across the slope at vertical intervals, supported by steep banks or risers. Bench terrace consists of series of platforms along contours cut into hillslope in a step like formation. Bench terraces are effective soil conservation measures used on relatively high slope lands for crop production. On the other hand it is an engineering soil conservation practice, used to control the soil erosion in highly sloped areas.

D. Trench

In soil and water conservation, trenches are dug across slopes to intercept and slow down rainwater runoff, allowing it to infiltrate to soil and reduce erosion. These trenches can be continuous or staggered, and they play a crucial role in water harvesting and moisture retention for agriculture.

Trenches play a significant role in soil and water conservation by intercepting surface runoff, promoting water infiltration, and reducing soil erosion. They are particularly effective when constructed along contours on slopes, creating a series of small reservoirs that capture rainwater and allow it to soak into the ground.

Trenches can be artificially dug along the contour lines, across the slope so that water flowing down the hill is retained by the trench, and is infiltrating the soil below. For optimal performance, trenches are constructed along contour lines, similar to contour bunds. Therefore, the lines need to be marked before starting shoveling. When digging the trench, the excavated soil is placed downslope along the edge of the trench. Crops are then planted on the elevated land between the trenches.

The design of contour trenches can be continuous or intermittent. While the continuous ones are best suited for moisture conservation in regions with low rainfall, interrupted trenches are best suited to high rainfall areas.

E. Eyebrow basin

Eyebrow basins are larger circular and stone faced (occasionally sodded) structures constructed in staggered arrangement and commonly practiced in dry areas for the growth of trees and support to plantations in area closure. It is applicable in hillside of greater than 50 percent slope and can be combined with other measures such as hillside terraces, stone bunds, and trenches based upon soil, slope and stoniness.

- Mark the location of eye borrow along contour lines in such way that the distance between two eye borrows along the contour as well as between consecutive rows of eye borrows is 2.5m.

- Mark a circle of 2.2 to 2.5m diameter in such manner that a soil from the upper side is taken of and pilled with stone riser or stabilizer in the lower side of the embankment. Commonly, a 1m by 1m rectangular pit is dug at center to accumulate and harvest water at the center of the circle.

- Dig a planting pit between the center of the rectangular pit and the edge of the circular embankment to plant a seedling in.

F. Micro-basin

Micro basins are a common technique used in agriculture to collect surface run-off, increase water infiltration and prevent soil erosion. Their principle is comparably simple: small pools are surrounded by stone walls and/or soil ridges on all sides to collect the rainwater and surface run-off. This allows storing rainwater and using it for small-scale tree and bush planting, enabling increased growth of plants if there is a moisture deficit. The basins may vary strongly in size (ranging between 10 and 100 m2) depending on the planted crop. Sometimes, basins are also constructed directly around the plant.

Micro basins are used in order to store precipitation water by collecting surface run-off: low soil ridges optionally supported with stone walls and are constructed in an enclosed shape to form a basin, which helps to prevent the water to further run off. The collected rainwater is then used for direct irrigation or infiltration into the soil to enhance soil moisture and recharge groundwater.

Micro basins show a similar design to semi-circular bunds, except that they are entirely surrounded by ridges. The benefit of this design using closed micro basins is higher water storage efficiency.

Different design types are possible, including half-moon, v-shaped, diamond-shaped, trapezoidal, as well as contour bund basins. Micro basins are mostly used for small-scale tree and bush planting in areas with moisture deficit. Each basin consists of a catchment area and an infiltration pit, which serves as the cultivated area.

- Select the appropriate place to start the first structure and follow the following steps and Mark contour line at the selected point to start by putting pegs every 5 meters

- Put a peg at one point on the contour where to start the first structure and use this point as a centre for the first structure

- Taking the centere point the structure and measure half the radius of the basin down slope and mark a rectangle equal to the dimensions of the planting pit to four sides of the point.

- Min 1 m and max 1.5 m, stone riser: 0.2m foundation and height 0.2-0.4m above ground based on slopes, plantation pit: 40cm diameter x 50cm depth. Micro basins are constructed in staggered position between rows and in rather close pacing within row in case of 1m diameter basins (some overlapping required between rows).

G. Half-moons

Half-moons are semi-circular structures made out of soil constructed along the contour for the main purpose of collecting and storing rainfall water, meant to support the growth of trees or crops. They are suitable for the gentle sloping and sandy areas of the dry zone.

2.2.2 Biological measures

These measures (also termed vegetative measures) are a combination of land use and management practices that promote sustainable land use and productivity. They can include:

i **Strip cropping-** Hedge rows of nitrogen fixing trees/shrubs/grasses are planted in between crops/fruit trees to reduce runoff/soil erosion and increase water infiltration. Here the owners can harvest two or more products and at the same time and the crops could also help in reducing soil erosion.

Figure 7: Strip Cropping

ii **Trash lines -** these are formed by placing crop residues in line across the field slope to form semi-permeable barrier to reduce the soil to be washed away by flooding water erosion that allows passage of runoff. The trash acts as barriers for floods and the water that flows to the trash and tied to it has chances to infiltrate to the soil rather than washing it.

iii **Alley cropping** - is an agroforestry system in which food crops are grown in alleys between rows of hedges. The hedges follow the contour and consist of trees and shrubs such as Leucaena or Pigeon peas. Here the crops cover the land as well as used to reduce the effects of soil and water loss from the land.

Figure 8: Alley Cropping, Source, Since Directory, 2013

iv **Home garden** –it is a mixture of different trees/shrubs and annual crops grown around home. This kind of cultivation gives two or more products sustainably and at the same time used to reduce the effects of soil erosion.

Figure 9: Home garden agroforestry, Source, Bishaw, 2013

v **Cover crops-** as much as possible covering the land with crops will reduce the effects of soil erosion. Here the crops intercept droplets of rainfall and reduce the detaching power of the rain as well as the covering materials intercept the flowing floods and reduce the effects of soil erosion.

vi **Mulching-** Mulching is the covering of soil between crop rows or around trees with materials, rougher than the surface of the soil to protect it from splash erosion and formation of crust.

viii **Grass strips-**Grass strips are dense strips of grass panted up to a meter wide, along a contour. With time, silt builds up above the strip and benches are formed. Grass strips can be planted along ditches to stabilize them, or on the rises of bench terraces to prevent erosion.

ix **Cut and carry-**Cut and carry is a system of utilizing forage for stall feeding. It is a way by which the crops/grasses are harvested and taken to feeding animals. The cut and carry system allows the land to be covered with can remnants of the crops/grasses on the land; this will help in covering the land as result soil erosion could be minimized.

x **Area enclosure:** Area enclosure is one of the components of the biological conservation measures and it is practiced on all land types where soil erosion has becomes serious and the land has lost its productive potential. However, generally the eroded hillsides are the prominent sites of area closure. Area closure is a simple conservation activity carried out on highly degraded lands. When land has been severely degraded due to soil erosion and it is unable to produce sufficient biomass. Especially when the chances of recovering this land by conservation measures are not encouraging, it is advisable that the area should be provided complete rest and this is called area closure.

xi **Hedgerows** - Hedgerow plantation is primarily a soil-conserving technique, which involves the planting of different types plants such as grasses, leguminous and fodder trees along the contour lines on the slope at a distance of four to six meters. Plantation can be done in mixed form and/or pure stands with recommended space between plants and rows, as well as, manageable height above the ground either on farmland or on hillside/degraded lands.

xii **Crop selection** -Perennial crops are more effective in soil conservation than annual crops. Tea, fodder grasses, sugar cane and sweet potatoes are among the most effective.

xiii **Crop rotation** - Crop rotation ensures the addition of humus, soil fertility, control of erosion and reduction of pests and diseases.

xiv **Early planting** - This ensures that the crop shoots from the ground within one or two weeks after the onset of the rains and protects the ground against raindrop impact.

xv **Inter-cropping** - Fast growing legumes such as beans and cowpeas provide soil cover early in the season before maize or cotton develop a canopy to shield the soil from impact of raindrops.

xvi **Afforestation-** Afforestation refers to the practice of creating forests in areas where there were no previous tree cover.

2.2.3 Gully treatment

Gully erosion is the erosion process whereby water concentrates in narrow channels and over short periods removes the soil. Gully erosion produces channels larger than rills. As the volume of concentrated water increases and attains more velocity on slopes, it enlarges the rills into gullies. Gully can also originate from any depression such as cattle trails, footpaths, cart tracks, and traditional furrows and indicates neglect of land over long period of time.

The gully channels carry water during and immediately after rains and distinguished from rills, gullies cannot be obliterated by normal tillage. Thus, gully erosion is the advanced stage of rill erosion much as rill erosion is the advanced stage of sheet erosion. **Basic Gully Treatment Measures**

Prevention of gully formation- The principle of "prevention is better than Cure" is highly relevant for gullies. Preventing the formation of a gully is much easier than controlling it once it has formed. If incipient gullies are not stabilized, they become longer, larger and deeper. Prevention is also more economical than cure because structural measures are considerably more expensive than preventive measures. But, occurred, again, before gullies enlarged, they should be treated and their treatments are described below

Gully control measures Stabilization of gullies involves the use of appropriate structural and vegetative measures in the head, floor and sides of the gully. Once gullies have begun to form, however, they must be treated as soon as possible, to minimize further damage and restore stability. There are a multitude of physical and biological techniques which can be applied for effective gully treatment. The combination of the two measures (biophysical approach) is the best solution for effective gully control and for productive use of the gully area. The construction of gully physical treatment structures will be followed by the establishment of biological measures. The natural regeneration which is coming after the gullies are protected and enclosed should also be considered in the overall rehabilitation scheme In gully control, temporary physical structural measures such as gully reshaping, brushwood, sandbag, loose stone, and gabion and arc-weir check-dams are used to dissipate the energy of runoff and to keep the stability of the gully.

i Gully head control

The gully head control has two options: one is to divert runoff away from the gully head so that it ceases to erode. The other is to place a check-dam close enough to the gully head so that it will trap sediment, raise the floor level and submerged the head.

Figure 10: Treatment of gully from head, Source, Nile Basin Initiative, 2012

ii Gully reshaping and filling

Gully wall reshaping is cutting off steep slopes of active gully flanks in to gentle slope and constructing small trenches along contours for re-vegetating slanted part of the gully walls and beds. Gullies with very little water flow can be stabilized by filling and shaping.

iii Brushwood check-dams

Brushwood check-dams made of posts and brushes are placed across the gully and supported with planting vegetation to make the coming water to be stored.

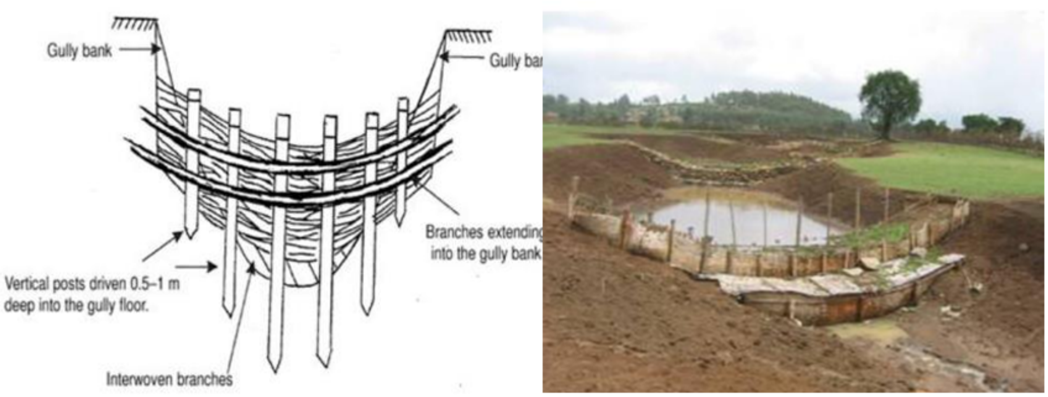

Figure 11: Brush Chekdam,Source, Nile Basin Initiative, 2012

iv Stone check dams Stone check-dam is a structure made of relatively small rocks and placed across the gully or small stream, which reduces the velocity of runoff and prevents the deepening and widening of the gully.

Figure 12: Stone Chekdam, Source Nile Basin Initiative, 2012

iv v) Gabion check-dam

Gabions are rectangular boxes of varying sizes and are mostly made of galvanized steel wire woven into mesh. The boxes are tied together with wire and then field with either stone or soil material and placed as building blocks. Small stones can be used as the wire mesh will prevent them being washed away. If large stones are used, they must be placed carefully with small stones filling the spaces between them otherwise water may jet through the gabion and undermine the ground beneath.

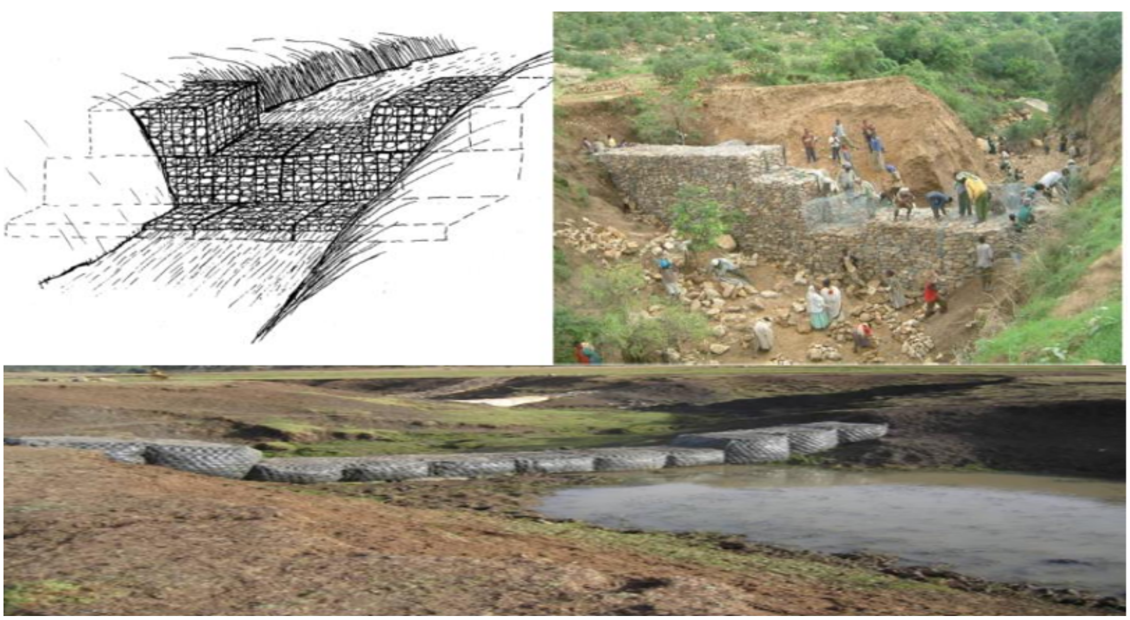

Figure 13: Gabion Chekdam, Source, Nile Basin Initiative, 2012

2.3 Water Resource Management

Water is an invaluable resource and is essential for sustainable developments and livelihoods. It is an essential need for all life forms on Earth and is the most important irreplaceable natural resource on which the socio-economic growth and long-term development of a country depends on greatly. For developing countries like Ethiopia, water is the most important natural resource and worth limitlessly.

2.3.1 Potential water resource of Ethiopia

The geographical location of Ethiopia and its endowment with favorable climate provides a relatively higher amount of rainfall in the region. Much of the water, however, flows across the borders being carried away by the Transboundary Rivers to the neighboring countries. According to [Mohammed et al., 2024] Ethiopia has abundant water resources, and the country is the source of many transboundary rivers, including the Nile. Rivers flowing west of the country (Abay, Baro-Akobo, Omo-Gibe, and Tekeze) receive much rainfall unlike the northeast- (Awash) and east-flowing rivers (Wabisheshebele and Genale-Dawa) which receive normal to low rainfall.

The document also showed that the country has about 124.4 billion cubic meter (BCM) river water, 70 BCM lake water and 30 BCM groundwater resources. It has a potential to develop 3.8 million ha of irrigation and 45,000 Mega Whatt hydropower productions. Due to its abundant surface water resources, Ethiopia is known as the water tower of Africa. According to [Mohammed et al., 2024], the country possesses 12 major river basins, which form four major drainage systems:

- The Nile basin (including Abbay or Blue Nile, Baro-Akobo, Setit-Tekeze/Atbara and Mereb) which covers 33 per cent of the country and drains the northern and central parts westwards;
- The Rift Valley (including Awash, Denakil, Omo-Gibe and Central Lakes) covers 28 per cent of the country;
- The Shebelli-Juba basin (including Wabi-Shebelle and Genale-Dawa) covers 33 per cent of the country and drains south eastern mountains towards Somalia and the Indian Ocean;
- The North-East Coast (including the Ogaden and Gulf of Aden basins) covers 6 per cent of the country.

Despite this richness in water resources, key water stress metrics suggest that Ethiopia is water stressed country. According to [Taylor, 1990], the total annual renewable water resources per person are 1,162 m3, which is below the Falkenmark Water Stress Index. The Falkenmark Water Stress Index measures water scarcity as the amount of renewable freshwater that is available for each person each year. A country is said to be experiencing water stress when water availability is below 1,700 m3 per person per year; below 1,000 m3 is considered water scarcity; and below 500 m3 is absolute or severe water scarcity.

So, for such changing climate and with scarcity of water resources in other parts of the country, effective and efficient utilization is crucial. In such cases, knowledge of water resource management as well as having know- how on the existing water related policies is essential.

2.3.2 Water resources management

Water Resources Management (WRM) is the process of planning, developing and managing water resources in terms of both water quantity and quality across all water uses. It includes the institutions, infrastructure, incentives and information systems that support and guide water management. Water resources management seeks to harness the benefits of water by ensuring there is sufficient water of adequate quality for drinking water and sanitation services, food production, energy generation and water-based recreation as well as sustaining healthy water-dependent ecosystems and protecting the aesthetic and spiritual values of lakes, rivers, and estuaries.

Water resource management also entails managing water-related risks, including floods, drought, and contamination. The complexity of relationships between water and households, economies and ecosystems requires integrated management that accounts for the synergies and tradeoffs of water's great number uses and values.

In order to alleviate the problems on agricultural outputs and other water users, sustainable and reliable development and proper use of the water resources of Ethiopia becomes an imperative. Comprehensive water management involves a number of functions that are closely related but which are carried out by different agencies and organizations. The functions include water law and policymaking, regulation, technical assistance and coordination, monitoring and evaluation, administration and financing, public education and involvement.

Efficient water resource management techniques include rainwater harvesting, wastewater treatment and recycling, ground water recharge, implementation of smart irrigation practices, the use of drought-resistant crop varieties and the adoption of integrated water resources management (IWRM) approaches that consider the entire water cycle.

i Rainwater harvesting

Rainwater harvesting is when the precipitation is collected from a small/large surface area (catchment) and directed through channels to a storage facility or to a nearby field or retained at the site itself (in-situ). It is the collection and storage of rain, rather than allowing it to run off.

Given that rainfall is sporadic and that only a small proportion of global precipitation is easily available for human use, rainwater harvesting can be an efficient means of capturing that precious resource. In cities, much of the rain that falls on buildings, roofs, roads, and other hard landscaping does not percolate into the soil and is instead directed into storm sewers for disposal. Impermeable surfaces cause urban flooding in many areas and generate contaminated unusable water that is directed away from potable water resources. During dry months, local groundwater can be depleted, and many localities struggle to consistently provide enough potable water to meet demand.

Similarly, in rural areas of Ethiopia, the farmers depend on rainfall in which much of the valuable is soon lost as runoff. On the other hand, drought has been destroying watersheds, farm lands, and pastures, contributing to land degradation and causing crops to fall and livestock to perish [Kassie, 2020]. To increase agricultural production, greater efficiency of water collection and utilization is required.

In such cases, collection and harvesting of the flowing and run off water in the working filed (in situ) or outside for later use during water scarcity could result in utilization of the resource for crop production as well as other uses.

Rooftop water harvesting - is a technique of collecting and storing rainwater that falls on rooftops for future use. It is an efficient way to conserve water and address water scarcity issues, especially in areas with irregular rainfall. In rooftop water harvesting, the roof becomes the catchments and the rainwater is collected from the roof of the house/buildings. This kind of harvesting is nowadays becoming common in urban areas, in Universities, TVET Colleges and industries and factories.

Run-off irrigation – Run off irrigation is a technique that uses dams to collect rainwater that flows over the soil and guide it to agricultural fields. The technique is based on the use of runoff produced from the adjacent upland farms and made to be diverted for use back in the farm at a lower elevation. It is widely used in Hararghe for the production of major crops in the area like sorghum and chat (Chat edulis). This technique is well adapted for crop production in the highlands of Hararghe. In these areas, crop productivity has been significantly increasing and production is getting stabilized even at bad seasons.

In most of our countries, the rainfall that drops on the surface of earth flows over the catchment; the adjacent agricultural field is mostly lacks the shortage of water for production of crops. So, as much as possible, diverting the run off and collecting it in to some appropriately predesigned dams, collection wells and thanks and storing it for later use during shortage of rainfall when the crops are in need of water. So, within this changing climate, application of these technologies and collection of the run off will not only help for harvesting water for latter uses, but also for reduction of soil erosion that and otherwise the run off could damage.

Water harvesting pond- water harvesting pond is a body of water that collects and stores rainwater from the surrounding area to prevent it from running off. Water harvesting ponds serve as water harvesting structures that capture surface rainwater runoff to support protective irrigation during lean periods. These ponds have a proper inlet for collecting the surface runoff from its catchment and may have an outlet for delivering water downstream.

ii Groundwater recharge

Groundwater recharge is the enhancement of natural groundwater supplies using man-made conveyances such as infiltration basins, trenches, dams, or injection wells and through activities that reduces the speed of run off and increases rate of infiltration like constructing soil and water conservation structures, through afforestation and reforestation and others.

These all activities allow the water to stay in an area and give tines to infiltrate to the ground and this in turn increase the ground water table. The water that infiltrate to the ground will have chance to be out at lower catchment as stream on the other side. The water that emerged as a new stream could be used as drinking water, irrigation, for livestock, cleaning and other domestic uses.

With this regard, Ethiopia has been Ethiopia has been constructing different soil and water conservation structures as well as implementing Afforestation/reforestation activities for years. The afforestation/reforestation and rehabilitation and soil and water conservation activities held in the country help in reducing the power of droplets of rain and reduce the speed of floods which help to infiltrate to the ground to recharge the groundwater. Even though Ethiopia has been constructing different soil and water conservation structures as well as implementing Afforestation/reforestation activities for years, still many more efforts are needed as our lands are bare.

iii Drip irrigation

A reliable and suitable irrigation water supply can result in vast improvements in agricultural production and assure the economic vitality of a region. The method, frequency and duration of irrigations have significant effects the amount of available water as well as on crop yield and farm productivity. Even though the most important objective of irrigation is to maintain the soil moisture reservoir, how this is accomplished is an important consideration. It is important that the scope of irrigation science not be limited to diversion and conveyance systems, nor solely to the irrigated field, nor only to the drainage pathways. Irrigation is a system extending across many technical and non-technical disciplines. It only works efficiently and continually when all the components are integrated smoothly.

Drip irrigation is a type of micro-irrigation system that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface. The goal is to place water directly into the root zone and minimize evaporation. Drip irrigation systems distribute water through a network of valves, pipes, tubing, and emitters. Depending on how well designed, installed, maintained, and operated it is, a drip irrigation system can be more efficient than other types of irrigation systems, such as surface irrigation or sprinkler irrigation.

In the drip irrigation process, water and nutrients are delivered across the field in pipes called 'dripper lines' featuring smaller units known as 'drippers'. Each dripper emits drops containing water and fertilizers, resulting in the uniform application of water and nutrients directly to each plant's root zone, across an entire field. Drip irrigation system delivers water to the crop using a network of mainlines, sub-mains and lateral lines with emission points spaced along their lengths. Each dripper/emitter orifice supplies a measured, precisely controlled uniform application of water, nutrients, and other required growth substances directly into the root zone of the plant.

Drip irrigation is nowadays practiced in production of fruits and vegetables of different species in in several parts of the country.

2.3.3 Ethiopian water resource policy

In order to efficiently and effectively utilize water resource of the country as well as to manage it, Ethiopia has developed water resource policy. The overall goal of Water Resources Policy is to enhance and promote all national efforts towards the efficient, equitable and optimum utilization of the available Water Resources of Ethiopia for significant socioeconomic development on sustainable basis.

Principles of Ethiopian water resource policy

The following are the fundamental policy principles that guide the equitable, sustainable and efficient development, utilization, conservation and protection of water resources in Ethiopia.

1 Water is a natural endowment commonly owned by all the peoples of Ethiopia.

2 As far as conditions permit, every Ethiopian citizen shall have access to sufficient water of acceptable quality, to satisfy basic human needs.

3 In order to significantly contribute to development, water shall be recognized both as an economic and a social good.

4 Water resources development shall be underpinned on rural-centered, decentralized management, participatory approach as well as integrated framework.

5 Management of water resources shall ensure social equity economic efficiently, systems reliability and sustainability norms.

6 Promotion of the participation of all stakeholders, user communities; particularly women's participation in the relevant aspects of water resources management.

2.4 Climate Smart Forestry

Importance of forests

Nowadays, as global warming and climate change have got attention at global agendas of Conferences of parties (COP), simultaneously, the issues of forest management and conservation, afforestation and reforestation has also got due attention. Because, forests, which cover about 4 billion hectares worldwide, equivalent to 31 percent of the total land area, store about 45 percent of the earth‘s terrestrial [MacDicken, 2015].

On the other, due to huge deforestation and degradation, forests also release considerable heat-trapping carbon dioxide (CO2) and other GHGs into the atmosphere, since half (50 percent) of the biomass in the lost forest is carbon. At the global level nearly 1/5th of GHG released into the atmosphere comes from the forest sector, and this is the second most important human induced sources of GHG after fossil fuel combustion [Narita et al., 2018]. From climate change perspective, the importance of forests are explained below.

i Forests for mitigation of climate change

Mitigation with forestry perspective refers to reducing drivers of climate change such as reducing heat trapping gasses from being emitted to the atmosphere or sequestering back from the atmosphere those already emitted. Forests play three integrated roles in the process of mitigating climate change.

- First, they are important component of the terrestrial ecosystems that remove (absorb) nearly 3 billion tons of anthropogenic carbon every year (3 Pg Cyear-1) through net growth. Therefore, if existing global forests are well conserved and managed, they can continue trapping GHGs and help mitigate climate change;
- Second, the 4 billion hectares of forest ecosystems existing today in the world are storehouses of large carbon. Avoiding the loss of this stock and managing it is essential in mitigating further release of GHGs and climate change.
- Third, reforestation/afforestation of degraded forestlands and non-forest lands and improving management of existing stands offer cheap and fast means of sequestering already emitted GHGs.

Forests also provide green energy when produced from sustainably managed forest or new forest (afforestation/reforestation balanced with harvesting) that can offset emissions from use of energy from non-green sources such as coal and fossil fuels; hence can reduce overall release of GHG from other sources as well.

ii Forests for adaptation to climate change

Adaptation refers to coping with the adverse effects of climate change such as drought, flood and others. Forests play multiple roles to safeguard households and communities against climate change.

First, they provide wild edible food. These foods enrich nutritional wealth but also help as coping strategies during food shortage seasons including during crop failures. Second, forests in particular are major sources of cash income and these incomes support households to purchase food and non-food items including during slack periods. Additionally, forests play roles in normalizing extreme weather events and provide prevention of frost, flood, heat and enhances ground water recharge, which strengthen adaptation and reduce vulnerability. Third, forests through sustaining and improving the quality and quantity of ecosystem services supply and sustain productivity of other economic sectors such as agriculture. Forests provide protection or regulatory services to watersheds. They reduce soil erosion and run-off, which improves water flow regime. They also provide supportive services whereby they play important roles in soil formation and enhance soil fertility and hence productivity.

The uses of forests are immense for countries like Ethiopia where an estimated 57 million people economically engaged with collection of one or more of forest products for their livelihoods. Forests ensure food security and sustainable livelihoods for millions of households and contribute an estimated 4 percent to the Gross Domestic Product (GDP) through production of honey, forest coffee, natural gums and timber [MEFCC, 2018].

Understanding the uses of forests as well as their effects on climate change, currently, commitment of the government to reverse deforestation through afforestation/reforestation and rehabilitating degraded areas as well as managing and conserving the existing forest is encouraging and is resulted in an increasing forest coverage of the country to 17.22 million ha which is about 15.7 percent of the total landmass [Sebrala et al., 2024].

Climate-Smart Forestry

For many millennia, forests have provided sustenance, materials, ecosystem services, and cultural values to human societies, who in turn have advanced various interventions to support these values. The long standing roles of forests as providers are well documented. Nowadays, climate change is presenting a global challenge to society and the forested ecosystem talked as one considered solutions. Assessments at international and national levels pointed to currently or potentially forested lands as the dominant opportunity for nature-based climate change mitigation strategies and came with new approach called Climate-Smart Forestry (CSF) that intends to capture a connection between forests, society, and climate.

Climate-Smart Forestry (CSF) is an approach that integrates sustainable forest management with strategies to mitigate and adapt to climate change while enhancing forest productivity and biodiversity. It aims to maximize the role of forests in addressing climate challenges and supporting livelihoods [Weatherall et al., 2022]. CSF builds on the concepts of sustainable forest management but has a strong focus on climate and ecosystem services. Adaptation, reduction of greenhouse gas (GHG) emissions and effective carbon sequestration, (as the core mitigation actions) and social dimensions are the core focus of the CSF definition,

CSF aims to have a mix of these measures by developing spatially diverse forest management strategies that acknowledge all carbon pools simultaneously to provide longer-term and larger mitigation benefits, while supporting other ecosystem services. Such strategies should combine measures to maintain or increase carbon stocks in forest ecosystems and wood products, and maximize substitution benefits. The message in the definition of CSF has three components:-

a Enhance global afforestation and avoid deforestation and degradation

Global afforestation and avoiding deforestation and degradation have received together with bioenergy significant attention in global forestry-related climate change mitigation efforts.

b Combine mitigation and adaptation measures in the management of forests

Improved forest management measures can contribute to climate change mitigation and are additional to the contribution of forest management to afforestation efforts. That is, the composition of forests in terms of tree species and provenances, and their rate of removing carbon from the atmosphere should be taken in to account.

c Use wood sustainably and substitute non-renewable carbon-intensive materials

Decarbonizing the economy and decoupling economic growth from resource use and environmental impacts requires moving from fossil and non-renewable resources to intelligent and sustainable use of renewable resources as the basis for products and materials. Industries that rely on fossil-intensive materials (e.g. the construction sector) or fossil-based resources (e.g. textiles, chemicals, or plastics) need to transform towards fossil-free, renewable solutions and wood can be an important alternative raw material.

Climate-Smart Forestry Practices in Ethiopia

When looking the messages in the CSF, and evaluate the practices, Ethiopia has already the implementation of CSF and in fact many more efforts should also be needed.

i Reforestation and Afforestation

With this respect, Ethiopia has been implementing encouraging initiatives across different regions. For example, the Green Legacy Initiative of the country and REDD+ and REDD+ Investment Project as well as other projects have been afforesting and reforesting huge amount of degraded lands in the country. However, it is becoming increasingly clear that tree species richness is positively related with forest productivity and biodiversity which is interesting from both a mitigation and adaptation perspective. With this regard, even though we have been planting millions of seedlings, selection and focusing to indigenous species was given less attention and we have to do more efforts.

ii Participatory Forest Management (PFM)

Participation of the community on the whole cycles of forest management ensures sustainable use while offering alternative livelihoods to reduce pressure on forests. Local communities are empowered through co-management systems with the state on management as well as utilization of the forest resources. With this regard, the new approach, Participatory Forest Management (PFM), that emerged in late 1990s shifted forest management system in to involvement of the community. The practical application of the new approach in South-Western and South-Eastern Ethiopia are encouraging.

With this point, the approached attracted many global NGOs and projects like Farm Africa, GIZ, JICA,REDD+, REDD+ Investment Project and others which have contributed countless results in reducing deforestation and forest degradation. However, the longevity of PFMs should be tied with strong forest governances, policies and standards making strong low enforcement implementation, observable supports to Community Based Organizations and development incentives which attract investors.

iii Agroforestry

Integration of trees into agricultural landscapes with the production of livestock to enhance soil fertility reduces erosion, income diversification and increasing productivity of farm land in nowadays observed in many areas of the country. Such practices will help in contribute or withstanding during climate change shocks. So, application and scale up these and other similar climate smart forestry activities should be practiced at each farm land of our farmers.

2.5 Biodiversity Conservation

Biodiversity is defined as the variety and variability among all groups of living organisms and the ecosystem in which they live. Biodiversity includes genetic diversity, species diversity and ecosystem diversity [Kahsay et al., 2022].

1 **Genetic diversity:** Genes are the basic unit of hereditary information, transmitted from one generation to the other. Within individual species, there are a number of varieties, which are slightly different from one another. These differences are due to difference in the combination of genes. Example: all rice varieties belong to the species "Oryza sativa"; but there are thousands of wild and cultivated varieties of rice, which shows variations at the genetic level and are different in their color, size, shape, nutrient content of the plant.

2 **Species diversity:** A discrete group of organisms of the same kinds is known as species. Species diversity is the diversity between different species. The sum of varieties of all the living organisms at the species level is known as species diversity. Example: There are many types of species of organisms on the earth, which have been identified and given names. For example; Apple, Mango, Grapes, Wheat, Rice, etc. are examples of plant species.

3 **Ecosystem diversity:** It is a set of biotic components (such as plants, animals and microorganisms) interacting with one another and with abiotic components (such as soil, air, water, etc.). The diversity at the ecological or habitat level is known as "ecosystem diversity". A large region with different ecosystems can be considered as ecosystem diversity. The ecosystem also shows variation with respect to

physical parameters like moisture, temperature, altitude, precipitation, etc. Example: Forest ecosystem is supposed to have mainly dominance of trees. But, while considering a tropical rain forest, a tropical deciduous forest and a temperature forest, variations observed are numerous due to variations in the physical factors.

Biodiversity conservation types -

Conservation of biodiversity is basically carried out using two methods. Namely: in-situ and ex-situ conservation methods as outlined below.

a In-situ conservation

In-situ conservation means “on-site conservation”. It is the process of protecting an endangered plant or animal species in its natural habitat, either by protecting or cleaning up the habitat itself, or by defending the species from predators. This term refers also to the conservation of genetic resources in natural populations of plant or animal species, such as forest genetic resources in natural populations of tree species, and is increasingly being applied to conservation of agricultural biodiversity in agroecosystems by farmers. Wildlife and livestock conservation is mostly based on in-situ conservation. This involves the protection of wildlife habitats.

b Ex-situ conservation

Ex-situ conservation means literally, “off-site conservation”. It is the process of protecting an endangered species of plant or animal by removing part of the population from a threatened habitat and placing it in a new location, which may be a wild area or within the care of humans. While ex-situ conservation comprises some of the oldest and best known conservation methods, it also involves newer, sometimes controversial laboratory methods.

Normally the best method of maximizing a species chance of survival (when ex-situ methods are required) is by relocating part of the population to a less threatened location. It is extremely difficult to mimic the environment of the original colony location given the large number of variables defining the original colony (microclimate, soils, symbiotic species, absence of severe predation, etc). It is also technically challenging to uproot (in the case of plants) or trap (in the case of animals) the required organisms without undue harm.

Biodiversity of Ethiopia

Ethiopia possesses an estimated number of 6,000 species of higher plants of which 10 percent are endemic. The country has 284 species of wild mammals and 861 species of birds. Data on other wild animals are scanty; and the number of reptile, fish, amphibian and arthropod species identified so far are 201, 200, 63 and 1,225, respectively. Of these faunal resources, 29 wild mammal, 18 bird, 10 reptile, 40 fish, 25 amphibian and seven arthropod species are endemic to Ethiopia [Kahsay et al., 2022].

The same document indicated that Ethiopia is a center of origin for cultivated crops such as coffee, tef, enset, and a center of diversity for many crop species such as durum wheat, barley and sorghum. In addition, the country has a rich resource of indigenous farm animals comprised of 28 cattle, 9 sheep, 8 goat, 7 camel, 6 donkey, 8 horse, 2 mule and 7 chicken breeds.

Natural ecosystem of Ethiopia

Knowing ecosystem of the country helps in understanding the classification and as well as knowing the location of each biodiversity to be conserved. These diverse ecosystems have endowed Ethiopia with a diverse biological wealth of plants, animals and microbial species. According to [BES-NET, 2023] report, the natural ecosystem of Ethiopia are classified in of the following classes.

a Afroalpine and Sub-afroalpine Ecosystem

The ecosystem includes areas, which on the average are higher than 3200 m. The ecosystem is characterized by most conspicuous giant Lobelia and evergreen shrubs including Erica arborea and perennial herbs. The endemic mammals in this ecosystem include Walia Ibex, Mountain Nyala, Starck's Hare, Ethiopian Wolf and Gelada Baboon. The Giant Mole Rat is also a characteristic species to this ecosystem. Apart from the Simien and Bale, most of the afroalpine and subafroalpine ecosystems in Ethiopia are not effectively conserved through effectively managed protected area or through sustainable use systems.

b Dry Evergreen Montane Forest and Grassland complex

This ecosystem represents a complex system of successions involving extensive grasslands rich in legumes, shrubs and small to large-sized trees to closed forest with a canopy of several strata occurring between (1600-) 1900-3300 m. This ecosystem covers much of highland areas and mountainous chains of Ethiopia in Oromia region (Shewa, Arsi, northern Bale and western Hararge), Amhara Region (Gojam, Welo, Gonder) and SNNP region (Sidamo and Gamo Gofa). The areas with Dry Evergreen Afromontane forest have canopies usually dominated by Tid/Gatira (Juniperus procera) as a dominant species, followed by Weira/Ejersa (Olea africana), Zigba/Birbirsa (Podocarpus falcatus) is also found in sheltered valleys.

The grasslands occur in the areas where human activity has been largest and most intense, and found at altitudes between 1500 and 3000 m. The montane grassland in most places is derived from forest and other woody vegetation types. There exists also some edaphic grassland. The evergreen scrub vegetation occurs in the highlands of Ethiopia either as an intact scrub in association with the dry evergreen montane forest or usually as secondary growth after deforestation of the dry evergreen montane forest.

The characteristic mammals of the dry evergreen montane forest and grassland complex are more or less similar with the Afroalpine ecosystem. The endemic species in this ecosystem include Mountain Nyala which is considered rare as well as globally threatened. The characteristic birds include Black-headed Forest Oriole and Abyssinian Wood pecker.

c Moist Evergreen Montane Forest Ecosystem

This ecosystem is in most cases characterized by one or more closed strata of evergreen trees, which may reach a height of 30 to 40 m. Forests of these areas occur in the south western part of the Ethiopian Highlands at between 1500 and 2600-m elevation and the Harenna Forest on the southern slopes of the Bale Mountains. The forests characteristically contain a mixture of Zigba (Podocarpus falcatus) and broad leaved species as emergent trees in the canopy including Kerero (Aningeria adolfi-friederici). Kerkha (the mountain bamboo-Arundinaria alpina) is also one of the characteristic species, although not uncommon is found locally.

There are also a number of medium-sized trees, and large shrubs. The second type includes the Transitional Rainforest, which includes forests known from the western escarpment of the Ethiopian Highlands, in Wellega, Illubabor and Kefa. The forest type occurs between 500 and 1500m elevation. The larger mammals that are characteristic include the Blue Monkey, Leopard, Guereza, Wild dogs and lions, which characteristically are found in open Acacia woodland ecosystems.

d Acacia-Comiphora Woodland Ecosystem

This ecosystem is characterized by drought resistant trees and shrubs, either deciduous or with small, evergreen leaves occurring between 900 and 1900 m. This vegetation type occurs in the northern, eastern, central and southern part of the country mainly in Oromia, Afar, Somali, and Southern Nations, Nationalities and Peoples Regional States. The trees and shrubs form almost complete stratum and include species of Grar/Lafto (Acacia senegal, Acacia seyal and Acacia tortilis), Bedeno (Balanites aegyptiaca), Kerbe (Commiphora africana, and other Commiphora species).

Most of the National Parks of the country (Abijata-Shala Lakes National Park, Nechisar National Park, Omo National Park, Mago National Park, and Yangudirassa National Park) are found in this ecosystem.

e Combretum-Terminalia Woodl and Ecosystem

This ecosystem is characterized by small to moderate-sized trees with fairly large deciduous leaves. These include Yetan Zaf (Boswellia papyrifera), Anogeissus leiocarpa and Stereospermum kunthianum and species of Weyba (Terminalia), Combretum and Lannea. The solid-stemmed lowland bamboo, Shimel (Oxytenanthera abyssinica) is prominent in river valleys of western Ethiopia.

The vegetation type occurs along the western escarpment of the Ethiopian Plateau, from the border region between Ethiopia and Eritrea to western Kefa and the Omo Zone; it is the dominant vegetation in Benshangul-Gumuz and Gambella Regions, and the Dedessa Valley in Wellega in Oromia Region, where it occurs between 500 and 1900 m. The vegetation in this ecosystem has developed under the influence of fire. The soil erosion rate is very high especially at the onset of rains.

f Desert and Semi-desert Scrubland Ecosystem

This ecosystem is characterized by highly drought tolerant species of Grar/Lafto (Acacia brichettiana, Acacia stuhlmanii and Acacia walawlensis), Etan (Boswellia ogadenenesis) and Kerbe (Commiphora longipedicillata), as well as succulents, including species of Euphorbia and Aloe. This ecosystem type occurs in the Afar Depression, the Ogaden, around Lake Chew Bahir and the Omo Delta below an altitude of 500 m. The semi-desert parts are found in the northern western and north eastern parts of the country, southern and the south eastern and eastern parts.

g Aquatic Ecosystem

This ecosystem consists of both running (lotic) and standing (lentic) inland water bodies, including rivers, lakes, reservoirs, swamps, wetlands and aquatic bodies with transient water contents during some time of the year. Although the floristic composition of the riverine vegetation varies depending on altitude and geographical location, in general it is mainly characterized by species of Celtis africana, Mimusops kummel, Tamarindus indica, etc. The swamps, reservoirs and shores of lakes are dominated by species of sedges and grasses.

Aquatic resources in this ecosystem include over 180 fish species of which some 30 to 50 are endemic. Moreover, the aquatic ecosystem harbours over 200 species of phytoplankton, including many important Blue-green algal species such as Spirulina (Arthrospira). Aquatic mammals that frequently use this ecosystem include Hippopotamus, Nile Lechwe, Common Water buck and Bush Elephant. The habitat is also used by considerable species of reptiles such as the Nile crocodile.

Importance of biodiversity conservation

Biodiversity provides free of charge services worth hundreds of billions of Ethiopian Birr every year that are crucial to the wellbeing of Ethiopia's society. These services include clean water, pure air, soil formation and protection, pollination, crop pest control and the provision of foods, fuel, fibers and drugs. As elsewhere, these services are not widely recognized, nor are they properly valued in economic or even social terms. Reduction in biodiversity affects these ecosystem services.

The sustainability of ecosystems depends to a large extent on the buffering capacity provided by having a rich and healthy diversity of genes, species and habitats. The conservation of biodiversity is fundamental to achieving sustainable development. It provides flexibility and options for our current (and future) use of natural resources. Conservation of biodiversity is crucial to the sustainability of sectors as diverse as energy, agriculture, forestry, fisheries, wildlife, industry, health, tourism, commerce, irrigation and power. Ethiopia's development in the future will continue to depend on the foundation provided by living resources and conserving biodiversity. Losing biodiversity is like losing the life support systems that we and other species, so desperately depend upon.

3 Supporting Polices, Case Studies and Best Practices

3.1 Supporting Polices

It was stated that climate change related impacts will increase in the future unless effective steps are taken to build resilience. [Aragie, 2013], suggested that climate change may reduce Ethiopia‘s GDP by up to 10 percent by 2045. Various studies have stated that climate change will influence production of various crops such as teff, wheat, Enset and Coffee [Hadgu et al., 2015]7; [Davis et al., 2012]; [Teklewold et al., 2013]. These declines are caused through shortening of growing season and increased prevalence of crop pests and diseases.

In order to address these challenges, there have been lots of activities that considered the consequences of climate change. Parallel to this, climate change adaptation policies, strategies and programs have been developed by the country and started to be implemented.

i National Framework for Climate Services - Strategic Plan: 2021-2030

The NFCS Strategic Plan aims to help decision-makers use climate information to manage climate-related risks in key sectors. The vision behind Ethiopia's National Framework for Climate Services (NFCS) Strategic Plan is "seeing Ethiopians whose livelihoods are resilient through climate-informed decisions." More specifically, it aims to help five priority sectors (health, agriculture, disaster risk management, water resources and environment) achieve their development and adaptation goals in the face of variable and changing climate. This will be accomplished by supporting decision-makers to use weather and climate information to understand, anticipate and manage climate-related risks.

ii Climate-Resilient Green Economy (CRGE) Strategy

The CRGE Strategy is the basis of Ethiopia's NDC and aims to reduce emissions by 64 percent by 2030. The CRGE's vision was achieving middle-income status by 2025 in a climate-resilient green economy, outlining four pillars.

- **Agriculture:** Improving crop and livestock production practices for higher food security and farmer income while reducing emissions
- **Deforestation:** Reducing emissions by protecting and re-establishing forests for their economic and ecosystem services including as carbon stocks.
- **Power:** expanding electricity generation from renewable energy for domestic and regional markets
- **Transport, industrial sectors and buildings:** Leapfrogging to modern and energy efficient technologies.

iii National Adaptation Plan (NAP)

Ethiopia's National Adaptation Plan (NAP) builds on ongoing efforts to address climate change in the country's development policy framework, including the CRGE strategy and the second Growth and Transformation Plan (GTP II) as well as electoral climate resilience strategies and regional and municipal adaptation plans. Its goal is to reduce vulnerability to the-impacts of climate change by building adaptive capacity and resilience. NAP aims to strengthen holistic integration of climate change adaptation in Ethiopia's long-term under development, supported by effective institutions and governance structures, finance for implementation and capacity development, strengthened systems for disaster risk management and integration among different sectors. The plan and its implementation are guided by the principles of participation, coherent interventions, stakeholder-empowerment, gender sensitivity, equitable implementation and partnership.

NAP focuses on the sectors that have been identified as most vulnerable to climate change, namely: agriculture, forestry, health, transport, power, industry, water and urban. Within these sectors, 18 adaptation options have been identified for implementation at all levels and across-different development sectors, recognizing the considerable diversity in context and vulnerability across Ethiopia's regions and social groups.

Ethiopia's National Adaptation Plan provides a road map for reducing vulnerability to climate change by mainstreaming adaptation into development activities across sectors and levels. It elaborates how the country will build resilience in order to achieve middle-income status by 2025, in line with the Climate Resilient Green Economy (CRGE) strategy.

iv Long-Term Low Emission and Climate Resilient Development Strategy (LT-LEDS)

A Long-Term Low Emission and Climate Resilient Development Strategy (LT-LEDS) is a policy instrument that helps countries transition to a low-carbon economy while also meeting their socioeconomic development goals. LT-LEDS are critical for limiting global warming, achieving net- zero emissions and preventing the worst effects of climate change. Ethiopia also developed the LT-LEDS as strategy that outlines long-term mitigation pathways up to 2050.

Ethiopia's LT-LEDS has been developed in tune with the Paris Agreement on Climate Change adopted in 2015 which encouraged countries to produce an LT-LEDS, as a roadmap for long-term decarburization to limit the global temperature increase to 1.5 degrees Celsius. The overarching objective of Ethiopia's LT-LEDS strategy is to help the GoE to pursue a green growth pathway by keeping its carbon emissions target to net-zero by 2050.

v Nationally Determined Contribution (NDC)

Ethiopia submitted its updated NDC in 2021. The updated NDC has an emissions reduction target of 68.8 percent by 2030. The NDC covers actions for land use change and forestry, livestock, energy, waste, industry, health, water, transport, urban settlements and disaster risk reduction. The updated NDC builds upon several national climate policies and initiatives including the CRGE, the Green Legacy Initiative and Ethiopia's 10-Year Development Plan.

vi Ethiopia's Green Legacy Initiative

Green Legacy Initiative of Ethiopia, launched in 2019 by Prime Minister Abiy Ahmed, aims to plant 20 billion trees across the country in four consecutive years and planted 25 million seedlings by the end of 2022. Green Legacy Initiative is one of the most ambitious environmental restoration programs in the world. This initiative is part of Ethiopia's commitment to the United Nations' Sustainable Development Goals and its pledge to combat climate change. Through the initiative, the government of Ethiopia hopes to combat deforestation, increase the country's forest cover, and enhance the ecosystem services that forests provide. Furthermore, the initiative also aims to create green jobs and stimulate economic growth by promoting sustainable land-use practices. Since then, the Green Legacy Initiative targets as well as performances are increasing from year to year.

vii The 10-Year Development Plan of Ethiopia (2021-2030)

It outlines the country's vision, objectives, and strategic pillars for sustainable development. It addresses economic, social, administrative, and institutional challenges through homegrown reforms and policies. The plan also incorporated and considered climate change adaptations options across sectors.

3.2 Best Experiences

Ethiopian farmers have been practicing some climate-smart natural resource management activities which helped them on increasing their livelihood incomes as well as using the incomes during the occurrences of shocks like during climate change. Some of the following activities could be taken as best experiences.

i Agroforestry:

Home garden agroforestry of Gedeo Zone has compositional, structural and functional diversity and playing key roles in on-farm conservation and ensuring environmental well-being while contributing to livelihood support systems. Mainly indigenous tree species such as Ficus spp., Cordia africana, Croton macrostachyus and Millettia ferruginea and fruit trees such as mango (Mangifera indica) and avocado (Persea americana) form the upper story. Dominant species such as coffee (Coffe arabica.), an evergreen shrub, and enset (Enset eventricosum), a large non-woody evergreen perennial herb form the middle story. The low story is often occupied by vegetables, spices, and herbs [Lemma et al., 2025]. The architectural design of this system helps to use space effectively in such a way that the combination enhances beneficial interactions and nullifies adverse ones.

Figure 14: Agroforestry at Gedea Zone, Source, Bishaw, 2013

Gedeo agroforestry has myriad unique features. It is not a supplementary production system in which only fruit and vegetables are grown to supplement field grown staple crops. Instead, it is a principal livelihood system in which all forms of crops, including staple, cash and supplementary crops grow together. The system supports a population of close to 900 persons/km2 (Sileshi, 206). The main component crops, enset (Enset eventricosum; a herbaceous monocarpic banana-like plant) and coffee (Coffe arabica) are the pillars of food security. The same author indicated that Gedeo agroforest hosts diversity as high as 50 woody plant species belonging to 35 families in each plot of 100m2. Its uniqueness also emanates from its exclusive reliance on indigenous knowledge (IK).

ii Crop diversification

In many parts of Ethiopia, a single farmer can cultivate different crops like potato, maize, peas, barely, wheat, teff, check peas, millet and lentil by allocating small proportion of farmlands from what she already holds. In this case, one crop helps to secure food in one month and the other crops for the other months. By doing so, a farmer can close food gaps in each month of the year and builds family resilience in food security. These kinds of activity have been practice in many parts of the country. On the other hand, mixing two or more crops on the same time on the same field is commonly also practiced in many parts of the country. In addition to providing multiple products, the system has been used for increasing soil fertility.

iii Participatory Forest Management (PFM)

PFM is defined as the sustainable management and use of forest and forestlands through a partnership between state forestry service and organized villagers within and around forests to sustain the flow of benefits which are to be fairly shared between the community and the state forest agency (through involvement of other stakeholders). Since its commencement in late 1990s, many Forest Based Community Organizations (CBOs) established across different districts of the country and enabled many forest sites to be incorporated and managed under this approach.

For example, in Oromia region alone, more than 792 Forest Based Cooperatives are established and coercively working with the state on managing and utilizing the existing forests. So, by now about 18 percent of the region's forests are transferred to cooperatives and managed by them [Bekele et al., 2022]. Similarly, 578 CBOs are currently established in South West Ethiopia region and managing 683,755.8 ha of forest through PFM approach.

Those CBOs have bylaws, forest management plan, agreement with forest governing state, development and protection plan and monitoring and evaluation plans which encourage members of CBOs to participate on forest development, abstain from illegal tree cutting and sustainably managing the forest. These all activities have positive contribution for adaptation of the climate change.

iv Soil and water Conservation of Hararge Zones

Land degradation is one of the major challenges causing food insecurity and instability in Ethiopia. Land degradation is a process that reduces the capability of the land to carry out functions of vital importance and provision of ecosystem services. In order to reverse these land degradation, the community, has been using indigenous knowledge to construct physical soil and water conservation practices with supporting of planting vegetation. In many instances in the past, different soil and water conservation structures have been constructed in all Hararge Zones and these are also up-scaled to different parts of the country. The construction of these structures with support from biological conservation has been helped in reducing the longer slopes into smaller, reduces soil erosion and used to cultivate the unproductive lands.

3.3 Indigenous Knowledge in Climate Smart Natural Resource management

Ethiopia has reach in community indigenous knowledge in a wide range of fields like soil and water conservation, seed selection and preservation, advancement of traditional farm implements, development of appropriate farming systems, and adaptation of effective coping mechanisms in withstanding food insecurities through time.

Indigenous technologies that have been devised by the community, using their own indigenous knowledge to cope up harsh time and be able to sustain the livelihoods, have been acknowledged. Traditional knowledge plays a role in awareness creation in the community to manage their day-to-day activities. For example, the communities have been using their knowledge during unseasonal rainfall to harvest crops. Many communities in Ethiopia have accustomed to own different landscape management practices. The following indigenous knowledge exist at different parts of the country could be cascaded and unscaled to other areas.

i Gedeo Cultural Landscape

The Gedeo agroforestry system is another exemplary local knowledge to mention in sustainable landscape management in Ethiopia. Despite that the Gedeo landscapes are undulating and rugged which are vulnerable to soil erosion and land degradation, the communities have sustained the landscapes for their ecosystem functions and livelihood support for longer periods by averting those risks [Kanshie, 2002].

The Gedeo communities have adopted two systems of natural resource management-locally named baabbo and mona [Maru et al., 2019]). The first is about retaining or planting native trees on farm for cultural, socio-economic and ecological reasons by which those trees have been given critical care for conservation by the community member. The second is a soil acidity amendment practice by which farmers collect animal manure and other organic inputs in order to improve soil fertility to sustain production and productivity.

The old-aged traditional knowledge of agroforestry and soil management practices of the Gedeo communities have build the resilience of the landscapes irrespective of that the Gedeo zone is one of the most densely populated. The combinations of efficient agronomic and soil management practices and nutrient supply, not only enabled to increase the productivity of crops but also to improve the status of the natural resource base.

The cultural knowledge of how to manage and conserve the agroforestry system stems from the customs and beliefs of the Gedeo people, leading to a mutualistic human-environmental relationship. The area contains several sacred forests from which harvesting are prohibited. Fifty different species of native woody plants have been found within these traditional farms, 22 of which are of particular conservation concern. The most common native plants are Millettia ferruginea and Cordia africanaand. The old-aged traditional knowledge of agroforestry and soil management practices of the Gedeo communities have built the resilience of the landscapes irrespective of that the Gedeo zone is one of the most densely populated.

ii Konso houses and terraces

Konso people, have centuries of accumulated knowledge in managing the landscape sustainably. They accustomed to construct stone terraces and cultural dams combined with agroforestry in such a way that could prevent soil erosion and store rain water to maintain productivity [Mezgebe, 2011]. These practices help to build landscape and livelihood sustainability of the community even in extreme cases of climate variability and environmental changes.

That is the reason why the Konso community has managed to survive for centuries in marginal and harsh environments. For their marvelous work, they have won the UN prize award in 1995 for being one of the best among fifty communities in the world. Later on, these indigenous talents of Konso community with their role in sustaining landscapes, livelihoods and means of tourist attraction have been given recognition by UNESCO (2012) and registered as World Heritage Site in 2012.

The synergies in the landscapes which integrate crop-livestock, multi-cropping and multi-story trees have helped the community in climate change adaptation. For instance, the multipurpose tree, Moringa stenopetalla, has been used as food and water purification by Konso people for long before it has been known to be a magic tree throughout Ethiopia for its food, soft drinks, tea indigents and water purification.

iii Geda system in Oromia region

The Gada system is an Oromo traditional system of governance that governed political, economic, social, and cultural life. It included strict environmental protections, such as prohibitions against cutting certain trees, protections for forests and water sources, and respect for wildlife.

In Oromo community, Gada and natural sites are two inseparable entities, the natural sites are places dedicated to rituals of the Gada system and adoring of Waaqaa (God). Hence, the Oromo community has conserved natural sites in their area for millennia. Therefore, natural areas are dedicated to various rituals and other cultural events in the Gada system. Moreover, they are places where praying of God for sustainable peace, health and wealth. Therefore, probably, due to the influence of Gada system in natural resource conservation, there are better natural resources in Oromia region as compared to the rest of the regions.

iv Forest Management in South-Western Ethiopia

In south and south west Ethiopia, forests are managed by local knowledge systems to sustain livelihood in forest coffee, different spices, honey, bamboo, timber, civet cat, and so on. For instance, the Sheka Forest, which is registered by UNESCO as biosphere reserve in 2012, has been the efforts of long time conservation of the forest by the diverse communities inhabiting in and around the forests. The same is true for Yayu coffee forest biosphere reserve (designated in 2010) in Ilu Aba Bora Zone in Oromia regional State. Rangeland Management in Southern Ethiopia

v Forest Management through Churches and traditional believes

The local knowledge used around churches helped to manage and preserve indigenous tree species at many Churches in Ethiopia. This type of forest management is common in Orthodox Tewahido churches and Monasteries in Ethiopia where church forests are protected and remained intact even in places where the surrounding landscapes remained bare.

Here, one who breaks the rules and regulations concerning the monastery's forest management will be penalized by the monastery's administration. On the other hand, traditional institutions related to traditional beliefs including, but not limited to, rituals and sacred places have also played important role in forest conservation and conflict resolution. This in turn helped to build carbon stocks in the church forests both in biomass and soils.

vi Rangeland Management in Southern Ethiopia

Borena traditional rangeland management is also local community knowledge to mention that help the pastoralists to sustain the rangeland for centuries and thereby builds the resilience of the community's livelihoods in times of climate change and variability impacts.

vii Crop management

Farmers throughout Ethiopia cultivate diversified varieties of crops having different growing periods. They know which variety is better to address their local requirements. In central Ethiopia, a single farmer can cultivate potato, maize, peas, barely, wheat, teff, check peas, millet and lentil by allocating small proportion of farmlands from what s/he already holds. In this case, potato help to secure food in the months of June to July, maize spike in August to September, short rotation peas and barely in October to November, and so on. By doing so, a farmer can close food gaps in each month of the year and builds family resilience in food security.

Intercropping is commonly adopted by farmers in different parts of Ethiopia. A study in Dawro Zone in southern Ethiopia for instance, identified that farmers grow bean, pea, yam, cotton, and sometimes teff in maize or sorghum farms. This arrangement provide ssoil moisture and fertility maintenance, support to weak crop by strong crop and increase productivity per plot of land. In turn, it helps farmers in reducing risk in times of climate change and variability. That is, if one crop failed due to extreme weather, at least one other crop will give production thereby sustains farmers' livelihoods.

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