MANUAL 3

Water Productive and Resilient Landscape Management Technologies and Approaches

Part of a series of six manuals for Integrated landscape and water management training

SIWI

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Introduction

This manual is the third manual out of six that provides basic training on water management in multifunctional and productive landscapes. It is an abbreviated version of a manual developed by the Stockholm International Water Institute (SIWI) and the International Water Management Institute (IWMI) on Water Productive and Resilient Landscape Management Technologies and Approaches commissioned by the Sida-funded programme on Strengthening Water and Landscape Governance in Ethiopia implemented from 2018 to 2022.

1. Definitions of terms and concepts around resilient landscapes

Guiding questions

Why is it important to improve water-use efficiency (WUE) and water productivity (WP)?

What is the difference between WUE and WP?

1.1 Water productive agricultural systems

When freshwater resources in a landscape are scarce, improving water efficiency and productivity is vital. Agriculture (crop and livestock) consumes the largest portion of freshwater resources, therefore, developing a water efficient and water productive agricultural system is important. Applying the concepts of irrigation efficiency (IE), water use efficiency (WUE) and water productivity (WP) can be complicated. Efficiency and productivity are two different but interconnected indicators of performance of water uses.

Water use efficiency (WUE): Refers to the ratio of water used in the plant metabolism, to water lost by the plant through transpiration. From an irrigation engineering perspective, efficient water use is defined as the ratio between the actual volume of water used for a specific purpose, and the volume extracted or derived from a supply source for that same purpose. WUE is a dimensionless ratio of total amount of water used to the total amount of water applied.

Water Productivity (WP): WP plays a crucial role in modern agriculture and aims to increase yield production per unit of water used, both under rainfed and irrigated conditions. It refers to the ratio of biomass produced to the rate of transpiration. This can be achieved either by 1) increasing the marketable yield of the crops for each unit of water transpired, 2) reducing the outflows/losses, or 3) enhancing the effective use of rainfall, of the water stored in the soil, and of the marginal quality water. Evaluating water productivity efficiency for agricultural landscapes requires disaggregating the entire landscape to lower levels (e.g. farm, farm system, community, watershed). A water productive system is then the ratio sum of water input to the system (through precipitation or irrigation) to the beneficial outputs delivered by system components, such as livestock products and services, crop production.

These concepts indicate that in a water productive agricultural system, unproductive depletion (evaporative losses and pollution) is minimized, whereas transpiration loss, which correlates with biomass yield, is maximized. The principle factors of water productivity enhancement are: to conserve and channel water to where it is most needed, enhance plant water uptake capacity, and convert water to instead reach more beneficial outputs. Water use efficiency and water productivity are interconnected; an increase of WUE would lead to better WP.

Figure 1. An agricultural landscape in Lake Chamo sub-basin, Rift Valley, Ethiopia (photo Anna Tengberg).

2. Approaches to resilient landscape and water management

2.1 Agricultural/farming/livelihood systems approach

Guiding questions

What characterizes the agricultural systems approach?

What are the different types of livelihood assets/capitals?

How do they enhance livelihood resilience and reduce vulnerability to climate change and variability?

The agriculture/farming/livelihood system approach of landscape and water management focuses on the understanding of the interactions between livelihood assets, agricultural activities and water resources management, and targets potential interventions for farms, communities, and production systems to build a more resilient landscape. Each individual farm has its own specific characteristics, which arise from variations in livelihood assets and capitals (Figure 2).

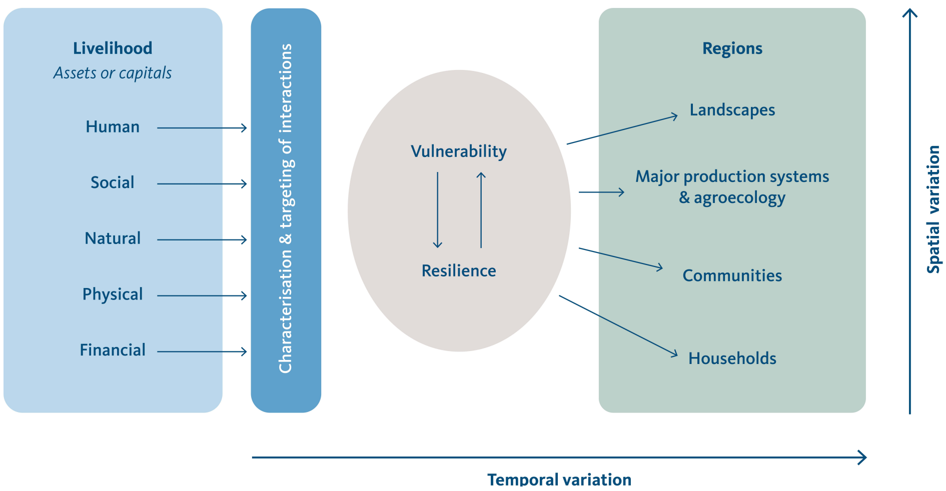

Figure 2. Framework for production and livelihood system (Source: Haileslassie et al. (2020)).

The household, its resources, and the resource flows and interactions at individual farm level are together referred to as a farm system. It is the level of endowment of livelihood assets that determines efficient use of water and enhancement of productivity Livelihood assets, livelihood outcomes and vulnerability interact in agricultural landscapes. Livelihood assets are interconnected and have synergetic effects, whereas livelihood strategies contribute to transformation between assets or capitals, to meet livelihood outcomes and enhance adoption and resilience. Considering linkages between different assets and existing structures and processes (policy, institutions) is important in building resilient landscapes.

2.2 Integrated and optimization approaches

One of the major challenges in Ethiopian and other African production systems (and landscapes) is referred to as the huge yield gap. The myth among farming communities is that applying more water to soils and crops will increase yield and implicitly close the yield gap. However, closing the yield gap and improving the productivity of scarce water resources requires an integrated approach.

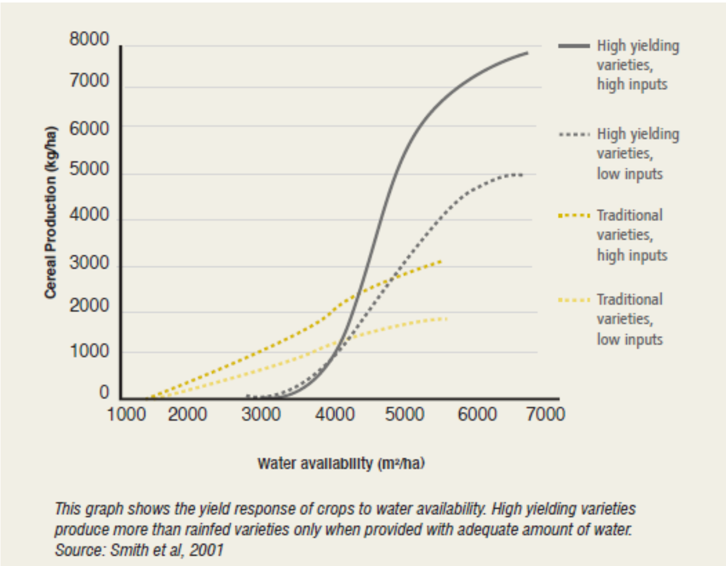

Figure 3. a) How integration of inputs save water and thus help in building resilient agricultural landscapes

With the same amount of water, farmers can produce more crops if they integrate different agricultural inputs (e.g., high yielding varieties, use of organic and inorganic fertilizers, Fig. 3a). Water can be saved through better integration or use of different yield-limiting factors, in turn making it more available. for other uses or for the expansion of production areas.

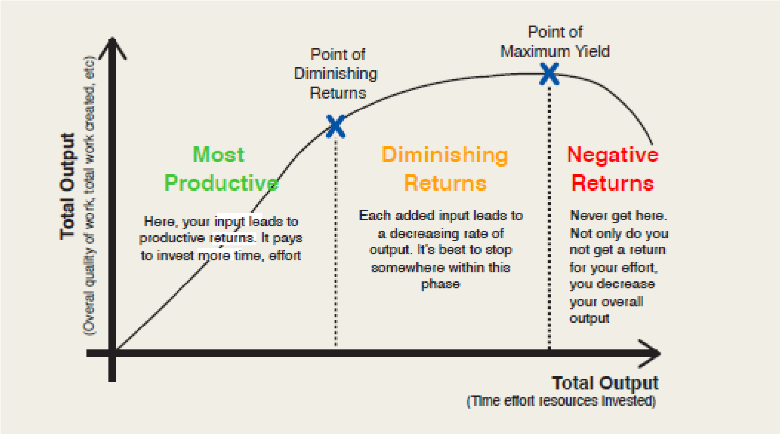

Figure 3. b) Economic and agronomic optimum level for productive use of water

For the same water input (e.g. at 5000 m3 ha-1), different levels of production could be obtained (Fig. 3a), however it is often challenging to identify which combinations best suit different environments. The economic and agronomic optimum level (Figure 3b) is an important tipping point. At a certain point, each added input leads to a decreasing rate of output and diminishing returns. It is best to stop investing more time and resources before reaching maximum yield. If properly managed in this way, livelihoods and landscapes will be more resilient to climate change. Further, improving the demand and supply side of water management, establishing longer-term data bases, and improving surveillances of system dynamics are key to optimizing water usage.

2.3 Value chains

Guiding questions

How can the value chain approach and its implementation help to develop more efficient use of water and resilient landscapes (link to integration and optimization above)?

The value chain concept is not a new concept, but agricultural water management is generally not integrated into value chain management. A value chain node, in its simplest form, is a step across clusters of activities that are interconnected, and where value is created. In summary:

- The value chain system comprises the value chain actors, service providers and the institutional environment in which the value chain operators and service providers operate.
- The institutional environment includes formal and informal institutions, policies, laws, regulations, trade agreements, customs, norms, traditions that govern the actions and interactions of value chain actors. Therefore, value-chain development requires systems thinking.
- Effective operationalization of value chains may need value chain accelerators. Value chain accelerators are interventions across value chain nodes to ensure sustainable and effective functioning of the value chain process. The accelerators involve capacity building, knowledge management and research and documentation.
- There are sequential and interconnected value-chain nodes ranging from input supply to consumption, and service provision is linked to each value chain node (Fig. 4).

Water management should be integrated into value chain nodes, such as input supply, production, post-harvest handling, processing and consumption to ensure efficient and sustainable use of water resources.

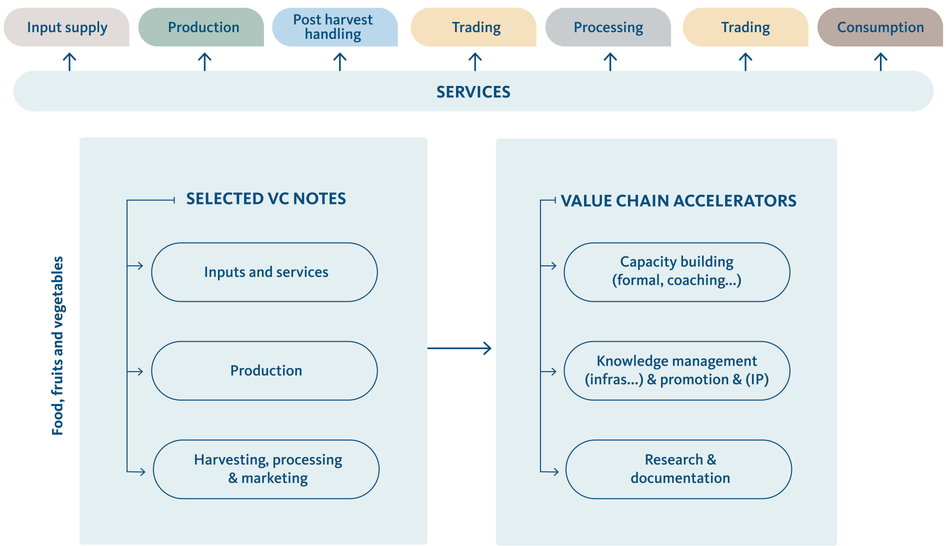

Fig. 4. Value chain nodes and value chain accelerators (Source: Haileslassie et al., 2015).

2.4 Rainfed-irrigation continuum and upstream – downstream interactions

Rainfed and irrigation systems on a landscape or watershed scale are interdependent units, although we give them different names to simplify management. Ethiopian water resource policy mainly focuses on the economic value of water. However, focusing the policies so narrowly could irrevocably damage ecosystem services that are not quantifiable or valued. Enforcement (of policies and regulations requires careful exercise of water allocation and policy frameworks. An integrated in-situ and ex-situ agricultural water management approach could be an option to minimize surface runoff and increase soil moisture (green water). Moreover, better management of agricultural water in a landscape context that supports the recharging of shallow groundwater would create an opportunity to practice irrigated agriculture at the middle and lower part of a landscape. This is an example of appropriate integration, one that ensures a rainfed-irrigation system continuum exists for sustainable agricultural production in landscapes (fig. 5).

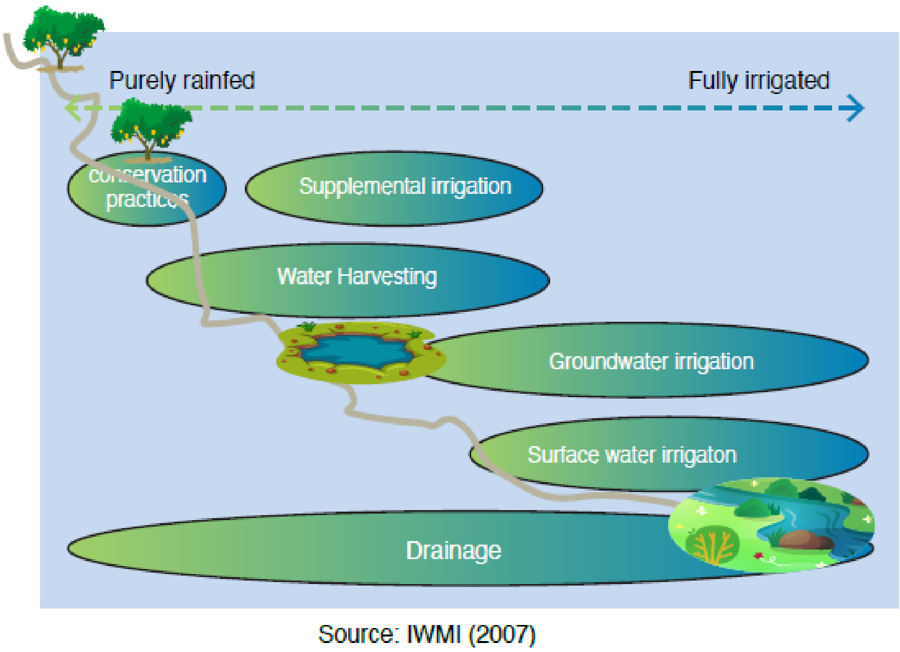

Figure 5. the rainfed and irrigation continuum across landscapes.

2.5 Agroforestry - integration of trees in agricultural landscape

Guiding questions

What are the positive effects of agroforestry on ecosystem services?

Where in a landscape would trees have the most positive effect on water ecosystem services (link to downstream-upstream interactions above)?

Agroforestry is the collective name for land-use systems and technologies that deliberately integrates woody perennials in the same land-management units as agricultural crops and/or animals, and includes some form of spatial arrangement or temporal sequence. Agroforestry is a dynamic ecological-based natural resources management system. There are both ecological and economical interactions between the different components of agroforestry systems (trees, crops and animals).

Agroforestry systems are multifunctional systems that can provide a wide range of economic, sociocultural, and environmental benefits. Through the integration of trees, agricultural landscape production can be sustained, livelihoods diversified, and incomes increased. There are three main types of agroforestry systems:

i) *Agrisilvicultural* systems are a combination of crops and trees, such as alley cropping or home gardens;
ii) *Silvopastoral* systems combine forestry and grazing of domesticated animals on pastures, rangelands or on-farm; and
iii) *Agrosylvopastoral* systems integrate all three elements, namely trees, animals and crops, and can be illustrated by home gardens involving animals as well as scattered trees on croplands used for grazing after harvests.

While trees can affect some ecosystem services positively, they can affect others negatively. Competition for nutrients, water and light are the most reported trade-offs. Tree management determines the overall effects, such as the resource use efficiency and ability to favourably modify a microclimate of a multi-functional tree species for crops (Figure 6). See also Manual 1 for an overview of the impact of trees and forests on the hydrological cycle in the landscape.

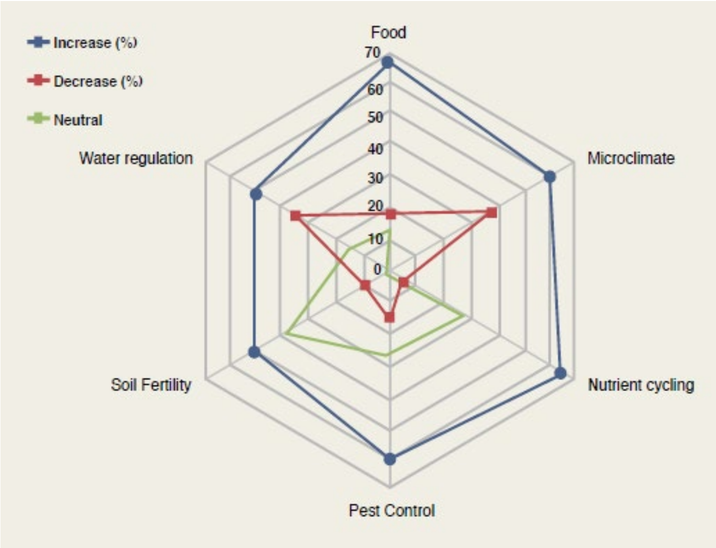

Figure 6. Proportions (%) of ecosystem services that increase and decrease by trees in Sub-Saharan Africa (Adapted from Shem et al., 2016).

3. Module 3: Sustainable agricultural landscapes

Guiding questions

What characterises sustainable agriculture?

What are the outcomes for people and nature?

What are the different domains/ groups of indicators for sustainable agricultural intensification?

3.1 Agricultural sustainability

Sustainable agriculture focuses on increasing agricultural production while having minimal effects on the environment. This type of agriculture tries to find the balance between food production needs and the preservation of an ecological system within its environment. In addition to finding this balance, there are several other overall goals associated with sustainable agriculture, including: conserving water, reducing the use of fertilizers and pesticides, and promoting biodiversity in crops grown and in the ecosystem.

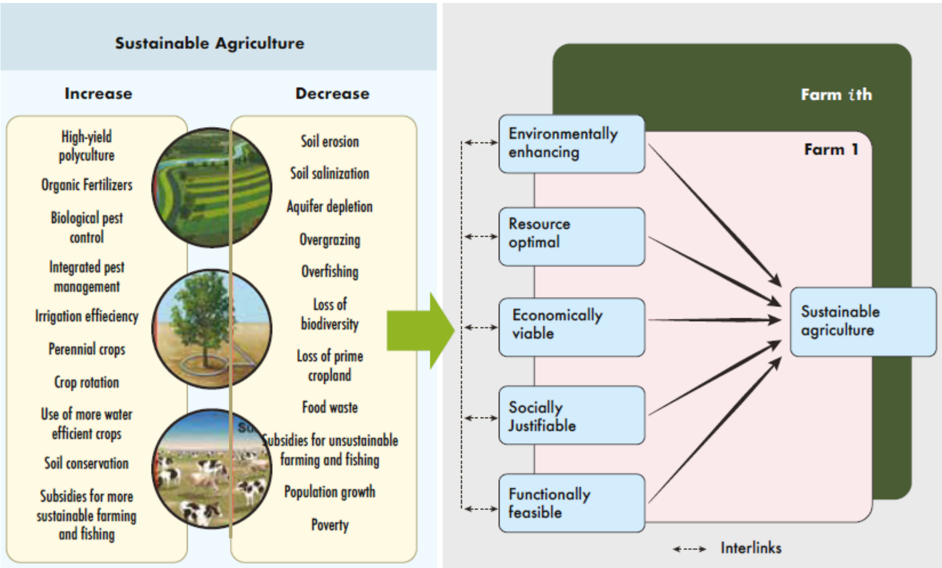

Figure 7. Sustainable agricultural practices and outcomes (Source: Tey et al., 2012)

Sustainable agriculture also focuses on maintaining economic stability of farms as well as helping farmers to improve their techniques and quality of life. There are many farming strategies that help make agriculture more sustainable. Some of the most common techniques are included in Figure 7, including outcomes and best practices.

3.2 Measuring sustainability

Sustainable agricultural intensification (SAI) utilizes indicators and associated metrics to track progress, assess trade-offs and identify synergies. SAI indicators can be organized into five domains:

1) **Productivity** is usually expressed in a variety of indicators and metrics including yield, input efficiency, water efficiency, and animal health.

2) **Economic sustainability** indicators include agricultural income and crop value. Metrics of agricultural income at the field level include net income from agriculture, disposable income losses of agricultural income due to natural disaster or changes in total agricultural income.

3) **Human well-being** is related to food and nutrition security. This is the ability of smallholders to meet their own food needs and can be measured in terms of the net production of nutrients on the farm relative to the food needs of the farming household.

4) **Environmental sustainability** includes biodiversity, carbon sequestration, soil erosion, nutrient dynamics, soil biological activity, and soil quality. In many cases, this also includes productive uses of water.

5) **Indicators for social sustainability** include information access, gender equity and youth involvement.

Although sustainability matrices and indicators are functions of time, space and the social dimension, and the five domains of SAI indicators could potentially be adopted across scales, there is no common indicator consensus. Indicator selection must be contextualized individually at this time.

4. Module 4: Water efficient and resilient landscape management technologies

Guiding questions

What is the difference between in-situ and ex-situ water management technologies?

What are the advantages and disadvantages?

Water harvesting is an important entry point to improving the productivity of dryland systems. This process could take the form of in-situ (in the original place) or ex-situ (away from the original location). Use of new technologies including subsurface soil hard-pan breaking have showed promising results, such as in reducing runoff and soil loss, increasing infiltration and overall crop yields. Technologies such as hillside micro-basins have also proved to work well, particularly on rangelands.

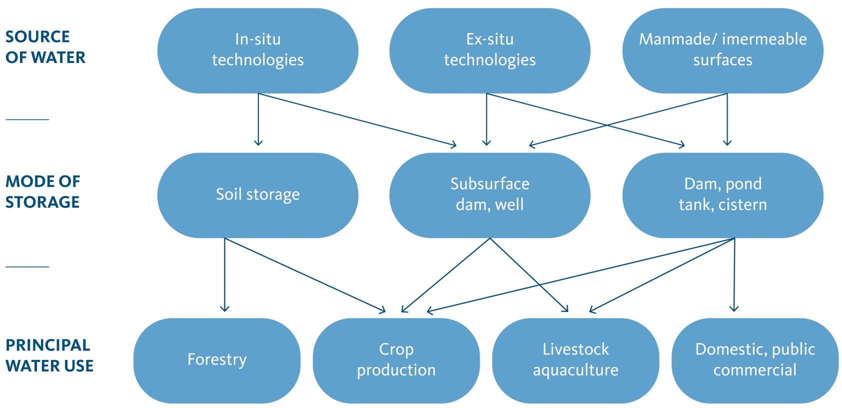

Figure 8. Sources of water, modes of storage and principal uses of water from different water management technologies (Source: Erkossa et al., 2020).

Farm ponds and micro-dams, despite positive impacts on crop production, have faced several challenges. These challenges range from siltation to seepage loss of the net harvested water. Better management of the irrigated areas could increase water saving if utilization measures and mechanisms are implemented. These examples illustrate the diversity of the impacts of water harvesting, as well as the need to improve water harvesting efforts, particularly related to macro-ponds and micro-dams. These efforts must also take future water demand into account.

4.1 In-situ water harvesting and soil and water conservation technologies

Rainwater harvesting for infiltration, also known as in-situ water harvesting, is a practice in which rainwater uptake in soils is increased through the soil surface, rooting system, and groundwater. The soil effectively acts as a storage agent, which improves water holding capacity and fertility, and reduces risks of soil loss and erosion. Common examples of water harvesting practices include trenches, terracing, pitting and conservation tillage. Due to variable and unpredictable weather patterns, these practices have served as important water sources for agriculture for centuries. They also play an important role in climate change adaptation due to increases in unpredictable weather patterns.

Apart from their predominant function of improving cropland and vegetation, water harvesting practices can also help ensure sustainable water supplies are available for livestock or domestic use by improving the recharge of nearby water-flows or ponds, as well as groundwater. More specifically, the benefits of in-situ water management include: increased infiltration, recharge, soil fertility, water holding capacity of soils, and reduced risk of soil erosion and loss (Fig. 8). Table 2 indicates the types, purposes, and management options of in-situ water management practices.

Table 2: Examples of in situ-water management technologies

Soil-water management strategy	Purpose	Management options	Management type
Soil-water management strategy	Maximize infiltration capacity of the soil	Improve topsoil conditions	-Protective surface cover: cover crops, residue, mulches against disruptive action of raindrops -No or reduced soil disturbance by tillage -Conservation agriculture -Soil amendments -Fallowing under cover crops or natural vegetation - Temporary closure of grazing land and subsequent protection
	Slow down and/or impede runoff	Improve subsoil conditions	Deep tillage: subsoiler or paraplough to break-up water restricting layers
		Improve surface roughness	-Surface cover: cover crops, residue, mulches, geotextiles -Conservation agriculture
		Apply physical structures across slope or along contour	Terracing: level terraces, bench terraces, Zingg, fanya juu, murundum, contour bund, graded channel terrace, orchard terrace

4.2 Ex-situ water harvesting technologies

In ex-situ systems, water is not collected in the soil as the storage medium. Water is stored in natural or artificial reservoirs with different dimensions, i.e. wells, ponds or cisterns, for irrigation purposes or for domestic use. In contrast to the in-situ systems, the surface of storage infrastructure has little to no infiltration capacity. Collection of rainwater in small-scale basins or on rooftops are common ex-situ methods. Rooftop collections are mainly collected for domestic purposes but can also be used for small kitchen gardens. Ex-situ rainwater harvesting practices can reduce pressure on surrounding surface water and groundwater resources, as well as on peak flows and flow durations.

5. Module 5: Lifting, conveyance, and on-farm water applications

Guiding questions

What are the advantages and disadvantages of water lifting systems?

What are the advantages and disadvantages of drip irrigation?

5.1 Solar pumps

Water supply used for drinking or irrigation purposes remains an unresolved issue in many remote areas of Ethiopia and other parts of Africa, and would require a reliable source of energy that could pump water to usable heights. Currently, diesel generators are commonly used to provide pumping power, however, they have several disadvantages including unsustainable energy sources and further exacerbate pollution when used. Diesel generators also require regular maintenance and must be frequently replaced. Solar (photovoltaic) powered water pumps (PVP) (Fig. 9) offer a promising alternative to diesel pumps, as they are powered by renewable solar energy, they are not subject to price hikes.

Figure 9. Solar pump linked to drip system in central rift valley (Photo credit: Amare Haileslassie).

Although supply of PVP can vary due to cloudy conditions, long-term consistency of use is beneficial as the time of greatest water demand usually coincides with the maximum available solar energy. Furthermore, the absence of moving parts within a PVP offers high reliability and requires little maintenance. Sub-Saharan Africa, located in the tropics, has high solar radiation making the technology of PVPs relevant and applicable. Despite these advantages, the application of PVP remains low mainly due to cost and market access. As the amount of water supplied and other costs (such as, labour, agronomic practices and related costs) differ by irrigation method, it helps to do a comparative analysis between water application methods. For example, applying the drip system would provide precision in water application, which would lead to a decrease in water loss from wind and evaporation, making the long-term advantages lower energy, operating costs, and water savings.

If a minimum land size is available, investing in solar pumps can be beneficial and profitable. The profitability of the technology depends on crop type and water delivery system. For example, the drip system is superior to the furrow and overhead systems. In general, a solar pumping system has many advantages including its negligible operating cost. A well-designed solar pump requires little maintenance beyond cleaning of the panels once a week. Although high initial investment cost is a potential barrier for smallholder farmers to adopt the technology, cost sharing can be a solution, especially if additional investment is made in drip systems where land size can increase to about half a hectare. Moreover, partnerships between key actors including rural financial institutions are essential for a positive outcome of investment in solar pumps.

5.2 Drip system

Drip irrigation is one of the most efficient methods of irrigation today. It delivers water at the plant location, frequently and at a volume of water approaching the consumptive use of the plant. The unproductive depletion (evaporative loss) is minimal, as drip system water application is at the root zone and frequent, and it therefore maintains an optimum moisture level in the soil. The term “trickle” and “drip” are interchangeably used to describe such a system. The system delivers water through a pipe distribution network using low pressure (usually less than 40 m head). Water distribution and application in the field is applied by small-diameter flexible plastic lateral pipes (LDPE) with devices called ‘emitters’ or ‘drippers’ connected at selected spacings. Drip systems are usually most suitable in areas where water is scarce. They are also the preferred water application technique for high-value crops or in areas where topographical and other conditions might preclude the successful use of other types of irrigation systems.

Some of the advantages of drip irrigation systems are that they: save water and fertilizers, decrease operating costs and reduce weed infestation due to wetting of lesser soil volume. They also enhance plant growth and yields as the soil volume is always in near-optimum conditions. As water is only applied at localized places, it is a suitable system for irrigating leafy vegetables. Further, as the application is at, or near to, the plant location, there is more control of water by the system; it avoids sensitivity to wind, evaporation from soil and plant canopy, and leaf diseases and leaf burns. Drip systems have also several agronomical and agro-technical advantages. Due to partial wetting of the soil, it suppresses weed growth and reduces compaction of the soil. The system can be operated by using less energy and reduced operating costs. The system also enables application of liquid fertilizer and pesticides with water. One disadvantages of drip systems is that the emitters are prone to clogging unless the water is filtered before it gets into the system. Further, the lateral pipes are prone to mechanical and rodent damages, and the system has no influence on the microclimate unlike the sprinkler system. As the application is more frequent, crop damage is more likely if irrigation is interrupted.

6. Module 6: Productive use of water

Guiding questions

How could crop and livestock systems be further integrated to improve water productivity in drylands?

With increasing population, change in diets, and climate change, the challenge of shrinking freshwater resources will persist. As agriculture (combined crop and livestock) withdraws the bulk of fresh water, targeting the practices of efficient use of freshwater would benefit agriculture and other sectors competing for the same water resources, particularly if single commodities (e.g crops or livestock) are targeted.

In Ethiopia and other parts of Sub-Saharan Africa, livestock and crops are highly integrated. In major highland and mid-highland areas, a significant proportion of crop residues are used for animal feed and manure inputs into the crop system, which enhances nutrient recycling. With expansion of irrigation into the pastoral system, high-level complementarity continues to increase.

6.1 Improving water productivity of crop and feed

a) Increasing plant water availability: increasing water availability is the first step in more efficiently using water. Techniques for increasing plant water availability involve soil and water conservation, water harvesting, and improving drainage. These practices improve plant water availability by reducing runoff, increasing infiltration, and more efficiently distributing water across space and time. In particular, improving drainage creates opportunities for productive uses of excess water and reduces stress (due to waterlogged conditions and limitation on oxygen availability) and thus enhances vigorous plant growth and associated water uptake. Many Ethiopian smallholders have benefited from the Broad Bed Maker (BBM) technologies; integrating ex-situ water harvesting and productive livestock breeds by planting multiple-cut, high quality forage species, provides farmers with a prolonged green fodder supply for their livestock.. Over time, this type of intervention will increase farmers' incomes and land-water productivity value manifold.

b) Enhancing plant water uptake: Plant water uptake capacity can, to a large extent, be improved through crop and soil management. By optimizing depth and density of roots, as well as the development of canopy, the proportion of water flowing as productive transpiration will be increased. In this regard, for food crops, numerous agronomic practices are possible: improved tillage, crop rotations, crop choice, intercropping, weeds and pest management, plant breeding and genetic development. If farmers in your farming systems adopt these practices, and they are relevant to fodder crops and grazing lands in rainfed smallholder systems, plant water uptake will be enhanced significantly throughout the farming system. There are several animal feed management technologies that are tested and proven to affect plant water uptake capacity. These include:

> **i) Improving species diversity and composition:** Different plant species vary in their vertical and horizontal leaves and root structures. Plants on species-diverse grazing lands and crop lands have different water depletion zones and thus less competition for water. Thus, grazing land management activities that involve frequency, seasonality, and selectivity of grazing affect species diversity and thereby plant water uptake capacity.
>
> **ii) Grazing land management:** Grazing intensity is key to affecting plant species composition and biomass. Plots with moderate grazing display a better overall plant composition and productivity. It has been shown that grazing land enclosures can improve the biomass yields and therefore livestock water productivity, however such practices may increase species richness to a certain level and enclosed grazing lands may experience a decline in species diversity with time. This may question the long-term sustainability of such practices on system water productivity (WP) in general and Livestock water productivity (LWP) in particular.

c) Productive and more nutritive species: If the goal of increasing plant water uptake is to improve LWP, species selection (for diversity) productivity and feed values must be considered as criterion. Over the past decades, considerable efforts have been made to improve dry matter (DM) yields and the quality of forage species in grazing lands in Ethiopia. Among the selected grass species, Rodes grass (Chloris gayana) Guinea grass (Panicum maximum) and Napier grass (Pennisetum purpureum) are highly productive, with their annual DM yields ranging between 10 and 15 Mg ha-1. Moreover, in suitable areas, yields of oat-vetch mixtures commonly yield more than 8 Mg ha-1 and that of fodder beet ranged from 15-20 Mg ha-1. Focusing on those high yielding varieties can reduce competition for space with food crops. Among forage legumes, spurred butterfly pea (Centrosema virginianum) and cowpeas (Vigna unguiculata) have been identified as potential species for cut and carry systems of feeding, as these are good to plant on farm boundaries and also on physical conservation structures to conserve soil and water. Species recommended for under-sowing in perennial cash crops (e.g. coffee) or cereals (e.g. maize and sorghum) are Desmondium (Desmodium intortum, and Desmodium uncinatum) and Rhodes grass. In addition to the grasses and legumes, useful browse species for the purpose of hedge planting include: pigeon pea (Cajanus cajan), glricidia (Glricidia sepium) and, sesbania (Sesbainia susba) and leucena (Leucena leucocephala).

d) Soil fertility management: Soil fertility management is an important intervention for crop lands or grazing lands, andincludes physical, chemical and biological management. It requires vigorous plant growth and better water uptake. In many farming systems, soil acidity, alkalinity, and nutrient depletion are common issues. While fertilizer trials are common for crop land, application and research on fertilizer for grazing lands is rare. A significant question remains, whether fertilizer on grazing lands would pay off under current levels of animal productivity. There are promising results on the effects of stages of harvesting and the application of N fertilizer on the DM yield of natural pastures. Fertilizer application increased the DM yield by 36% and crude protein (CP) by 11.89%. In this respect, the relationship between nutrient supply and water uptake are inter-connected. For example, under low-nutrient conditions, pearl millet evapotranspiration efficiencies are roughly one-third of those obtained under higher nutrient input. This suggests that transpiration efficiency is also reduced by environmental stress such as poor soil fertility and acidity. Integration of legume and cereal fodder crops will have multiple effects, such as improving the feed quality (e.g. CP) and increasing the DM yields through improved nutrient inputs and better water uptake.

Summary

Increasing population and climate change are putting pressure on scarce freshwater resources. Predictions show that many African countries will be under economic distress and have physical water scarcity by 2030. Productive use of water and land is necessary to build resilient landscapes. Productive use of water is a process that combines different steps of adaptive management.

Approaches to water production and resilient landscape are diverse and can be very complicated. In many cases, they are context specific, and the approach chosen must be relevant to the context. Thus, this training manual focuses on approaches that complement each other, where water is a production input (e.g. system/livelihood), appears as an interface and medium of material flows between landscape (rainfed, irrigation continuum) components (upstream, downstream, upper slope, mid-slope and valley bottom), and keeps the landscape components connected. Some of these approaches can also facilitate landscape connectivity (e.g. value chain approach).

Sources and further reading

- Alemayehu, M., Peden, D., Taddese, G., Haileselassie A., Ayalneh, W., 2008. Livestock water productivity in relation to natural resource management in mixed crop-livestock production systems of the Blue Nile River Basin, Ethiopia. In: Humphreys, E., Bayot, R.S., van Brakel, M., Gichuki, F., Svendsen, M., White, D., Wester, P., Huber-Lee, A., Cook, S., Douthwaite, B., Hoanh, C.T., Johnson, N., Nguyen-Khoa, S., Vidal, A., MacIntyre, I., and MacIntyre, R. (Editors), 2008. Fighting Poverty through Sustainable Water Use: Volumes II. Proceedings of the CGIAR Challenge Program on Water and Food, 2nd International Forum on Water and Food, Addis Ababa, Ethiopia, November 10-14, 2008. The CGIAR Challenge Program on Water and Food, Colombo. 297pp. Balint, P.J., Stewart, R.E., Desai, A. & Walter, L.C., 2011. Wicked Environmental Problems: Managing Uncertainty and Conflict. Island Press, Washington D.C.
- Erkossa, T., Haileslassie, A., & MacAlister, C., 2014. Enhancing farming system water productivity through alternative land use and water management in vertisol areas of Ethiopian Blue Nile Basin (Abay). Agricultural Water Management, 132, 120–128.
- Gebremedhin B.; Tesfamichael G.; Kristine M.; Walraevens K., 2016. Overview of micro-dam reservoirs (MDR) in Tigray (northern Ethiopia): Challenges and benefits. Journal of African Earth Sciences 123:210–222.
- Haileslassie, A., Peden, D., Gebreselassie, S., Amede, T., Descheemaeker, D.,2009. Livestock water productivity in mixed crop–livestock farming systems of the Blue Nile basin: Assessing variability and prospects for improvement. Agricultural systems, 102, 1-3:33-40.
- Haileslassie, A. & Duncan, A., Peden, D., 2015. Strategies to integrate livestock into agricultural rainwater management: an example from mixed crop livestock systems in the Blue Nile Basin. 10.13140/RG.2.1.2304.5841.
- Haileslassie, A., Mekuria, W., Tengberg, A., 2020. Water Productive and Resilient Landscape Management Technologies and Approaches – training manual. June 2020, SIWI & IWMI.
- Lulseged G. Hiwot and Tadesse, A., 1985. Pasture Research and Development in Ethiopia. In: Kategile 1985 (ed.). Pasture Improvement Research in Eastern and Southern Africa. Proceedings of a Workshop held

in Harare, Zimbabwe, 17 – 21 September 1984. Ottawa, Ont., IDRC, 1985. 508 p.

- Rockström, J. Barron J.,2007. Water productivity in rain fed systems: overview of challenges and analysis of oprtunities in water scarcity prone savannahs. Irrig Sci 25:299–311.
- Shem K., Öborn, I., Jonsson, M., Dahlin, et al., 2016. Trees in agricultural landscapes enhance provision of ecosystem services in Sub-Saharan Africa, International Journal of Biodiversity Science, Ecosystem Services & Management, 12:4, 255-273, DOI: 10.1080/21513732.2016.1214178.
- Shibeshi, A. Birhanu, B. Alemayehu, M. Fantaw, Y. Haileslassie, A., 2016. Rainwater harvesting for supplemental irrigation of onions in the southern dry lands of Ethiopia , Agricultural Water Management 178:325-334.
- Smith A., Snapp S., Chikowo R., Thorne P., Bekunda M., Glover, J., 2017. Measuring sustainable intensification in smallholder agroecosystems: A review. Global Food Security 12: 127-138.
- Tey, Yeong Sheng and Li, Elton & Bruwer, Johan & Abdullah, Amin & Cummins, Jay & Radam, Alias & Ismail, Mohd & Darham, Suryani. (2012). Refining the Definition of Sustainable Agriculture: An Inclusive Perspective from the Malaysian Vegetable Sector. Maejo International Journal of Science and Technology. 6. 379-396. 10.14456/mijst.2012.2.
- The Montpellier Panel. Sustainable intensification: a new paradigm for African agriculture. (Agriculture for Impact, Imperial College, London, 2013).

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