# Resilience Design in Smallholder Farming Systems

## *A Practical Approach to Strengthening Farmer Resilience to Shocks and Stresses*

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Led by Save the Children, The TOPS Program draws on the expertise of its consortium partners: CORE Group (knowledge management), Food for the Hungry (social and behavioral change), Mercy Corps (agriculture and natural resource management), and TANGO International (monitoring and evaluation). Save the Children brings its experience and expertise in commodity management, gender, and nutrition and food technology, as well as the management of this 7-year (2010–2017) US$30 million award.

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# Abbreviations and Acronyms

| | |
|---|---|
| **ºC** | degrees Centigrade |
| **CRA** | climate-resilient agriculture |
| **CSA** | climate-smart agriculture |
| **GPS** | global positioning system |
| **HDD** | household dietary diversity |
| **M&E** | monitoring and evaluation |
| **mm** | millimeters |
| **MSC** | most significant change |
| **pH** | potential of hydrogen, a figure expressing acidity or alkalinity |
| **PIA** | participatory impact assessment |
| **PRA** | participatory rural appraisal |
| **RD** | resilience design in smallholder farming systems |
| **TOPS** | Technical and Operational Performance Support [as in The TOPS Program] |
| **USAID** | The United States Agency for International Development |

# Contents

# Executive Summary

The *Resilience Design (RD) in Smallholder Farming Systems* approach evolved from initial discussions at a TOPS Symposium on Agroecological Principles, Design and Practice in Washington, DC in January 2015, designed to improve agricultural programming in USAID/FFP programs. The two-day event brought together experts and practitioners to share knowledge on building resilience in smallholder farming systems. The RD approach builds from those initial discussions, combining elements from agroecology, permaculture, climate-smart agriculture, conservation agriculture, and bio-intensive methods, into a practical process that can be layered into existing activities within the development context.

The RD approach asks farmers to seek a deeper understanding of their farming systems within their agroecosystems to create a better farm design that optimizes the use of and enhances available resources over the long term and in response to external changes. It seeks to strengthen the resilience of smallholder farmers and their farming systems to environmental and economic shocks and stresses through: enhancing natural resources and ecosystem services; increasing energy efficiency; increasing income; contributing to increased nutritional status; and strengthening the skill set, adaptability and confidence of smallholder famers.

The RD approach methodology described in the following sections is a four-step, continual feedback loop that starts with engaging farmers and the local community, placing them at the center of the learning process. Together, field agents and farmers: (1) observe and assess what already exists within the farming system, then (2) analyze that information, and (3) design their land to create a more resilient farming system. Over time, as environmental conditions change, farmers (4) integrate feedback and adjust their practices accordingly. This ability to observe, learn, and adapt is the key to long-term resilience and enables the application of the approach at different levels (garden, farm, community, and watershed).

The RD approach is not the solution to all challenges a smallholder farmer faces when building resilience. Rather, it is designed to work with and complement additional ecological, economic and social interventions, and should be implemented in conjunction with other development activities.

Using the RD approach encourages farmers and those who support them to think differently about agricultural development and identify ways to work *with* natural systems rather than against them, resulting in a more resilient and productive farming system.

# How to Use This Toolkit

The Resilience Design (RD) in Smallholder Farming Systems Toolkit consists of the RD approach, seven brief tip sheets that summarize key sections of the toolkit, the RD measurement toolkit, and a summary video. The RD approach (this publication) includes an overview, detailed guidance on the four steps, and technical guidance on improving soil health and water management.

The background and overview of the approach are distinguished by the green section at the beginning of the toolkit. Colored sections (blue, orange, red, and brown) then indicate Steps 1 through 4, which outline the RD approach in practice. Each of those sections starts with a brief concept summary of the theory associated with the step, followed by the methodology that demonstrates the practical implementation of each step. Following the four steps, there are two technical guidance sections which provide details about the importance of increasing soil health (patterned brown color) and water management (patterned blue color) together with illustrations of how this can be achieved using the RD approach. Finally, a glossary and endnotes are provided. A number of short tip sheets are available separately. These sheets are designed for use in the field to provide field agent and farmers with a short overview of the different steps, as well as key information on the RD principles and techniques. The RD measurement toolkit, also available separately, provides detailed guidance on measuring impact of the RD approach. The RD video, provides a visual overview of the key elements of the approach.

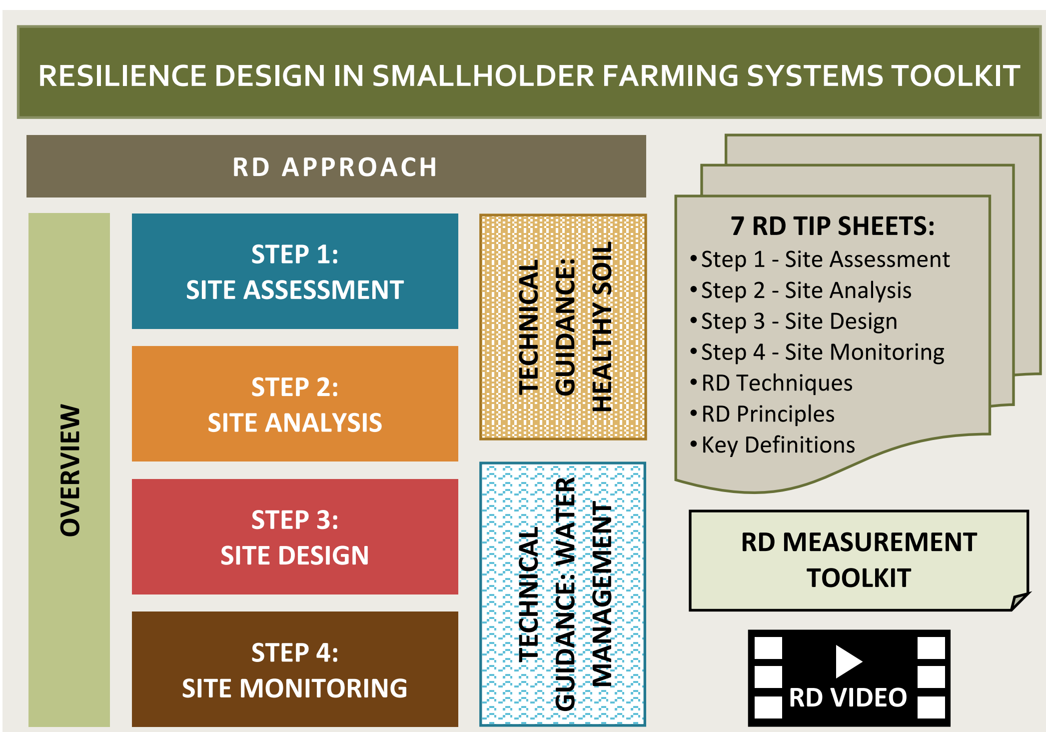



Photo: Talitha Brauer, Save the Children

# The Importance of Building Resilience in Smallholder Farming Systems

## Smallholder Farmers and Resilience

Smallholder farmers typically farm a small land area, usually defined as less than 2 hectares[1] but often less than 0.5 hectares. They generally grow subsistence crops for home consumption, sometimes complemented by a few cash crops. In the developing world smallholder farmers produce most of the food that is consumed in-country, making them important actors in the national economy.

In addition to the small size of their landholding, which limits their potential for economies of scale, smallholder farmers face many challenges in providing food and income for their households. These include insecure land tenure, poor soils, limited (or too much) water, limited access to inputs (e.g., seeds), limited access to capital, and poor linkages with markets.

All these challenges and obstacles leave smallholder farmers and their farming systems particularly vulnerable to shocks and stresses. **Shocks** are discrete events that tend to be relatively short term and easy to identify.

They range from low-intensity shocks with gradual onsets (e.g., drought) to more intense and sudden onset shocks (e.g., earthquakes). **Stresses** are conditions or pressures that grow more slowly and erode development progress over time, such as erratic rainfall, chronic malnutrition or ongoing community conflicts.[3]

> The definition of a **farming system** varies. It is sometimes referred to as farm units that preserve the resource base and maintain a high level of environmental quality, or a population of individual farm systems. For simplicity, this document uses the definition by Fresco and Westphal; "a decision making unit comprising the farm household, cropping and livestock system that transform land, capital and labor into useful products that can be consumed or sold."[2]

Shocks and stresses affect smallholder farmers in different ways depending on the type or scale of the shock or stress and the existing vulnerability of their farming system. Shocks and stresses also tend to have a compounding effect; for example, livestock already weakened by lack of food due to drought would be more prone to disease.[4]

The following table summarizes the different man-made or naturally occurring types of shocks and stresses and their effects on smallholder farmers and their farming systems.

| Typical Shocks & Stresses Affecting Smallholder Farmers and Their Farming Systems | | | |
|---|---|---|---|
| **Type of Shock or Stress** | **Example of Shocks** | **Example of Stresses** | **Where Shocks or Stresses Impact** |
| **Climatic and Environmental** | Drought, floods, earthquakes, cyclones, pest and disease epidemics | Erratic rainfall, land degradation, reduction in groundwater | Production, infrastructure, personal property and assets, markets, food consumption |
| **Economic** | Financial crises, sudden food price change, job loss, loss of remittances | Price instability | Labor demand, asset holdings, food consumption, market functions, food and commodity prices |
| **Social** | Conflict, changes in policies, land eviction | Persistent conflict | Income generating ability, infrastructure, assets, food consumption |
| **Health** | Serious illness, injury, death | Long term malnutrition, mental health | Productivity, income generating ability, level of assests, food consumption |

In particular, the onset of climate change,[5] including the size and frequency of changes associated with rising temperatures, changing rainfall patterns and further climate variability—coupled with human-caused factors such as urbanization and deforestation[6]—are exacerbating the challenges that smallholder farmers face. To secure their future in this rapidly changing world, smallholder farmers need to ensure their farming systems are **resilient** to continuous and increasing shocks and stresses.

Photo: Andrea Mottram, Mercy Corps

***Deforestation, Nepal.***

Resilience is defined by USAID as "the ability of people, households, communities, countries and systems to mitigate, adapt to and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth."[7] The following table summarizes the strategies that smallholder farmers can adopt to build the resilience of their farming systems to shocks and stresses.

| Three Key Ways to Build Resilience of Smallholder Farming Systems: ABSORB, ADAPT, TRANSFORM | | |
|---|---|---|
| **1. Increase the ABSORPTIVE CAPACITY of the system** | **2. Increase the ADAPTIVE CAPACITY of the system** | **3. Increase the TRANSFORMATIVE CAPACITY of the system** |
| Absorptive capacity is the ability to prepare for, mitigate, or prevent negative impacts. Predetermined plans and coping responses are developed in order to preserve and restore essential basic structures and functions in the face of a shock or stress. | Adaptive capacity is the ability to adjust to changes in the system or modify characteristics of a system so that it can continue to function. This requires building capacity not just for existing shocks and stresses, but also for future changes and an evolving context. | Transformative capacity is ability to create a new system when ecological, economic or social structures make the existing system untenable. |
| Planting drought-tolerant crops and varieties and improving water-harvesting structures to capture and store water are two examples of building absorptive capacity to deal with drought. | Diversifying crops and types of livestock within the farming system is an example of increasing adaptive capabilities in the face of long-term climactic and environmental shocks and stresses. | Transforming the way natural resources are managed by changing basic attitudes about the role and partnership of different community groups is an example of a transformative adaptation. |

# Challenges of Building Long-Term Resilience

Building smallholder farmers' ability to effectively absorb, adapt and transform in the face of shocks and stresses is key to improving their overall development outcomes. While there exist many different approaches pioneered by development organizations to improve agricultural, market, food, financial, and social systems, as well as policy frameworks, most agricultural interventions tend to be centered on one part of the problem and may employ only a limited selection of agricultural techniques.

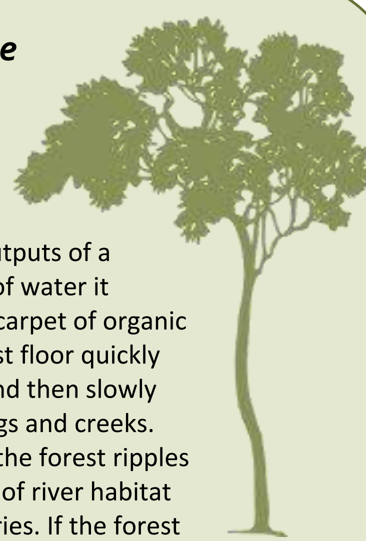
Many of these interventions aimed at improving agricultural production fail to take into account the context within which the smallholder operates, the extensive web of connections that exist between the various resources and influences that affect the farming system, and the broader ecosystem and its ecosystem services.

An **ecosystem** is a biological community of interacting organisms and their physical environment. **Ecosystem services** are the benefits provided by the ecosystem to humans. These benefits can be: **supporting services** (e.g., soil formation, nutrient cycling, primary production); **provisioning services** (e.g., food, fresh water, wood for fuel, fiber, biochemicals, genetic resources); **regulating services** (e.g., climate regulation, disease regulation, water regulation, water purification, pollination); and **cultural services** (e.g., spiritual and religious, recreational and ecotourism-related, aesthetic, inspirational, educational).[9]

An **agroecosystem** is an ecosystem under agricultural management, connected to other ecosystems.[10] The farming system (made up of a household, crops and livestock, vegetable garden and fields) sits within a watershed (a basin drained by a river or river system) and a broader landscape, all of which are supported by ecosystem functions and services. Systems are thus nested within each other, and the connections and interactions between them are constantly and dynamically changing.

Any intervention aimed at fostering long-term resilience needs to consider

### *The tree in the forest*



"A tree is a member of a larger community called a forest. One of the outputs of a forest is the quality of water it produces. The thick carpet of organic material on the forest floor quickly absorbs rainwater and then slowly releases it into springs and creeks. This contribution of the forest ripples outward in the form of river habitat and abundant estuaries. If the forest is compromised or lost, then the negative effects also flow downstream. Rainwater fails to absorb into soils and runs off too quickly into creeks and streams. This creates flooding and erosion, which degrade the aquatic habitats."[8]

the farming system and the watershed as parts of a dynamic and fluid agroecosystem. Building true resilience requires a deep understanding of the relationships between the different systems and how changes in one affect the others. The more conscious and supportive the connections are both within and between systems, the more vibrant and resilient the overall agroecosystem will be.

While interventions and activities that focus on just one part of the overarching system may improve production in the *short term*, the resilience of the system is limited if the ecosystem functions and services that are needed to support production over the *long term* are ignored. For smallholder farming systems to achieve long-term resilience to shocks and stresses, program activities must facilitate the development of the smallholder farming system as part of a **living, interconnected agroecosystem**.

Photo: Emily Wei, Mercy Corps

***An agroecosystem in Guatemala.***

***Example: Connections and Relationships***

The health of a garden or field might affect the health of the farm on which it is located. The field may absorb rainfall to irrigate it and the downslope fields for free (adding value), or it might drain most of the rainfall, drying the soil and flooding and eroding downstream areas (subtracting value). The health or condition of the farm in turn affects the health of the surrounding community and the health of the community's watershed, its groundwater, and how long into the dry season water is available from its borehole.

Photo: Benny Manser, Mercy Corps

# The Resilience Design (RD) in Smallholder Farming Systems Approach

## Overview and Aims

The RD approach helps smallholder farmers, and those who work with them, to think more broadly about their farming systems **within their agroecosystems**. It asks farmers to take a wider view and seek a deeper understanding of their farms and surrounding systems in order to better design a farming system that optimizes the use of, and enhances available resources over the long term and in response to environmental changes.

The goal of the RD approach is to **strengthen the resilience of smallholder farmers and their farming systems to environmental and economic shocks and stresses through improved farm design**. To meet this goal the RD approach has five main aims.

**Ecological** – Enhance natural resources and ecosystem services by improving soil and water health, increasing biodiversity, and reducing erosion

**Energy** – Increase energy efficiency by improving farm design to maximize the efficiencies of an integrated system and reduce time and energy spent tending crops and animals

**Social** – Strengthen the skill set, adapta-bility, and confidence of smallholder farmers by enabling them to understand the connections between their farm, community and watershed, maximize resources, and leverage natural influences to improve their farming systems

**Economic** – Increase income by reducing input costs and diversifying and intensifying production

**Nutritional** – Contribute to increased nutritional status by increasing soil biology, increasing access to a diverse diet, and improving critical nutrient uptake from the diet

The RD Approach draws elements from and builds on a number of well-known and tested approaches:

- It is based on the practice and principles of **agroecology**, the application of ecological concepts and principles to the design and management of sustainable agroecosystems.[11]
- It replicates the design elements of **permaculture**, a design science and methodology which copies or directly uses the patterns and features observed in natural ecosystems.[12]
- It incorporates **conservation agriculture practices** that focus on increased and sustained production levels while minimizing the disruption of soil structure and natural biodiversity to conserve the environment.[13]
- It is influenced by **climate-smart agriculture** that focuses on transforming and reorienting agricultural systems to support development outcomes and ensure food security under changing climatic conditions.[14]
- It integrates **bio-intensive methods** to achieve maximum yields from minimum land areas, while increasing biodiversity and sustaining the fertility of the soil.[15]

The RD approach combines elements from all of these approaches into a practical process that can be layered into existing activities within the development context.

The RD approach is not the solution to all challenges the smallholder farmer faces when building resilience. Rather, it is **designed to work with and complement additional ecological, economic and social interventions.** It should be implemented in conjunction with other development programs, including: landscape- and watershed-management approaches that address issues such as land conservation; market development approaches that address market system challenges and extend market opportunities to smallholder farmers; and governance and community development approaches that address underlying causes of land-tenure issues and social pressures.

# Key Elements

The RD approach incorporates the following key elements in the application of its methodology (described in the following section). The RD approach:

**Focuses on improving soil health and water management.** Soil and water are the two most important resources for agricultural production and are often mismanaged or underutilized. Farmers can increase their resilience over the long term by increasing the capacity of the soil to sustain plant and animal productivity, and by maximizing water availability.

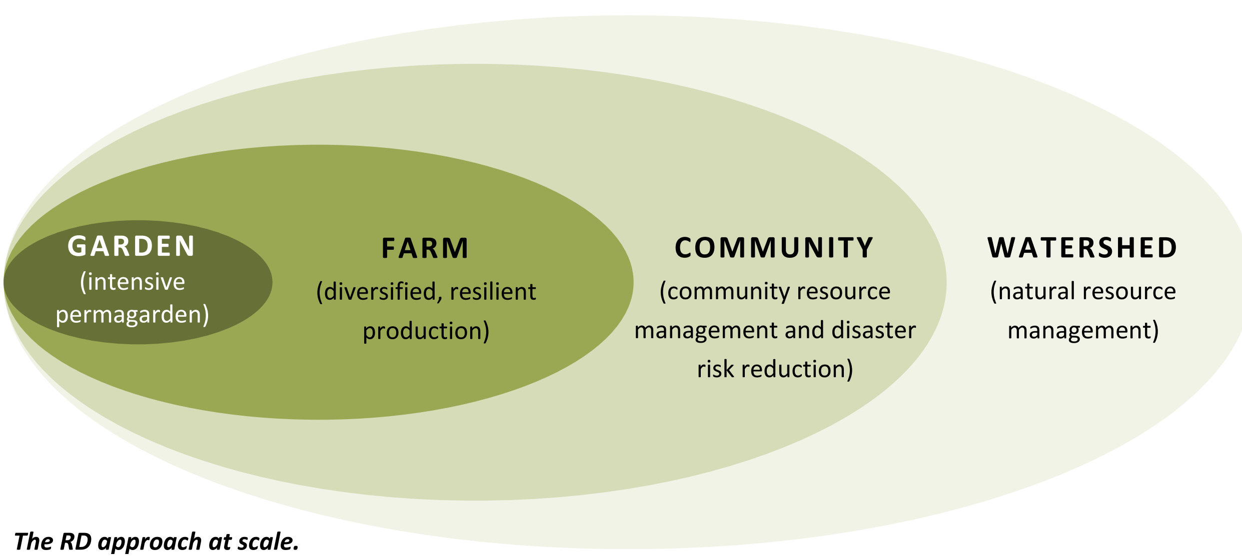
Technical guidance on the importance of soil health and water management, and how to improve them through the RD approach, is detailed in the technical guidance sections pages 61-106.

**Uses an integrated design process that is site and context-specific.** The RD approach does not provide a prescribed set of techniques for every situation but rather follows a design process that is informed and shaped by the unique characteristics, opportunities and challenges of each farming system. As well as deep observation and analysis of the local context, the approach uses **guiding principles** to develop a more integrated site design in relationship to its unique community and watershed. These ten RD principles are revisited continually over time to ensure the site is adjusted as external conditions change.

More detail on the RD principles and how they are used is described in Step 3 of the RD approach on pages 37-53.

**Can be applied at various scales for different and combined outcomes.** The RD approach can address the differing needs of the garden, whole farm, community and watershed for optimal site design:

- At the garden level, the RD approach is adapted to increase production on a small scale; the permagarden method[16] is an example of the approach at this level.
- At the farm level, the RD approach is used to diversify and develop more resilient agriculture; this RD toolkit focuses at this level.
- At the community level, the RD approach is used to strengthen communal community resources such as recharging boreholes and animal watering holes.
- At the watershed level, the RD approach is used to improve the management of ecosystems such as degraded grazing lands.




***The RD approach at scale.***

**Views the farming system through a regenerative lens.** The RD approach considers how farming investments can produce more resources than they consume. Three types of investments – degenerative, generative, and regenerative – are described in the table below. While resilient systems can have, and often do have, all three types of investments, the overall resilience of the system increases with more regenerative investments.

<table>
<tr><th colspan="3">Characteristics of Degenerative, Generative, and Regenerative Investments</th></tr>
<tr><th>A degenerative investment:</th><th>A generative investment:</th><th>A regenerative investment:</th></tr>
<tr>
<td>• Starts to degrade or break down as soon as it is made<br>• Requires ongoing investments of energy and outside inputs to keep it functional<br>• Consumes more resources than it produces<br>• Degrades the health of its surroundings<br>• Typically serves only one function</td>
<td>• Starts to degrade as soon as it is made, but can be used to make or repair other investments (as is the case with tools)<br>• Requires ongoing investments of energy and outside inputs to keep it functional<br>• Produces more resources than it consumes<br>• Conserves other resources<br>• Typically serves multiple functions</td>
<td>• Can repair, reproduce, and/or regenerate itself – starts to grow or improve once it is made<br>• Does not require ongoing investments of imported energy and outside inputs to keep it functional<br>• Produces more resources than it consumes<br>• Improves the health of its surroundings<br>• Typically serves multiple functions</td>
</tr>
<tr><th colspan="3">Examples:</th></tr>
<tr>
<td>Off-contour planting/cropping resulting in bare furrows running downslope and hastening erosion of the land.</td>
<td>Contour planting/cropping resulting in furrows that capture and infiltrate rainfall and runoff, thus reducing erosion.</td>
<td>Contour planting/cropping of perennial species well-adapted to the local climate that will repair and reproduce themselves.</td>
</tr>
<tr>
<td>Monoculture gardens and farms producing a single crop dependent on imported chemical pesticides, fertilizers, and pumped or imported water, contributing to water extraction rates that exceed natural water recharge rates and dry out wells.</td>
<td>Polyculture gardens and farms producing many different crops (including animals) producing multiple resources such as diverse foods harvested at different times throughout the year, medicines, and building materials.<br><br>Using multiple water-harvesting strategies that increase the recycling and accessibility of free, on-site water resources, while conserving overall regional waters and other resources.</td>
<td>Polyculture gardens, farms, orchards, and natural forests and grasslands producing many diverse crops while also:<br>• Growing their own pest control (e.g., pest-trap plants)<br>• Growing their own fertilizers (e.g., nitrogen-fixing plants)<br>• Growing their own shelter (e.g., windbreaks, living fences)<br>• Increasing water management to enhances water resources over time</td>
</tr>
</table>

**Strengthens farmer capacity and innovation.** To ensure long-term success and replication, the RD approach facilitates farmers to design their farming system through better understanding their location, its resources and influences. The approach helps farmers build a holistic overview and understanding of their farming system and then test and select the appropriate mix of agricultural techniques and innovations that are best suited and adapted to their particular context.

**Encourages adaptation**. The RD approach helps farmers develop critical thinking skills that will assist them to identify ways to adapt to changing conditions in the agroecosystem. A monitoring and feedback loop built into the approach helps to identify constraints and opportunities that farmers can address to continuously optimize their farming systems over time.

**Involves a wide range of stakeholders and communities.** A critical component of the successful RD approach is involving farmers and their communities, as well as other stakeholders that influence or are influenced by activities on the farm and may be involved in complementary programs. Linking activities ensures improved understanding of the local context to inform site design, improved relationships between different community members that share the same resources, increased uptake of the knowledge beyond the farmer for broader, more systemic change over the long term, and the ability to leverage other project outcomes for improved development.

***Example of the RD approach in practice***

Soil health is influenced by many factors, one of which is temperature. The temperature of the soil affects the production of the plants growing there. If soil temperature rises above 37°C, the microorganisms, or living things, in the soil do not function as well, or die. Microorganisms are critical within the soil, as they help develop good soil structure and help plants take up macro- and micro-nutrients. Cooler soils also allow water to sink further down into the root zone of the plants.

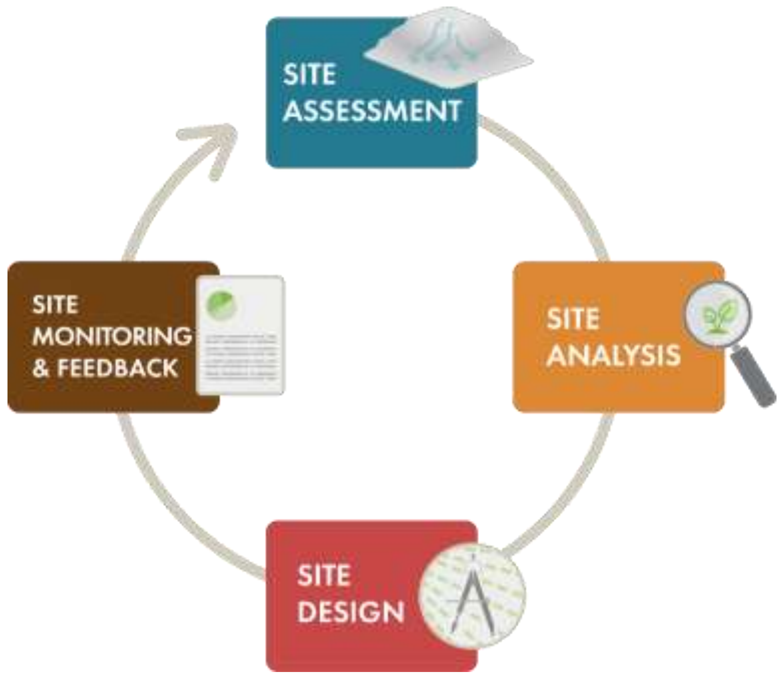
Farmers using the RD approach would design their farm sites to take into account the aspect of the slope to the sun, the availability of shade from trees, mulch availability, and more. At the same time, since rainwater is the ultimate source of groundwater that recharges boreholes required by the household and for agriculture, farmers would identify where and how rainwater is draining away, and how they can design their site to enable the infiltration and storage of rainwater in their soils. This helps keep soils cooler, provides moisture for plants, and recharges the borehole. Farmers would also identify opportunities to redirect storm water off roads and paths to areas of vegetation to help absorb and bank it in the ground, rather than eroding the roads and paths.

# Applying the RD Approach

Photo: Andrea Mottram, Mercy Corps

The RD approach methodology is a four-step continual feedback loop that starts with engaging farmers and the local community and placing them at the center of the learning process. Together, field agents and farmers **observe and assess** what already exists on the farm site, then work through an **analysis and design process** to create a more resilient farming system. Over time, as environmental conditions change, farmers **integrate feedback** and adjust their practices accordingly. This ability to observe, learn, and adapt, built in to the RD approach, is key to long-term resilience.

# Four Steps of the RD Approach




**1. Site Assessment**: Observe key resources and natural influences that impact the farm site, both within the farm and within its interdependent landscape. Assess external influences that affect the site, including social or economic factors.

**2. Site Analysis**: Analyze the resources and influences identified in the site assessment to understand the effects they have on the farm.

**3. Site Design**: Using the information from the site assessment and site analysis, design the farm for maximum resilience. Incorporate the RD guiding principles to inform resource placement and choice of agricultural techniques.

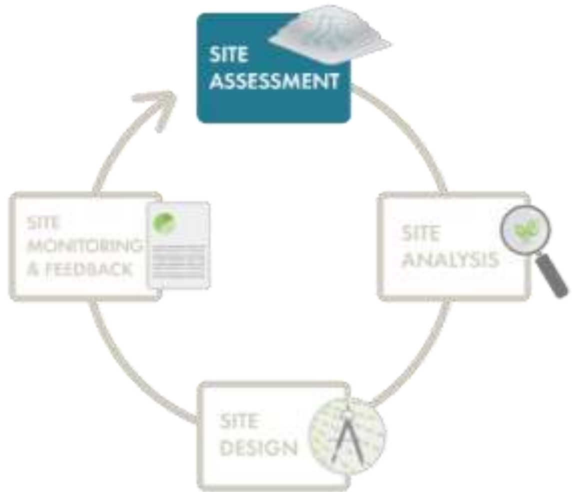
**4. Site Monitoring and Feedback**: Continually monitor the site and the influences affecting it to ensure that the selection and design of techniques is dynamic and responsive.

By understanding and applying these four core steps, farmers are better able to continually adapt their farming system in response to shocks and stresses and to rely less on external guidance.

The following sections provide more detail on each of these four steps, outlining both the theory behind each step and how each step is implemented on the ground. Further details on the practical methodology of each step are provided in the additional *technical guidance sections* on Healthy Soil, and Water Management.

Photo: Colin Crowley, Save the Children

# Step 1: Site Assessment – Engaging, Observing, and Gathering Data




**Aim: Engage farmers and the community to observe the farm site, identify available resources and influences that affect it, understand farm practices, and gain a deeper knowledge of the site.**

Photo: Andrea Mottram, Mercy Corps

***Assessing a farm site in Zimbabwe.***

## Concept Summary: Site Assessment

A good site assessment is a critical first step in gathering the information that will enable farmers to make the decisions about their farming system site design that will increase sustainable production and overall farm resilience.

The RD site assessment is structured around a series of participatory activities designed to identify and map resources and external influences that affect a particular farming system. It is carried out through careful observation and facilitated discussions with farmers, and builds on their knowledge of current farm practices and any cultural or social factors that may affect agricultural production. It also provides for the incorporation of additional information and data that may be obtained from outside sources that will enable the farmer to create a complete picture of their farming system within its wider context. The information gathered during this process will inform the analyses, design, and decision-making in the subsequent steps of the RD approach.

The essence of the RD approach is to work *with* the natural agroecosystem and not against it. Farmers, and those supporting farming systems development, must be able to identify **resources** within the farming system and the **external influences** that affect it.

A **resource** is an element or supply that benefits a site; it includes **natural resources** (e.g., land, soil, water); **man-made resources** (e.g., farm buildings, human labor), and **agriculturally-derived resources** (e.g., food products, mulch).

The RD approach encourages farmers to think broadly and with innovation about available resources and their uses, for example; Could weeds be used as a resource in hot compost? Could waste water be used as a resource in the garden or fields? Could trees be used as a resource in mulch or animal feed, or for protection from wind?  Ensuring farmers recognize and use all available resources—ranging from those on the farm and in the community to those within the broader agroecosystem—will guide a site design that ensures long-term resilience.

**External influences**[17] include any element that impacts the farm site, either **natural** (e.g., sun, wind) or **man-made** (e.g., roads, agricultural incentives). Influences can have positive or negative effects. For example, the sun can provide warmth and light in cold months but be hot and drying in hot months; the wind can bring resources (such as nitrogen-rich leaf litter) or be strong and damaging; water flow over the land can bring water and nutrients or be erosive; and paths can bring water and nutrients to nearby land, or drain them away.

Observing influences over time, between seasons, and from year to year will provide important information to the farmer about where plants and animals might grow best, where to locate shade and shelter, where to build structures to harvest water and nutrients, and where to add protection.

Observing these influences can also help the farmer recognize the underlying and past conditions that are responsible for present conditions and events. For example, flooding—a result of water-flow disturbance from uphill or upstream—is often related to soil compaction, deforestation, or overgrazing on or surrounding the site.

## Methodology: Site Assessment

The process of gathering data from a specific farm or a particular program catchment area is an essential entry point for engaging farmers and communities with the RD approach. Throughout the process, farmers participate so they can learn for themselves how to conduct an assessment of their own land and how to identify useful resources and external influences within their farm and community.

To ensure ownership and understanding, field agents should use **participatory activities** during the assessment and in subsequent steps.

The information that surfaces through the site assessment belongs to the farmers, and they should feel empowered to own it and continually add to it. This should be clear from the beginning of the site assessment and is a message that should be carried through all subsequent steps of the RD approach.

The site assessment consists of four activities:

1. Community engagement
2. Resource identification and influence observation
3. Primary and secondary data collection
4. Farming system assessment

The first two activities (community engagement, then resource identification and influence observation) are always performed in the field with farmers and community members. These two activities are the most important part of the site assessment and they provide the minimum of information required for the follow-on design steps. These activities should be repeated regularly in order to track how the farming system and community change over time and in relation to the farm design.

The other two activities (primary and secondary data collection and the farming system assessment) are project-level activities that link with the *Resilience Design Measurement Toolkit.*[18] Information collected during these two steps complements the information gathered during the first two activities and ensures, as much as possible, the development of a complete picture of the farming system and of the community and agroecosystem within which it sits. Field agents are primarily responsible for gathering this information though it should also be openly and continuously shared with farmers and the community.

Each site assessment activity is described below, along with sample tables and diagrams that may be useful for information collection. The final decision on what information should be collected, and how, should be based on audience and site-specific requirements. For example, pictures may be used instead of words, or additional mapping exercises may be incorporated as a way to visualize the information. Regardless of what methods are used, it is important that farmers and field agents eventually capture all information on paper as a permanent record.

See also the Site Assessment Tip Sheet.

## 1. Community Engagement

People and their communities are inseparable from their agricultural systems and the broader agroecosystem. To fully understand the farming system, it is essential to understand what is important to farmers and their communities so that their priorities can be incorporated into the eventual farm site design. The community should to be at the center of the information-gathering process and engaging members from diverse groups (e.g., elders and youth, men and women, from the local village and up to a regional level) is particularly important, especially when discussing shared resources, such as water, that can be drivers of conflict.

Photo: Thomas Cole, African Women Rising

***Community meeting, Uganda.***

Community engagement begins with dialogue and workshops where field agents explain the RD process and start gaining buy-in and trust from farmers and community members. This initial phase should be followed by the participatory activities outlined below. It is important to note that after the initial engagement and the activities described in Step 1, community engagement does not stop; it is central to the entire RD approach and informs all subsequent steps.

For optimal community engagement, ensure the following:

- **Seek diversity and difference**. People often have different perceptions of the same situation and it is important that the views of different stakeholders are represented in the data collection.
- **Reduce barriers to engagement**. When working with communities, be aware of potential barriers to engagement and design the process to minimize them. Examples of barriers could include literacy and numeracy levels, income, cultural sensitivities, location and accessibility of community venues, childcare needs, and transport required.
- **Be gender sensitive**. Ensure gender sensitivity is incorporated throughout the process, starting with ensuring equitable engagement in the beginning and enabling different gender perspectives to be presented in safe environments.
- **Facilitate role reversal**. Learn from and with local people, eliciting and using their symbols, criteria, categories, and indicators of success. Find, understand, and appreciate local knowledge, rather than assuming and delivering information top-down.
- **Have a positive attitude**. For the most successful engagement, build a positive relationship with women and men in the community. Outsiders must have an attitude of respect, humility, patience, and a willingness to learn from community members.

More information on community engagement best practices is outlined in *Participatory Learning and Action: A trainer's guide*.[19]

Photo: Sean Sheridan, Mercy Corps

***Group of women, Niger.***

## 2. Resource Identification and Influence Observation

Resource identification and influence observation is the most important activity in the site assessment. At the end of this activity, farmers will have a better understanding of their farm within the local agroecosystem, as well as a site map of their farming system.

### *Resources*

Helping farmers recognize the true extent of the available natural, man-made, and agriculturally derived **resources**—within the farming system, the community, and the broader agroecosystem—will improve the resource base that the farm depends upon and will inform a site design that optimizes resource access and utilization.

It is important for farmers to understand what resources are available on and around their farm and community. Some are straightforward, such as rainwater or manure from animals, but others may be less well known or evident. Charcoal dust used to enrich the soil, or a skilled neighbor that provides important guidance when planting are two examples of resources that may be less well known. An important goal of this process is to show how many of the materials and resources required to build a more resilient agricultural system can be found and used at little or no cost to the farmer.

During resource identification, local knowledge around resources will surface that the field agent may not have been aware of and that the farmer may not have actively considered. For example, there may be herbs and plants traditionally used in their area for medicine (or to treat ailments in domestic animals) that might have further applications in helping to protect crops from pests and disease. Examples of the types of resources include:

- **Water resources**: Rain, wells, boreholes, springs, rivers, streams, grey water, runoff from roofs or along paths and roadways
- **Different kinds of plants**: Grasses, trees, and seeds (medicine, timber, fuel, construction material, food, fodder, forage, fertilizer, cordage, dyes, thatch, mulch, planting material)
- **Animals:** Cows, goats, pigs, chickens, sheep, camels, rabbits, and wild animals
- **Waste streams and materials**: Manure, processing waste, charcoal dust, wood ash, kitchen waste, sawdust
- **Compostable materials**: Grasses, dried and green leaves, crop residue, manure
- **Landscape and soils:** Grazing areas, forests, fishing areas, soil types
- **People**: Neighbors, small business owners, animal keepers, local officials, family
- **Buildings:** On-farm buildings (houses, water tanks, animal pens), health clinics, markets, schools, processing and handling facilities

### *External Influences*

Alongside resource identification, it is also necessary to identify what **external influences** impact the farming system and potential site design. Observing external influences can provide important information about where plants and animals might grow best, where to provide shade and shelter, and where to build structures to harvest water and nutrient flows.

Examples of external influences include:

- **Sun:** Orientation and path through the day and over different seasons, winter and summer angles
- **Wind:** Directions, temperature, pollution and salt levels, seasonality
- **Slope:** Basic direction and steepness, gravity
- **Water flow:** Intensity and frequency of rainfall patterns over time, water and nutrient flows through the site
- **Boundaries:** Of the farm, community or watershed, together with indications of orientation and scale
- **Landscape and soils:** Hills, valleys, flat areas, slopes, rocky or sandy areas, swamps, etc., as well as differences in altitude and soils
- **Land uses:** Cropped areas, crop types, wet and dry season grazing areas, forest; and land-tenure issues (private or common land, owner or tenant or leasehold farmer, farm size and fragmentation)
- **Wildlife**: Wildlife corridors, paths and grazing patterns
- **Problem and success areas:** Areas impacted by deforestation, erosion, pollution, invasive species as well as areas with higher growth, more soil moisture, and healthier soil
- **Man-made influences:** Roads, paths, noise, theft, cultural norms, agricultural incentives

### *Resource and Influence Walk*

Resource and influence identification starts with a **resource and influence walk**, a participatory activity often done in small groups and designed to help farmers recognize key resources and external influences. To perform the walk, field agents accompany the farmers through their farm site, community and local market. The field agent should guide the farmers to identify all the visible household and community resources, paying special attention to those resources that are freely available and may be seen as waste or without value. At the same time, field agents and farmers identify external influences and discuss how they positively or negatively affect the farm site. During this walk farmers can also identify which farm functions are most critical to address, for example water supply or crop fertility needs, and which farm activities are degenerative and could be made generative or regenerative.

It is the responsibility of the field agents to facilitate a dialogue around these resources and influences by observing, asking questions and encouraging discussions of what they see.

Information resulting from the resource and influence walk will be used to identify which resources the community values and how these resources can be used in the site design, as well as which influences need to be managed or used to better advantage. The walk is also an opportunity to ask questions about and collect historical information from the community.

It is important that observations be made from different perspectives: elevations, directions, times of day, seasons, weather events, and across time and history. Examples of types of information that can help explain how changes in patterns over time might affect resources and influences include:

- Observed rainfall patterns and perceived rainfall amounts for the season (to be compared with rainfall data for the area, if available)
- Seasonal hunger trends
- Planting patterns and crop choices
- Sunlight path and shade patterns (see also external influences, below)
- Seed selection and availability
- History of land tenure, ownership, and use and possible future changes
- How the health of the land changed over time (deforestation, erosion, etc.)

A good facilitator will draw linkages between what is observed on the walk and the types of constraints often encountered in local agricultural production. For example, the field agent may see an eroded foot path—indicating heavy water flow during rainfall—next to a dry field. He can then ask the community members, “How might you use the water that flows here when it rains to irrigate your field?” Potential answers can be shared with others in the group who have experienced similar challenges.

It is important to write down all resources and influences identified. Some farmers may want to complete a **resource and influence table** similar to the one below, and others may choose to collect specimens of identified resources. If time permits at the end of the walk, and to promote community engagement and common understanding of shared resources, it can be beneficial to continue the dialogue sitting together as a group.

| Resource and Influence Information Collection Table – Example | | | | | |
|---|---|---|---|---|---|
| **Resource/Influence** | **Purpose** | **Benefit** | **Cost** | **Location** | **Ownership** |
| | | | | | |
| | | | | | |
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To further complete the information collected, farmers may want to fill out a **climate risk calendar** and a **livelihood calendar**. A climate risk calendar identifies what climate-related shocks or stresses—such as droughts, floods, or extreme temperatures—may occur throughout the calendar year. If a calendar cannot be created, a conversation around climate risks should be incorporated as part of the external influences discussion. As much as possible, the information collected during this exercise should be layered onto the site map described below.

| Climate Risks Calendar[20] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Climate risk | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **July** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** |
| *Drought* | | | | | | | | | | | | |
| *Flood* | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |

A livelihood calendar documents what the farm produces through the year and allows the farmer to identify how much is consumed and sold each month. Placing this information on a calendar establishes a baseline level of production, identifies production gaps, and helps the farmer identify changes in production within the year and across years.

If not readily available, exact production, sales and consumption figures are not required; rather, the goal of this tool is to quickly identify those times in the year when production is higher than consumption, and vice versa. As a tool, it also helps identify off-farm income-generating activities that may affect the farming system (e.g., a job in town that reduces labor availability during certain months) and pinpoint opportunities for increased production and/or diversification throughout the year.

| Livelihood Calendar – Example | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Livelihood | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **July** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** |
| *Bean production* | | | | | x | x | x | x | | | | |
| *Bean sales* | | | | | | | | x | x | | | |
| *Bean consumption* | x | | | | | | | x | x | x | x | x |

### *Resource and External Influence Mapping*

The final stage in the resource and external influence activity is to create a **resource and external influence map** (also referred to as a **site map**). The goal of this map is to capture and visually display all the information generated during the observation. It should be developed via a participatory mapping activity—a facilitated process by which farmers use the ground or paper to create a visual display that tells the story of their farming system. It can be as basic or as detailed as the farmer or group chooses.

Photo: Sandrine Chetail, Mercy Corps

***Resource and external influence mapping in Malawi.***

The map should include all of the resources and influences identified, as well as physical structures and other markers that help to define the site and community. As much as possible, patterns such as nutrient flows and sun and shade movements should be layered on to the map, and additional influences such as gender dynamics should also be added. For example, who in the household is responsible for tending the livestock? Who collects water? This information will be used in the gender analysis in Step 2: Site Analysis.

Displaying all the resources and influences visually on a map enables farmers to see what resources and influences are present, how they are linked, how they may affect the whole system, and how they can be used advantageously in the site design. Though a site map is a static presentation, as much as possible patterns and changes in influences and resources throughout the year and between years should be captured.

This site map forms an important basis for Step 2: Site Analysis and Step 3: Site Design.


Photo: Andrea Mottram, Mercy Corps

***Resource and external influence map, Zimbabwe.***

## 3. Primary and Secondary Data Collection

Gathering primary and secondary data that may not be readily available from simple observation and identification is the next activity of Step 1. How much additional data is gathered will vary depending on what is available and what is deemed necessary for a comprehensive site design.

Before collecting external data, it is important for field agents to determine:

1. What external information are farmers able to collect themselves (e.g., rainfall patterns, cultural norms)?
2. What information do farmers need but are unable to collect themselves (e.g., regional price information, government regulations)?
3. How can the program facilitate longer-term access to external data (e.g., through working with mobile phone providers)?

Answers to these questions help inform how and by whom data will be collected in the short term, and what processes need to be put in place for farmers to access this over the longer term.

Some examples of the types of data to collect and how they can be collected include:

- **Rainfall patterns and other climate data:** It is important to create a rainfall and temperature record at the farm level to accurately understand rainfall quantity, variability, and distribution. Data can be collected using rain gauges and the participatory tools described previously; additional data sources include national climate and meteorological authorities.[21, 22]
- **Soils, geology, and land capability:** Farmers may want a deeper understanding of the capabilities of their land than the *Soil Health Assessment* (described in the following section) provides. This requires a more in-depth assessment of the soil health at the farm level. Data can be collected from publications and tools such as the Comprehensive Assessment of Soil Health: The Cornell Framework Manual;[23] the USDA Guidelines for Soil Quality Assessment in Conservation Planning;[24] soil quality indicator sheets;[25] and ArcGIS World Topographic Map.[26]
- **Biological baseline (native fauna and flora):** Having an understanding of what animals and plants originate on a farm site provides guidance on what crops and trees may be most successful in the design. Data can be collected from farmers or other community members, literature reviews, and fauna and vegetation surveys.[27]
- **Government regulations and subsidies:** It is important to understand how government regulations and subsidies impact farming systems and farmers' decisions. Data can be

collected from group or individual interviews with farmers on what regulations affect them and what subsidies they benefit from; interviews with local authorities and government agencies; interviews with economic and market actors; and government reports, assessments, and regulations.

- **Labor resources available in the farming system:** Labor availability, costs and opportunities in farmers' communities may affect farm production and system design decisions. Data can be collected via questionnaires; focus group interviews; livelihood calendars; and market, labor, and gender assessments.
- **Social and cultural norms:** Social norms may affect farmer decision-making and behaviors. Data can be collected via semi-structured individual or group interviews with farmers and participatory observations.
- **Economic and market information:** The economic and market environment will greatly impact farming decisions and profitability, as will farmers' access to information about input and output markets. Data such as market prices can be collected via commodity exchanges, market assessments, surveys conducted by the project or other organizations, and market interaction during community engagement activities.

All of the relevant information gathered from the steps above should be layered, as much as possible, onto the site map.

## 4. Farming System Assessment

The farming system assessment focuses on collecting additional information about the farming system, such as production, income, soil health data and farm resilience activities. Though the information gathered during this step will be useful for the farmer, this assessment and its accompanying tools are designed for field agents to incorporate into their daily activities. The assessment incorporates gender and resilience information and is an important part of the monitoring process that is used to assess, at the project-level, the impact of the farm design on the overall productivity of the farm and the effectiveness of RD strategies. [See Step 4: Site Monitoring, on page 55].

Tools that all form part of the *Resilience Design Measurement Toolkit* and may be used for this activity include:

- Farm Resilience Assessment
- Farm Production Assessment
- Soil Health Assessment

### *Farm Resilience Assessment*

The *Farm Resilience Assessment,* located within the *Resilience Design Measurement Toolkit*, is a tool to continually assess progress on farms. It is designed to be a participatory monitoring and learning tool that facilitates a discussion between the field agent and the farmer about what kinds of activities they are implementing that align with the RD approach, and how that affects farm site resilience. The assessment can be completed at different times to track how the farming system design changes over time, to identify areas for improvement, and provide a baseline and end line for impact measurement purposes. The tool also contains suggestions for how to improve farm production and resilience by integrating feedback from the monitoring process.

### *Farm Production Assessment*

The *Farm Production Assessment*, located within the *Resilience Design Measurement Toolkit*, helps to gather data on total production, income and expenses over time. The tool is designed for field agents to use with farmers after each growing season.

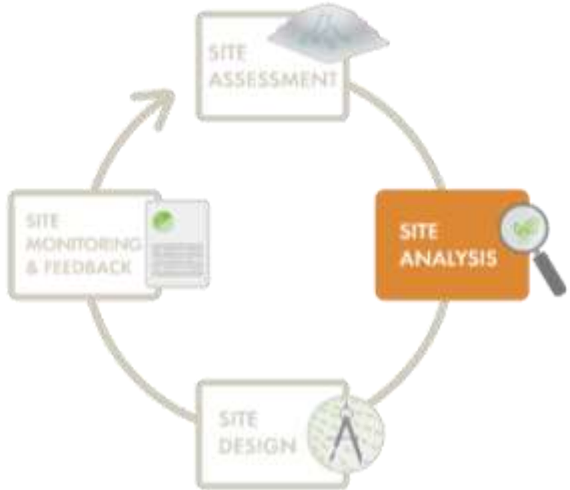
The tool consists of two tables that field agents fill out during discussions with farmers in charge of harvesting and selling produce. Information includes crops and livestock produced, amount harvested, amount sold, income from sales, and expenses related to each crop or livestock category. The *Farm Production Assessment* collects all the data needed to calculate "total farm value" — an indicator used by many programs.

### *Soil Health Assessment*

Healthy soil is critical to a more resilient farming system and an effective farm design will help build healthy soils. The *Soil Health Assessment*, located within the *Resilience Design Measurement Toolkit*, helps field agents working with farmers identify and assess the quality of the soil and, if measured regularly, provides information on how it may change over time and in response to what changes in the system.

Once a year, field agents together with farmers should use the *Soil Health Assessment* to measure soil quality. Field agents can use information from the 'Improving Low Scores' section to discuss with the farmer ways to improve soil health.

# Step 2: Site Analysis – Assembling, Organizing and Translating Data




**Aim: Critically analyze the information gathered in Step 1 in order to initiate the design process.**

Photo: Abby Love, Mercy Corps

***Site analysis in Nepal.***

# Concept Summary: Site Analysis

The site analysis is the process by which the information gathered in the site assessment is assembled, organized and translated into usable data to inform a resilient site design. The site analysis helps farmers identify, for example, which resources are producing well, which are available but not being used, how external influences are helping or hindering the site, and where energy is being used efficiently or not. It also analyzes the economic, cultural, and gender context within which the farming system exists and explores ways to create beneficial connections between resources and influences with the goal of increasing overall productivity and resilience.

Six key analyses make up the overall site analysis:

1. Resource analysis
2. Energy analysis
3. External influence analysis
4. Slope analysis
5. Economic analysis
6. Social and gender analysis

# Methodology: Site Analysis

The amount of effort and depth required for each of the six analyses will vary depending on the specific context of the individual farmer's site. As with the site assessment step, it is useful to capture the different analyses on paper as they will feed into the site design in Step 3. It is also important to ensure that farmers and community members are part of the process, understand the process, and feel ownership of the results.

See also the Site Analysis Tip Sheet.

## 1. Resource Analysis

For the resources considered during Step 1, analyze them to identify how well they are producing or working and what their needs, products, behaviors, characteristics, and functions are. Analyzing resources in this way helps to identify which are producing well; where inputs needed for one resource might come from another; what is needed to ensure healthy production; what risks the resource might pose (e.g., animal feces affecting child health); and what opportunities there are to introduce additional resources.

The diagram below provides an example of a resource analysis (in this case a chicken) and how the results can be captured on paper. If there are many resources identified, and the process of analyzing them all at the same time is too time consuming, then start with the most critical ones or those that support the most critical farm functions identified during the resource and influence walk.

The goal of a resource analysis is to guide the placement and utilization of a resource for the highest productivity and overall benefit to the system. For example, one of a chicken's possible functions is "fertilizing." A farmer's crops need fertilizer. Is there a way to integrate chickens into the garden part of the site design to help fertilize, weed, or control pests?

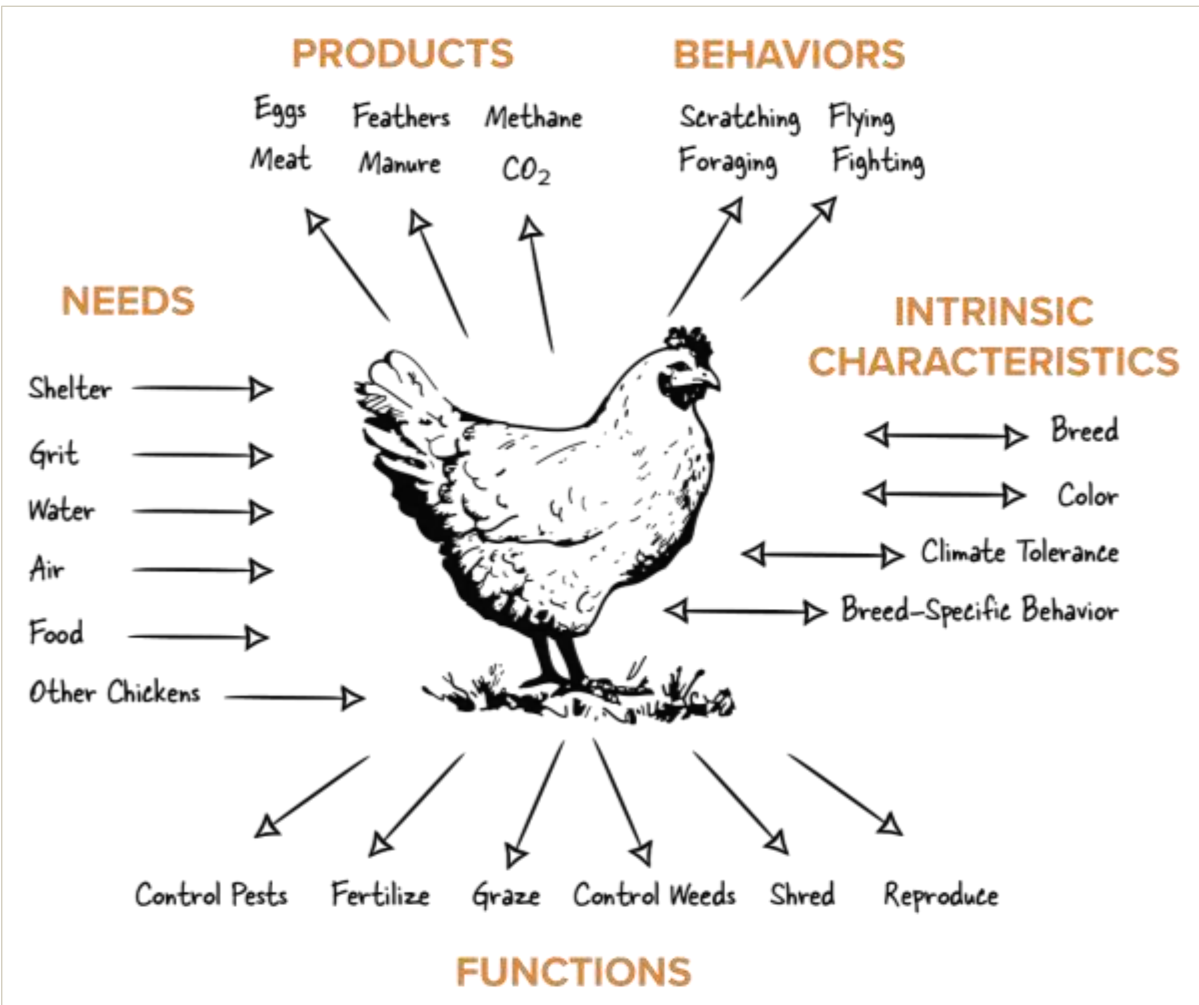



Illustration: Holly Collins, adapted from original drawing in Mollison, B. and Slay, R.M. 1991. *Introduction to Permaculture.* Tyalgum, Australia: Tagari Publications

***Resource analysis of a chicken.***

Questions to use during a resource analysis:

- What are the most important resources and critical functions?
- What is growing or working well, and why?
- What is not growing or working well, and why?
- What products from one resource might provide resources for another?
- What are risks of using this resource?
- Are there any degenerative resources that can be improved?

The information produced by this analysis will help guide the resource-planning activities of Step 3: Site Design.

## 2. Energy Analysis

For each resource identified in Step 1 and analyzed above, determine how much energy is required to maintain it, where that energy comes from, and how it is provided. Energy in this context could be human energy (labor and time), as well as non-human energy sources such as electricity or gasoline. For example, if a water pump needs electricity, is there enough affordable electricity available locally? Are there other ways to provide energy to the pump? Does water have to be carried (an expenditure of human energy) to irrigate a crop or does enough rain and runoff collect and sink into the soil around the crop? It is useful to break labor energy needs down by gender. For example, who carries water to the crop, how far, and how many times a day?

Questions to use during an energy analysis:

- What are available sources of energy?
- Are sources of energy available on-site or are they brought from elsewhere?
- Where are sources of energy or energy requirements located?
- What types of energy does the resource require and is it possible to use alternative types?
- How often does the resource need tending?
- Who provides the specific labor energy (men or women, youth, hired labor, etc.)?

This information will be used to inform **energy efficiency planning** in Step 3, a process that maps resources into specific zones according to how much energy they need. The results of this analysis will help guide the placement of resources on the site to maximize energy efficiency.

## 3. External Influence Analysis

For each external influence identified in Step 1, analyze them in relation to the resources on the farm site. On the site map, identify whether resources are located to maximize the positive effects of external influences and to minimize the effect of negative ones. Ensure resources are optimally locate to channel external influences into or away from the site as required.

Questions to consider for the external influence analysis:

- How does the sun's path affect the growth of a particular resource in its current or future location? Would the resource flourish better in a different location receiving more or less sun?
- Are the winds eroding and drying out particular areas and are there resources that need to be relocated to minimize this effect?
- Are the winds depositing nitrogen-rich leaf litter in certain locations that be captured for mulch or fertilizer?
- Are wildlife influences such as grazing and migration patterns impacting crop production?
- Are roads and paths appropriately bringing or draining resources such as water, nutrients, and sediment?

Information from the location analysis will be used to inform **external influences planning** in Step 3.

Photo: Andrea Mottram, Mercy Corps

***Captured leaf litter used as mulch and fertilizer, Malawi.***

## 4. Slope analysis

The slope analysis evaluates the slope of the land, and how it moves nutrients and water into, across and out of the site. This analysis will help guide the placement of resources to maximize the use of gravity and the sun. One way to evaluate the slope is to use an A-frame. More information about A-frame construction and usage is available in the Water Management Technical Guidance on page 92.

**Questions to consider for the slope analysis**:

- How do upslope elements (for example bare or forested hills) affect the downslope site? For negative effects, are there opportunities to improve them?
- How steep is the slope and how does it affect water and nutrient flows? Do they flow to where they are needed to supply resources?
- Where can nutrient sinks and harvesting structures be placed to maximize the volume of water and nutrients flowing to agricultural production areas?

The information from the slope analysis will be used to inform **slope planning** in Step 3.

## 5. Economic Analysis

Using the information gathered in Step 1, evaluate market constraints and opportunities for products already being produced, and identify opportunities for new ones. This analysis will refine the selection and placement of resources to maximize return on investment and optimize economic opportunities.

Questions to consider for the economic analysis:

- Is there is a high demand for certain commodities? Can production of that commodity be increased or introduced into the farming system?
- Are there limitations on access to any inputs, for example seeds?
- Is there potential to add value to primary agricultural products for enhanced shelf life and economic gain such as producing sun-dried tomatoes to sell later in the season when tomatoes are not able to grow?

This activity should be complimented by other economic project-level activities such as value-chain and market-facilitation activities, and they should target the same farmers so that different project elements are incorporated together to improve market linkages for farmers. Over time, farmers can use these linkages to monitor changes in demand and incorporate market opportunities into their farm design.


Photo: Andrea Mottram, Mercy Corps

***Market in Kyrgystan.***

The information from the economic analysis will be used to refine the **selection and placement of resources** in Step 3.

## 6. Social and gender analysis

Using the information collected in Step 1, evaluate gender issues within different age groups and the social and cultural norms that affect or influence the farm site, and how these norms in turn might affect the selection and placement of resources and crop and livestock planning decisions.

Questions around social, gender and cultural influences:

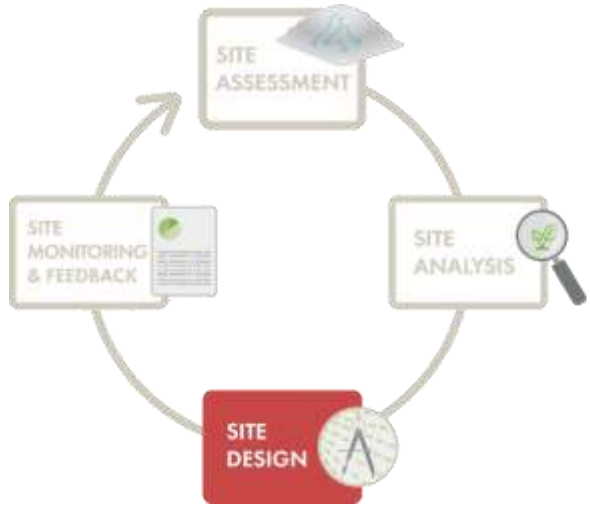
- What are the roles of men, women and children (both boys and girls) with respect to the activities on and off the farm?
- What resources are under the control of male and females of different age groups (e.g., youth, adults, elders)?
- Can resources under the control of one group be located together to reduce labor (energy) requirements?
- How do the cultural norms and laws affect selection and placement of resources?
- How do land tenure policies affect the choice of resources?

- Who within and outside the household influences the farm decisions? Who do farmers go to for advice and information? Do these actors need to be consulted and can they be influenced if needed?
- What are the potential gathering places that build social capital, such as a local seed bank or storage area?
- Are there social tensions within the community (e.g., different religions, social groups, internally displaced people, refugees or returnees) that affect the site in some way?
- How do local agricultural incentives such as fertilizer subsidies affect the use of resources?
- How are people rewarded or recognized for good work, or how could they be?

The social, gender and cultural evaluation should be complemented by other existing project activities such as projects focused on girls or conflict mitigation. Assessment data from these activities will help inform a more detailed analysis of the local context.

The information from these analyses will be used to refine the **placement of resources** linked to social and gender norms in Step 3.

# Step 3: Site Design – Locating Resources, Channeling Influences, and Building Soil and Water Health




**Aim: Use the information and critical thinking from the previous two steps to design a site that optimizes resources and influences for a more resilient farming system.**

Photo: Warren Brush, True Nature Design

***Smallholder farm in Mazvihwa, The Muonde Trust, Zimbabwe.***

# Concept Summary: Site Design

Following the identification and analysis of resources and influences in Steps 1 and 2, use the information collected to create a **site design** that best organizes and optimizes the overall farming system.

The goal of the site design is to select and place resources, channel influences, and apply agricultural techniques to build soil and water health and increase energy efficiency. Combined, these activities will improve productivity and household nutrition and the overall resilience of the farming system to environmental and economic shocks and stresses.

The site design might produce a map of all of the requirements of an ideal design, but not all of the changes required can be implemented at the same time. The key to the design process on the farm site is to start small and simple and consciously and incrementally integrate techniques together over time. In this way the process is simpler, and farmers can observe changes and adapt their system slowly while limiting risk.

The following process outlines the four activities involved in the development of a new site design:

1. **Initial site planning**, through resource planning, energy efficiency planning, external influence planning, and slope planning
2. **Review of gender, social, and economic influences** to further refine resource placement
3. **Layering in appropriate agricultural techniques** to improve soil health, water management and agricultural production
4. **Review using the RD principles** to refine the preliminary site design, as described below

## RD Principles for Site Design

The ten RD principles are **design guidelines** (or guiding questions) that farmers should use when planning their site. The 10 principles draw from those used in agroecology, permaculture, and water harvesting.[28] Rather than representing a specific procedure, they are a lens through which to review all the elements of a site design and modify as appropriate.

The principles guide field agents and farmers through a series of questions about the choice and location of resources on the site to ensure farmers are making the most of their time, energy, and investments on the farm.

These guiding principles should inform all decisions during the site design phase, and then revisited once the design is complete. As the system evolves over time and resources and influences change, the principles should be considered and applied on a continuous basis.

**The RD principles:**

1. Observe and mimic healthy and resilient living systems
2. Start small and simple
3. Start at the top (highpoint or source) and work down
4. Slow, spread and sink the flow of water and nutrients
5. Grow natural resources
6. Place every resource for energy efficiency
7. Locate and use each resource so that it provides several benefits to the farming system
8. Ensure critical functions in the farming system are supported in several ways
9. Change a problem into a benefit
10. Continually reassess the system using the feedback loop

Photo: Shashank Shrestha, Save the Children

| Description and Examples of the 10 Resilience Design Principles | | |
|---|---|---|
| Principle | **Guiding Question/ Description** | **Example of Principle in Action** |
| **1. Observe and mimic healthy and resilient living systems** | What patterns do we observe in healthy systems within the local landscape, and how can they be used to guide the site design? What regenerative examples can we replicate? | Copy a polyculture system that occurs naturally in or near the site. For example, grow beans (which provide nitrogen and create a living mulch) up maize stems, plant squash below them and *Desmodium* shrubs as a ground layer. Around the plot, create a border of perennial fruit trees and nitrogen-fixing legume trees to provide high-value mulch, shade, building materials, saleable crops and more. In this way, multiple crops work together to mimic a natural biodiverse system that is less prone to pests, has fewer weeds and is more climate-stable than monocropping. |
| **2. Start small and simple** | How can we start by making a few small changes, and build on them over time?<br>A range of small activities can be more effective than one large one. | Plant a tree within or beside a water-harvesting basin in such a way that it maximizes the use of the sun for growth yet also provides shade to the house or water tank. Choose a tree that provides food for humans or animals, or mulch for the land. Next, plant another tree nearby to capture the overflow water from the water-harvesting basin above it and continue to gradually expand. |
| **3. Start at the top (highpoint or source) and work down** | Water (and everything carried with it) travels downhill.<br>Where does water begin to flow across or down the land, and how can we work from there to slow water and nutrients? | Collect water at high points (upslope) where it is easier to manage; upslope the water has less volume and velocity, and enables easier gravity-fed distribution. |
| **4. Slow, spread and sink the flow of water and nutrients** | What is the direction of the slope, and are we using sufficient techniques to slow, spread, and sink the water into the soil? | Place a swale (a ditch or low place on the landscape) and perennial plantings on-contour at the top of the site to capture water as it begins to flow downhill. The swale and plants will slow, spread and help sink the water into the soil, and minimize erosion. |
| **5. Grow natural resources** | What natural resources can we grow within the farming system to avoid having to buy or build them? | Grow a multifunctional living fence rather than building a wooden or metal one; for example, Moringa oleifera (thorny acacias) or Opuntias (prickly pear) are both plants that provide protection, mulch, fertility, food and fodder. Plant sections of the living fence on the contour |

| | | |
|---|---|---|
| | | to better slow and capture runoff and the organic matter it carries, which in turn will result in a healthier and more vigorous fence. |
| **6. Place every resource for energy efficiency.** | Where can we place resources to allow for efficient tending and beneficial connections to other resources? | If a farmer visits the chicken coop four times a day, place it closer to the house to reduce time spent visiting the coop. Also, place the coop upslope of the garden or cropland, so nutrients flow down naturally with gravity to where they are used or needed. On the way to the chickens, the farmer can pick weeds from the garden that can then be fed to the chickens. |
| **7. Locate and use each resource so that it provides several benefits to the farming system** | How can we place and use resources that are grown or built in such a way as to provide several benefits (preferably three or more) to the farming system, instead of just one? | Place a small water tank (a resource) on the farm site where it can provide water, shade, and a windbreak as well as a place on which vines can grow. In addition, gravity can direct roof runoff into the tank and then distribute water from the tank to all points below. |
| **8. Ensure critical functions in the farming system are supported in several ways** | What are the critical functions in the farming system (e.g., water, soil health, crop fertility needs, seeds, labor, markets and income), and how can we support them in several ways to increase resilience? | If water is a critical function, ensure the household has several diverse sources of supply: a rain-fed water tank, a well, a river, a road diverted into an agricultural swale, and by reusing wash water. |
| **9. Change a problem into a benefit** | Think about how a problem on or around the farm site could be transformed into a benefit. Turn waste into resources to get the maximum efficiency from the system. Change a degenerative investment into a generative or regenerative one. | If a road channels rainfall and runoff and creates an erosive gully that dries the land, consider capturing the rain and redirecting the runoff to where it will become a resource. For example, at points along the road use various strategies to divert the water from the road, then slow, spread and sink it into the soil to help irrigate crops and recharge the local aquifer and boreholes. |
| **10. Continually reassess the system using the feedback loop** | Observe how the changes made affect the site—beginning again with the first principle. Use the principles to guide you in making any needed changes. | |

# Methodology: Site Design

The site map developed during Steps 1 and 2 will inform decisions about the site design, including which resources should be moved or added, how to manage external influences, and how to improve the site by applying relevant agricultural techniques. It is important that the site design exercise takes place with the farmers at their farms; this ensures that the site design is responsive to the actual conditions of the farming system and also helps the farmer build ownership of the process. The four activities of the site design should all follow this approach.

Though the four activities are presented as separate stages, in reality they are heavily interconnected and should all be reviewed and developed in conjunction with each other.

See also the Site Design Tip Sheet.

## 1. Initial Site Planning

**a. Resource Planning**

Using the assessment and analyses from Steps 1 and 2, resource planning helps farmers to select and place crops, livestock, plants and other resources to build the most productive and efficient farming system.

For example, at a farm level, what crops and livestock are being produced and how successful are they? Should they be moved to different locations to improve their productivity? Does the farmer need to consider changing crops, or adding in new plants and crops? Are there any structures on the site that can be improved or moved to provide extra benefits to the farming system? Are there generative or regenerative examples that the farmer can mimic, grow or expand?

At a broader community or watershed level, resource planning might include selecting what tree species to use in a re-greening activity or selecting plants, trees or crops that might be planted around a water point (and combined with soil- and water-harvesting strategies) to improve water management, recharge groundwater, and produce a community commodity such as fruit.

Using the principles, particularly principles #1 (mimic natural systems), #5 (grow your own resources), #7 (multiple benefits from one resource), and #8 (support critical functions) will help guide resource placement for maximum efficiency and effect.

Photo: Sean Sheridan, Mercy Corps

***Smallholder farmer with livestock, Ethiopia.***

### b. Energy Efficiency Planning

Energy efficiency planning helps farmers strategically place plants, animals and other resources together to reduce the amount of energy required. Energy could be human energy (in the form of labor and time) or non-human energy sources such as wood, electricity or oil.

To reduce human energy requirements, locate plant and animals within "zones" on the farm based on how much attention they need and how often they are visited. This type of planning can also be used at the community and watershed levels. For example, mapping the community according to zones can be used to support ecosystem functions and designate areas for conservation and other uses.

Using the site map developed in Step 1, divide the site into "tending" zones according to how frequently the farmer visits (tends to) them. Zones should be divided based on accessibility and on household members' schedules rather than on distance to the area. Locate or relocate resources according to how much attention they need. Place resources that need more attention in zones closer to the house; those farther away can be left alone for longer periods of time.

The diagram below is an example diagram of tending zones. This is a schematic diagram, in reality zones are irregular shapes with no clearly defined borders. Zones may even be separated physically from one another, for example in the case of a smallholder farm that consists of parcels of land in different places. Paths and movement corridors can also be considered zones and special attention should be paid to them.


Illustration: Jak Ritger, Jak Ritger Design

***Tending zones in a farming system.***

***Zone O*** is the center of the farm, typically where the house is located.

***Zone 1*** then consists of the most visited areas close to the house or possibly along a frequently travelled path. Place everything that needs a lot of attention, or that farmers visit and tend often, in Zone 1. Permagardens, seedlings that require daily watering, frequently used herbs and vegetables, a chicken coop, and possibly a compost collection area are all examples that belong in Zone 1. For example, a farmer may locate a seedling-growing area along a route from the house to the chicken coop so that she can water seedlings at the same time as the daily egg collection; this both reduces energy expenditure and also minimizes the chance of forgetting to water. If the farmer rarely visits one side of the house, it would not be part of tending Zone 1 no matter how close to the house it is.

***Zone 2*** also receives a lot of attention, but less than Zone 1. It might contain smaller fruit trees, shrubs and trellised fruit, hedges, ponds and windbreaks. Zone 2 includes crops, livestock or other elements that do well without daily supervision or work, such as hardy perennial herbs and spices, and vegetables that take a long time to mature and are only picked once or twice. This area is densely planted and, where possible, should be mulched. It may also contain livestock such as goats and pigeons.

***Zone 3*** is still a managed tending zone, but not as intensively and the farmer does not visit it on a regular basis. It includes the main crop fields, large fruit and nut trees, and pastures for grazing cows, goats, and sheep, and keeping bees.

***Zone 4*** is only semi-managed and is an area for gathering wild foods and growing timber. Farmers can use this zone for managed grazing and it may contain livestock watering holes.

***Zone 5*** is not actively managed and would include bush land and possibly forest. Like Zone 4, it might also be an area for gathering wild foods and occasional grazing, as well as for natural livestock watering holes. There may be restrictions on access to areas within this zone as it would normally fall within the sphere of the wider community or watershed.

Within the farming system, determining tending zones and placing resources accordingly will help reduce the time, energy, and labor requirements of the smallholder.

In addition to tending zones, it is important to think about how resources might be placed together or in sequence so that the needs of one resource are provided by the products or functions of another. For example, situate a chicken coop upslope of a garden so that nutrients flow down to the garden, reducing the time required to add fertilizer and allowing chickens to run through larger crops to reduce weed growth and time spent weeding. Developing efficient water harvesting structures in a garden can infiltrate more water into the soil so that less water is required for irrigation in dryer times, requiring less energy to collect the water and place it on the garden.

Other types of energy requirements can also be reduced by resource placement or by adding new resources. For example, the amount of electricity required for a water pump in a borehole could be reduced by capturing water in a rainfed water tank and using it for washing clothes or drinking water for animals. Other options to reduce or improve energy consumption include fuel efficient stoves and solar energy panels.

Keeping principle #6 (place resource for energy efficiency) in mind will help with energy efficiency planning.

### c. External Influence Planning

External influence planning helps farmers strategically place resources to channel external influences into or away from their farming system. Using the site map with identified resources, influences and zones, resources should be placed or moved to appropriate areas so they can:

- Block negative influences (e.g., hot winds)
- Channel external influences for use (e.g., water into a field to irrigate crops)
- Open the area to allow in positive influences (e.g., prune trees to let winter sun reach crops)
- Reduce or enhance man-made influences (e.g., decrease road noise and theft, or increase privacy)

Examples of questions the farmer may want to consider when planning for external influences include: What trees can I grow in the farming system that will protect my garden from the wind, but also provide other benefits such as nitrogen rich leaves? How can I change the problem of animals walking onto my land into a solution where they can help manage weed control or provide manure?

Applying the principles, especially #5 (grow your own resource), #7 (multiple benefits from one resource), and #9 (turn problems into benefits) will inform external influence planning.

**Photos:** Brad Lancaster, ***www.HarvestingRainwater.com***

***Community pond (right) receiving runoff from the road (left).***

The diagram below provides an example of channeling and blocking some of the influences e.g. trees shading the garden, goat pen, house and toilet from the hot afternoon sun and hot winds, water harvesting structures and mulch channeling water and infiltrating it into the ground so support crop and tree growth, a live fence along the path providing shelter and fodder for animals. A farmer could also plant trees along the road to provide privacy and reduce noise, a compost area near the garden, and trees to shade the chicken pen.

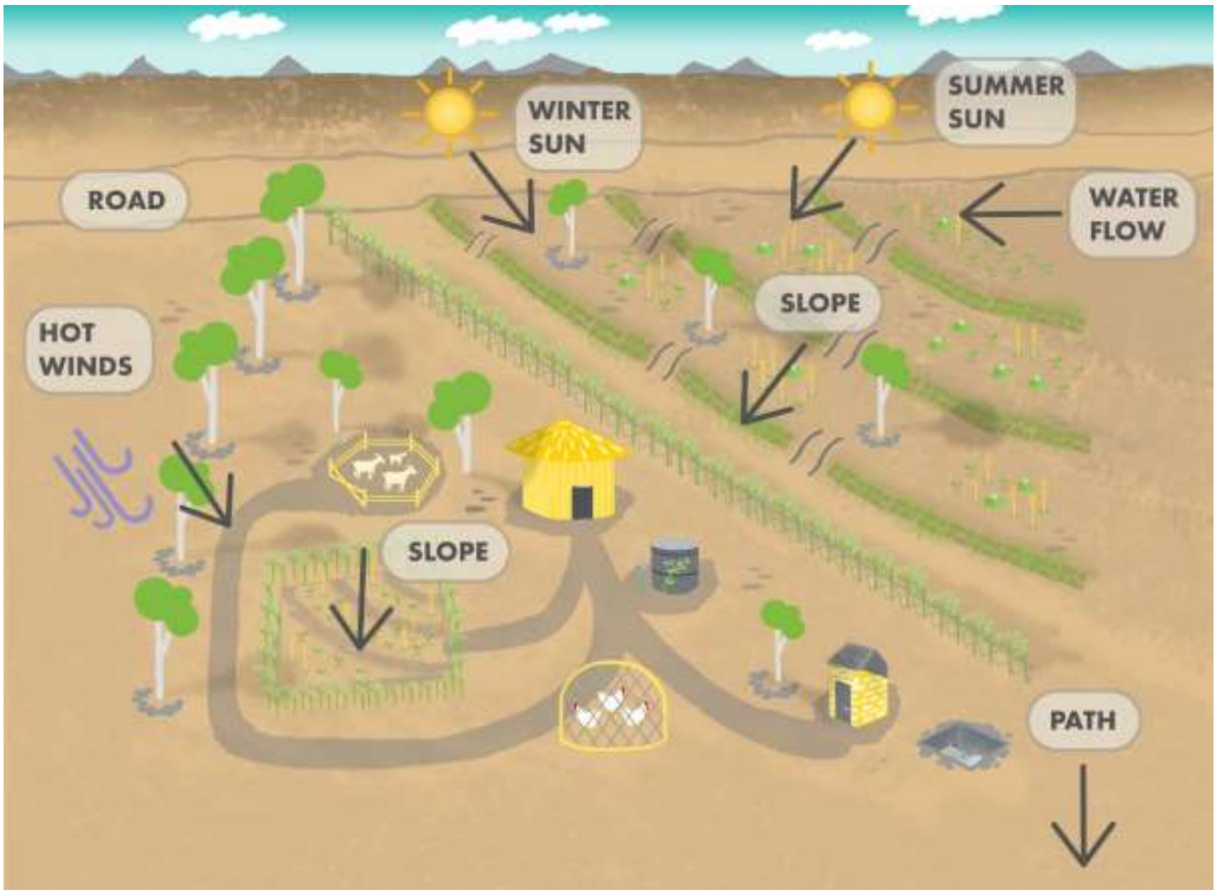



Illustration: Jak Ritger, Jak Ritger Design

***Influences affecting the farm site.***

***Example: Minimizing the effect of too much wind***

A farmer has her plot near the top of a ridge where the wind is too strong, causing drying and structural stress to the plants due to the constant exposure. After observing the main wind direction during the growing season, the farmer places a multifunctional tree system upwind of her crops to slow and divert the wind. Additionally, by planting legumes and other beneficial trees as the windbreak the farmer produces fertility for the crops, fodder for livestock, and firewood that can be sustainably harvested. By limiting wind exposure, the crops have less stress to detract from flowering and fruiting, and the soils and plants have better water retention and infiltration.

### d. Slope Planning

Slope planning helps farmers place resources to maximize the use of gravity and the sun. While sun and gravity are external influences and are captured within external influence planning, here farmers consider the specific effects of slope on these influences.

Appropriately placing a resource on a slope can:

- Capture or cascade water and nutrients, minimize water and sediment loss, and maximize irrigation benefit
- Optimize microclimate production opportunities by using thermal zones (where warm air rises and cold air sinks), and open or shaded areas.
- Increase production and diversity by appropriately placing those plants and animals that tolerate heat and those that prefer shade, as well as extend or reduce the growing period depending on sun angles
- Reduce human energy expenditure

Applying principle #3 (start at the top) and #4 (slow, sink, spread) will help guide slope planning.

Photo: Erin Gray, Mercy Corps

***Rock check dams slowing water flow in Ethiopia.***

## 2. Review of Economic, Social, and Gender Influences

Using the information gathered during Steps 1 and 2 review all four components of the resource planning activity (above) for economic, social and gender influences. For example:

- Consider producing inputs that are expensive or not readily available elsewhere (e.g., a local seed variety)
- Incorporate commodities with a high market demand into the design
- Review the placement of resources with a view to cultural norms and laws that might affect placement, such as animal pens placed in a specific area of the homestead
- Review gender divisions of labor and control of resources, and consider co-locating resources that are under the control of one gender or the other to reduce time accessing those resources

Photo: Michael Bisceglie, Save the Children

***Taking gender and economic issues into account, Malawi.***

***Example: Reducing gender-related energy needs through site design***

During the energy and gender analyses, a farmer notes that she spends 9 hours per week collecting water to irrigate her fruit tree during the dry season. During the design step, the farmer decides to add heavily mulched boomerang berms on the downslope of the fruit trees to capture water and nutrients, and sink them into the root zone to store water for the tree long into the dry season. These techniques reduce the number of trips the farmer has to take to the watering hole during the dry season, saving both time and energy.

## 3. Layering In Appropriate Agricultural Techniques

After mapping resources for maximum efficiency and reviewing them within the context of gender, social and economic influences, select and combine the appropriate agricultural techniques that will improve soil and water health, agricultural production, and the overall resilience of the farming system. Review the site map to consider what techniques to layer in and where, and how these might influence crop and livestock choices. Adjust any plant, animal, or building placements on the map to link with the chosen techniques.

The selection and combination of the appropriate bundle of techniques will depend on the specific site location and design, and on the relevant opportunities and constraints as determined in the site assessment and analysis. Farmers should choose and modify the techniques that are right for them and the context of their farm.

Determining the appropriate location, scale and combination of agricultural techniques in relation to a particular site, guided by observations and principle application, is key to the effectiveness of the RD approach. Some techniques to build healthy soil and better manage water include:

- Planting **vegetation** to help build, anchor and shelter soil, increase filtration, support soil microorganisms, and reduce erosion
- Using a **rain garden** (a shallow, wide, and level-bottomed hole with gradually sloping sides) to catch and sink rainfall, runoff, and grey water to store water within the soil


Photo: Eric Carlberg, Mercy Corps

***Series of boomerang berms capturing water for mango trees, Zimbabwe.***

- Placing a **one-rock-check-dam** (a small dam used to slow, spread, and sink more of the water's flow into the drainage bed and banks) to reduce flooding and erosion
- **Composting** kitchen scraps and other brown and green materials to increase soil fertility
- Practicing **agroforestry** (combining crops with trees) to improve soil fertility, increase soil moisture, and increase tree cover

More detailed descriptions of techniques are in the technical guidance sections on healthy soil and water management on pages 61-106.

***Example: Combining techniques through the RD approach***

Instead of building a berm to slow water and then leaving it bare, using the RD approach a farmer would cover the berm with vegetation to help stabilize and build the soil. The berm might also have a ditch (or swale) on the upslope to collect more water and form part of a rainwater harvesting system. This system would direct water to numerous smaller water infiltration points within which trees would be planted. These trees would then provide shade for crops below, including leguminous species that help improve soil fertility and fodder grasses that can also be used as mulch. To enhance production, the crops would be oriented to maximize influences of the sun, shade, and wind. The livestock pen would be situated upslope so that nutrients flow down toward the crops.

## 4. Review using the RD Principles

Finally, review the initial site design to make sure it conforms to the guiding principles; adjust or modify the placement of resources as needed.

See also the RD Principles Tip Sheet.

### 1 Observe and mimic healthy and resilient living systems

Observe patterns in healthy natural systems within the local landscape and consider how they can be built upon or used to inform the site design. Questions to consider: Have I copied healthy and resilient living system examples in my farming system? Are there other ways I can use those patterns to amend the site design further?

### 2 Start small and simple

Keeping in mind that several small activities can be more effective than one big one, look for small investments or changes that have a large impact. Questions to consider: Are there any additional small changes I can make to improve the efficiency of the system? Am I planting on the contour? Am I capturing all the water that is flowing freely (e.g., from a roof, down a path)?

### 3 Start at the top (highpoint or source) and work down

Water (and everything that it carries with it) travels downhill. Start at the top or at the source of water runoff where water has less volume and speed and is easier to manage. Questions to consider: Did I identify the top of my land? What is happening above that? Where does the water begin to flow across or down the land, and have I built in techniques to slow water and nutrients?

### 4 Slow, spread, and sink the flow of water and nutrients

Rather than having water run across and erode the land's surface, place resources to encourage it to slow down, spread out, and infiltrate the soil – "Slow it, spread it, sink it." Questions to consider: Have I identified the direction of the slope? Have I addressed water erosion on my land? Am I using swales or berms to slow and sink the water? Am I using mulch to help water infiltrate into the soil? Have I planned overflow routes to allow water to escape during heavy rainstorms?

### 5 Grow natural resources

As much as possible, grow resources that the farming system requires rather than buying or building them. Questions to consider: Am I improving the growth and health of natural resources growing in the area? Am I growing some of the resources that I need and currently buy? Can I make improvements to naturally enhance their growth and health?

## 6 Place every resource for energy efficiency

Place every resource in the location that allows for the most efficient energy efficient tending and allows for beneficial connections to other resources. Questions to consider: Are there any resources I have not placed to improve energy efficiency? Can I place resources differently to enhance production and reduce the time spent tending them?

## 7 Locate and use each resource so that it provides several benefits to the farming system

Situate and use resources so that they provide several benefits to the farming system instead of just one. As much as possible, ensure that each resource serves multiple functions. Questions to consider: Is every resource providing more than one function or benefit (e.g., is my water tank providing water, shade and a frame for growing vines)? How could I rearrange resources, or how I use them, so that they provide more than just one benefit?

## 8 Ensure critical functions in the farming system are supported in several ways

Ensure critical functions (e.g., accessing water, accessing food, nutrient availability, conserving energy) are supported by multiple resources. Questions to consider: Have I identified the critical functions in my farming system? Are there multiple resources supporting each function? What functions am I not supporting with multiple resources? How can I change this?

## 9 Change a problem into a benefit

Think how a problem on or around the farm site could be transformed into a solution. Questions to consider: What are the current problems within my farming system? Have I incorporated solutions to transform them into benefits? Where are the wastes on the farm? Have I identified opportunities to transform waste into resources?

## 10 Continually reassess the system using the feedback loop

Observe how the changes made affect the site over time. Review progress using the lens of the 10 principles to determine if there are additional ways to improve the system. Further details on how to continually monitor reassess the system and implement responsive changes are presented under Step 4 – Site Monitoring and Feedback Integration.

Photo: Andrea Mottram, Mercy Corps

# Step 4: Site Monitoring and Feedback Integration – Closing the Loop


**Aim: Evaluate the effectiveness of the farm site design and identify areas for improvement.**

Photo: Nancy Farese, Mercy Corps

***Improving the site design, adding seedlings in Haiti.***

## Concept Summary: Site Monitoring and Feedback Integration

Farmers are best placed to monitor their own site designs and adapt them as necessary to changing external influences and resource availability. At a basic level, they can do this by closely following how their farm design is working and by asking questions to determine the effectiveness of the decisions made during the site planning exercise. Farmers should also revisit the observation and mapping process conducted during Step 1: Site Assessment to map changes over time and identify new opportunities.

Field agents also need to be able to monitor the implementation of the RD approach and the overall health or success of the farming system. Field agents need to ensure that the recipients of the RD knowledge (farmers) are implementing their learning effectively and are taking ownership of the process. Field agents also need to be able to measure the impact of the RD approach at a project level, both for the project cycle and for external donors.

The process of monitoring how the site design is working and integrating feedback based on its successes and failures will, over time, lead to the design of a better and more resilient farming system.

## Methodology: Site Monitoring and Feedback Integration

See also the Site Monitoring and Feedback Tip Sheet.

### 1. Farmer-Led Monitoring

Farmers can monitor their own sites by closely viewing how their farm design is working, and by asking questions such as:

- Is water flowing to the right places?
- Am I capturing positive influences as much as possible?
- Am I excluding negative influences at the right times?
- Are the trees, crops and livestock looking healthier and producing more? If not, why not?
- Which principles do I need to utilize more in my design?

These questions encourage farmers to revisit the steps of the RD approach, starting with the observation and site assessment of Step 1. For example, they may notice that even with a series of swales with overflow routes, one part of their field still erodes during heavy rains. As part of the monitoring and feedback integration process, they would walk the site to observe and assess the water flow when it rains (Step 1), then analyze this influence (water flow) and use an A-frame to check the contour of the land (Step 2). They may notice that a few of the swales are off contour, increasing the likelihood of erosion during heavy rains. With this information they adjust their farm design to capture more water (Step 3).

## 2. Field Agent-Led Monitoring

The *RD Measurement Toolkit* is intended for field agents. It provides a detailed monitoring system for tracking changes over time and for capturing data required for project level indicators. At the most basic level and to provide agents and farmers with quick feedback on the productivity of their farming system, field agents may find it useful to do a quick "field check" using the questions presented in the table below. The checklist is not meant to serve as a formal monitoring and evaluation tool but rather as a quick snapshot of the farmer's practices. The questions asked should be adapted as required to better reflect the unique context of the farmer or of the program objectives.

The table on the next page provides an example checklist. The first column lists a number of activities (identified by field agents in discussion with a select number of farmers) that are required for optimal site design. Columns are then added to the right of this for each site (or farmer) implementing the RD approach. Site details are captured on a separate sheet, e.g., Site 1 = Mr. Tsinguy, Farm 15, Chikuwa village. Field agents record how well the activities are implemented on the site—*none existent*, *practice observed but not very effective*, *practice good* and *practice exceptional*—using the key provided. The ✪ symbol denotes that it would be a good model for other farmers to learn from.

Percentages can then be assigned to the symbols to determine the effectiveness of the activities. Field agents can capture the percentage of each symbol *across one site for all activities*, to see how well the site is progressing against each activity, or *across all the sites for one activity*, to monitor the effectiveness of a particular activity and perhaps indicate whether further training or improvement is required. These results should be compared over time to monitor changes.

Photo: Andrea Mottram, Mercy Corps

***Checking the fields in Zimbabwe.***

***Key:***

**✖ None existent** **✓⁻ Practice observed but not very effective** **✓Practice good**

**✪ Practice exceptional, a good model for other farmers to observe.**

**Field Agent Name:** ____________________________________________

**Date:** ____________________________________________

## Simple Monitoring Checklist Example

| | Practice (examples are provided below) | Site 1 | Site 2 | Site 3 | Etc. |
|---|---|---|---|---|---|
| 1 | Mulch is applied to crops and/or the soil is with covered plants | ✪ | ✓ | | |
| 2 | Plants or trees are used to improve soil fertility | ✓⁻ | ✓ | | |
| 3 | Rainwater is captured using dams or water-harvesting techniques such as swales, demi-lunes, berms, zai pits, or other earthworks such as directing run-off by the side of a road into the fields | ✓ | ✓ | | |
| 4 | Farm wastes or locally available materials are used to make organic fertilizer and soil amendments and added to the soil | ✖ | ✪ | | |
| 5 | Crop patterning is on-contour or trees are planted on-contour | ✓ | ✪ | | |
| 6 | Resources are intentionally placed to enhance productivity and efficiency | ✓ | ✓⁻ | | |
| 7 | Crops are well adapted to the local climate, such as drought-tolerant varieties for dryland areas | ✓⁻ | ✓⁻ | | |
| 8 | Farmer feels able to deal with shocks and stresses impacting agricultural production and/or the household | ✓⁻ | ✓ | | |
| 9 | Incidence of pests or diseases on the crops is low | ✓ | ✓ | | |
| 10 | Signs of erosion on the farm are limited | ✓ | ✓ | | |
| | **Score:** | | | | |
| | ✖ | **10%** | **0%** | | |
| | ✓⁻ | **30%** | **20%** | | |
| | ✓ | **50%** | **60%** | | |
| | ✪ | **10%** | **20%** | | |

## RD Measurement Toolkit

The more comprehensive ***RD Measurement Toolkit*** includes a number of tools and indicators that field agents can use to monitor changes at the farm level, as well as participatory activities involving the community for evaluating impact at this level. Details on each tool, and how and when to use it, are provided in the toolkit. These tools also linked to the Step 1: Site Assessment activities described on pages 15-28.

The farm-level tools from the RD Measurement Toolkit are designed to easily fit into and support a field agent's daily activities. These tools collect data for output indicators that track whether or not farmers are implementing RD strategies and techniques, as well as data for outcome indicators on production, income, production costs, and farm agroecosystem and household resilience.

Farm-level tools include the ***Farm Resilience Assessment***, ***Farm Production Assessment*** and ***Soil Health Assessment***. Among these, the most important tool is the Farm Resilience Assessment which tracks output indicators that show whether or not the farmer is applying the RD approach's techniques and strategies. More than just a monitoring tool, it is also a tool for learning. It facilitates a dialogue between field agents and farmers and helps to actively integrate feedback from the monitoring process for improved farm production and increased resilience.

Field agents and farmers should revisit these assessments annually to track the progress of the farming system. For example, improved soil health might indicate that techniques from the RD approach are being implemented successfully. Similarly, if the farm receives a lower score on the Farm Resilience Assessment, farmers can revisit the Improving Your Score section to consider ways to adjust their site design.

Participatory impact assessment (PIA) methods[29] are exercises carried out in conjunction with members of the community. The goal of these assessments is to measure the impact of the RD approach on farm production income and expenses, farmer workload, nutrition, and household resilience. This participatory method can be used alone, or alongside existing indicators that programs may be using for production, income, nutrition, etc. In the latter case, the aim of including PIA methods is to more accurately capture production and nutritional information from a diverse production system that incorporates many different crops and livestock. PIA methods also include "Most significant change" stories that document change and innovation at the farm, household and community levels. To ensure the most accurate results, the output of the PIA exercises should be triangulated with data from the Farm Resilience Assessment and Farm Production Assessment, as well as with other relevant project monitoring data.

All of the information gathered during Step 4: Site Monitoring and Feedback will help to inform continuous improvements in the RD approach, and ultimately, in farmers' livelihoods and resilience.

Photo: Mercy Corps

# Technical Guidance: Healthy Soil

Photo: Nancy Farese, Mercy Corps

***Healthy soils supporting seedling growth, Haiti.***

**The aim of this technical guidance** is to help field agents support smallholder farmers to create and maintain healthy, living soils. Healthy soils are crucial for productive agricultural systems; water (hydrological) and nutrient cycles that support individual- and community-level health; ecological stability; food security; and economic viability. A living soil is the basis of a sustainable agroecosystem, necessary for building the resilience of smallholder farmers to environmental shocks and stresses.

This section shows how the soil food web— the community of organisms living all or part of their lives in the soil—is integral to healthy soils, and how it can be achieved. It then describes a range of techniques farmers can use to create productive soils with a rich balance of microorganisms, organic matter, and other necessary elements to support optimal plant growth.

# Key Messages

- **Soil is a diverse and complex environment** upon which most of life on land depends. When healthy, it is responsible for nutrient cycling (the movement and exchange of organic and inorganic matter back into the production of living matter); the stability of water in the system, and good human nutrition.
- **Healthy soils contain many species of animals and microorganisms.** These species make up a living soil food web that contributes to many vital ecosystem services, such as: the number of ecological interactions among organisms (ecosystem biodiversity); soil formation; fixing nutrients from the atmosphere; soil moisture retention; and the removal of carbon dioxide from the air and storage of that carbon.
- **A healthy soil food web** reduces input costs for smallholder farmers, increases disease resistance in crops, and improves yields and crop quality.
- **The soil food web is easily disturbed** or destroyed through practices such as agricultural intensification, regular tillage, soil compaction, use of chemical fertilizers, and monocropping. These practices create a long-term decline in soil biodiversity and reduce the capacity of the soil to function efficiently and productively.
- **Soil and the soil food web can be improved**, even in badly damaged and eroded landscapes, through the RD approach and the application of effective techniques and land management practices.

Photo: Corinna Robins, Mercy Corps

***Healthy soils producing healthy snow peas (mange tout) in Guatemala.***

# The Importance of Healthy Soils

Soil health is “the capacity of soil to function as a living system…to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health.” From an ecosystem perspective, “a healthy soil *does not* pollute its environment and *does* contribute to mitigating climate change by maintaining or increasing its carbon content.”[30]

Soil health is a function of its physical properties, the soil organisms and their diversity, its food web structure, and the range of functions it performs.

A healthy soil is full of living organisms, high in fertility and organic matter, well-structured to optimize water and nutrient retention, adequate in moisture, and well-covered and sheltered by plants.

Given its vital importance, creating, maintaining, and improving a biologically rich and productive soil—one with a strong **soil food web**, good structure, and adequate nutrient balance—should be a key consideration for all farmers.

**Healthy soil with a well-balanced ecology will:**

- Increase plant and animal production
- Improve the production’s nutritional value
- Suppress diseases
- Increase nutrient retention
- Minimize runoff and leaching
- Reduce erosion
- Maximize infiltration
- Increase water-holding capacity
- Increase root depth
- Make plant-soluble nutrients available at rates plants need
- Break down toxins
- Capture and store (sequester) carbon

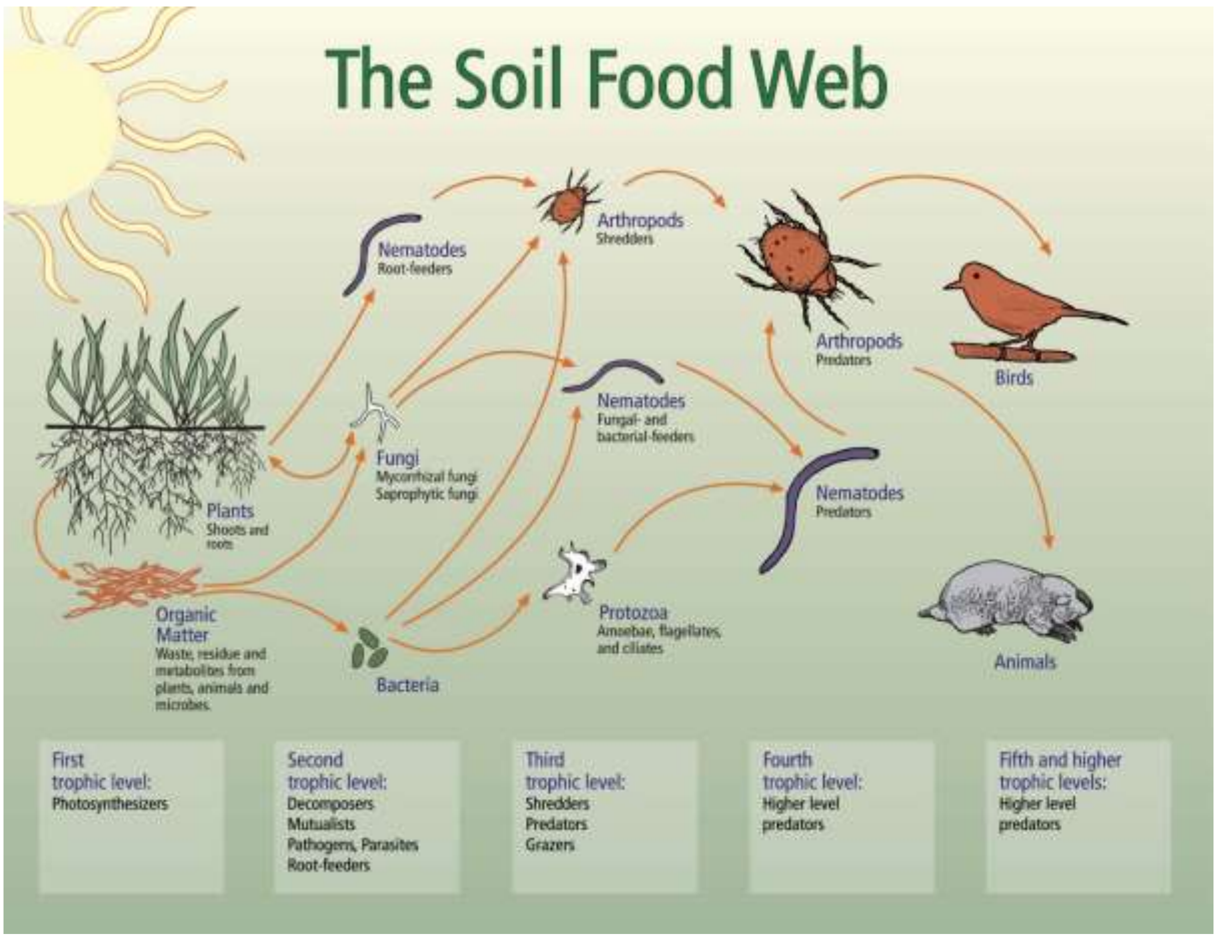
## The Soil Food Web

The soil food web incorporates the community of organisms—from bacteria and fungi, to earthworms and insects—living all or part of their lives in the soil. This community of organisms is part of a dynamic, living ecology and it performs necessary services in the plant root zone and in the water cycle. These organisms provide most of the functions that enhance the physical and chemical structure of the soil. They:

- Break down organic matter (decomposition)
- Fix nitrogen and other macronutrients from the atmosphere into the soils
- Provide nutrients to plants, and promote healthy plant root development

- Create defense systems to protect against pests and disease and the removal of contaminants from the soil (soil remediation)
- Build a soil structure that increases water's ability to infiltrate and drain, and improves soil moisture
- Provide essential pathways for oxygen and carbon dioxide, removing carbon dioxide from the air and storing it as carbon (carbon sequestration)

The soil food web is vitally important for building and improving soil capacity over the long term. For example, soil biodiversity may not necessarily be critical for the production of a given crop in a given season but it is very important for the *continued* capacity of the soil to produce that crop.




***The soil food web.*** Source: USDA Natural Resources Conservation Service [31]

The soil management techniques built into the farming system should be designed to result in six features of a healthy soil:

1. **Presence of soil food web:** A healthy soil food web is essential for soil structure, decomposition of organic matter and plant nutrient uptake. A well-developed soil food web with enough organic matter creates the conditions for the soil organisms to convert micro- and macronutrients into plant soluble nutrients that plants can uptake.

2. **Good soil fertility:** A fertile soil has all the main nutrients for basic plant nutrition (e.g., nitrogen, phosphorus, and potassium), as well as other micro- and macronutrients needed in smaller quantities (e.g., calcium, magnesium, sulfur, iron, zinc, copper, boron, molybdenum, nickel). A fertile soil will also usually have some organic matter that improves structure, moisture and nutrient retention, and a pH value between 6 and 7. If a healthy food web is present, as well as "food" for the web in the form of organic matter, ash, charcoal, etc., then the web can make all of these nutrients.

3. **Adequate organic matter:** Enough organic matter is needed to feed soil organisms, which then convert the matter into plant-soluble nutrients for healthy plant growth. Organic matter consists of anything that was once alive that can be layered into the soil as food for the organisms and, ultimately, for plants and livestock. Feeding the soil with adequate organic matter will allow plants to access a wide variety of nutrients to help them grow, resist insect infestation, and buffer them in extreme climatic conditions.

   Adequate organic matter consists of:

   - Decomposing organic matter: 33%-50%
   - Stabilized organic matter (humus): 33%-50%
   - Fresh residue: Less than 10%
   - Living organisms: Less than 5%

   Some smallholder farmers may want to use inorganic inputs such as chemical fertilizers or pesticides to increase productivity and this practice is often supported with government subsidies. While this can be a viable option and in some cases may increase production in the short term, it is important to understand that they negatively affect the soil food web; crucial fungal and bacterial relationships have difficulty forming in the presence of inorganic inputs. When a plant is chemically fed, it bypasses the microbial-assisted method it would use to naturally obtain nutrients. This creates a dependency on inorganic inputs, often from non-local sources, which must be added regularly to keep the plant productive. In many cases the plant becomes weakened and more susceptible to disease and its capacity to uptake micronutrients is diminished, resulting in a final product with a lower nutritive value for human consumption.[32]

4. **Well-structured soil:** Limited soil compaction and good soil structure allows the soil to "breathe". Having a good soil structure increases:

    - The amount of water that can be stored
    - The ability to resist erosion
    - Nutrient availability
    - Essential atmospheric gas exchanges that keep the plant root zone aerobic ("breathing")
    - Root spread and interaction for healthier and more productive plants
    - Infiltration for ground water recharge

5. **Adequate soil moisture capacity and content:** Well-balanced soil moisture is essential for seed germination and nutrient uptake and will help create and maintain a robust biological support system for plants. Excess soil salinity (salt) can hinder plant growth by affecting the soil-water balance.

6. **Well-protected and covered soil**: Protecting the soil from excessive wind and sun is critical as overexposure to these influences can lead to plants overheating; moisture evaporation; reduced water infiltration, and pressure on the growth cycles of plants.

Photo: Warren Brush, True Nature Design

***Healthy soil.***

Photo: Andrea Mottram, Mercy Corps

***Applying mulch.***

Photo: Warren Brush, True Nature Design

***Millipede.***

# Soil Health and the RD Approach: Practical Application

**The following section demonstrates how farmers can use the four steps of the RD Approach – assess, analyze, design, and adapt – to build and maintain healthy soils. See Step 1 – 4 of the RD approach for more specific details on the methodology.**

## Identifying Resources and Observing Influences

Using the RD approach to build healthy and resilient soils, farmers should begin with identifying resources and observing influences as part of the site assessment. From there, they analyze these observations to then select and combine appropriate techniques to sustainably feed the soil food web and build up the soil's physical and chemical properties.

### Resources

Food sources for soil organisms are essential to maintaining a biodiverse habitat that provides favorable conditions for plant growth. Organic matter comes in many forms, including living and dead material from plants and trees, mulch materials, water sources and flows, and plants that gather nutrients missing in the soils. Even stones can be used as mulch or in bunds to increase water infiltration, or they can act as soil nutrient and organic matter traps that help enhance the conditions for a healthy soil food web.

### External Influences

In addition to the three main influences listed below (slope, sun and wind), farmers should also take care to consider other external influences, such boundaries, land uses, wildlife, and man-made influences such as roads, path, noise and theft.

#### *Slope*

Water and nutrients flow downhill. Slope also influences air movement (hot air rising and cold air sinking) resulting in different microclimates at different elevations of the slope. When assessing a farming system it is important to look at where the site is on the slope, and then within the wider watershed.

Questions to consider when assessing a site for the influence of the slope:

- Is the farm on top of a hill where there is less water and fewer nutrients flowing onto it, or is it at a lower elevation?

- Where is the farm in the watershed? Is it in the less-sloped alluvial fan (fan or cone-shaped deposit of sediment crossed and built by streams) lower in the watershed or higher in the watershed?
- Are there sources of pollution upslope that result in impurities travelling down through the land with the water?

Different locations on different grades of slope require different sets of techniques to achieve the best soil conditions. Assessing flows of water, nutrients, and pollution onto the farm site will help determine where to locate resources and what positive influences need to be channeled and what negative ones need to be mitigated.

### *Sun*

Sun is essential to plant growth and soil health and it is important for the farmer to observe and understand its influence on the site, including how it moves across a site; the angle (aspect) of each slope in relation to the sun at different times of day and different times of year; and how sun exposure varies. Sun exposure may vary in different areas of the same site due to the angle of the slope. To ensure adequate moisture is maintained in the soil this variance should be taken into account during the growing season. The sun's intensity also varies by time of day–greatest in the late afternoon—and care must be taken in more arid environments to block the negative effects of excessive sun, including soil dehydration, high soil temperature, and associated plants stress and limits on growth and nutrient uptake.

Questions to consider when assessing a site for the influence of the sun:

- Where are the hottest, driest parts of the farm, especially in the hottest and driest times of the day and year? Are they sheltered or exposed?
- Does the soil have continuous protection from the sun throughout the year, and particularly at the hottest times of the year? Does the soil get excessively hot during the growing season?

### *Wind*

Too much wind increases evaporation rates from the soil, reduces their moisture content, and causes structural stress in plants. Learn about the wind conditions on the site through local knowledge and by looking for tree flagging, wind eddies and direct exposure. In many circumstances, a windbreak strategy will help reduce the negative effects of the wind, protect the soil from erosion and runoff, and create the best conditions for a vibrant soil food web.

Questions to consider when assessing a site:

- Which direction do the winds come from? Does the wind direction change throughout the year?
- Are the winds hot and dry, or cold and moist?
- Which plants are currently negatively affected by harsh winds?
- Are there any current wind-blocking techniques on the site? Could they be improved?

Apart from slope, sun and wind, other influences to consider include upslope influences such as erosive water flowing off poorly managed land, pollution moving down with water, and chemical drift as well as wildlife (e.g., hippos coming up from a lake); and domestic animals eating crops.

## Analyzing the Resources and Influences

After identifying the different on-site resources and external influences, farmers should analyze how they work together to highlight opportunities and constraints – Step 2 of the RD approach. This analysis will help guide the selection and placement of key water- and nutrient-harvesting techniques during the design process. *Opportunities* might include nutrient sinks that can be directed to agricultural production, water-harvesting from a nearby path or road, or the right amount of sun exposure for different plant species' growth needs. *Constraints* might include too much sun or wind on a particular field site, key resources being too far away, flooding, erosion, and more.

Photo: Andrea Mottram, Mercy Corps

***Path erosion, Nepal.***

Questions to consider when analyzing soil resources on a site:

- Is the soil protected from negative external influences? Are there opportunities to plant trees to use as cover and help protect the soil from too much evaporation?

- Are there opportunities to harvest nutrients flowing downslope with water? Is there a small erosion gulley that can be harvested for water and manure flows?
- Could a goat pen be placed uphill from a growing area, rather than downhill, to take advantage of the nutrients flowing downslope with gravity and to save time and labor by being able to move manure downhill to a field rather than uphill?
- Are there nutrient resources available but not being utilized? Are there old fire pits or ash piles that have charcoal that can be used in the compost to build up the microorganism populations?

# Designing for Soil Development

## Applying RD Principles to Soil Development

After observing and analyzing the site and its surroundings, application of the 10 RD principles will assist the farmer in selecting and combining the best techniques that respond to the unique opportunities and constraints of the specific site to increase overall productivity and resilience.

Below are a few of the many examples of how these principles can enhance the design process to create a healthy soil.

#### 1. Observe and mimic healthy and resilient living systems

It is easier to copy and build on what works than to start anew; look at what natural, healthy systems exist and how they might be applied to the farming system. For example, forests naturally build healthy soils, so observe how the forests creates soil and then identify and understand the various techniques that could be copied on the farm site. For example:

- In a forest, a thick layer of humus is added to the soil in seasonal patterns and is not disturbed; organic matter added to the top of the soil and not tilled would mimic this natural pattern
- Cover the soil to keep it cool increases soil life and water infiltration
- Integrate animals for light disturbance, pest control, and manure
- Use multiple crops in the same place (polyculture)

## 2. Start small and simple

Start small and simple so the farmer can learn as they grow what works best for them and their site; build the complexity of the farm site over time, using feedback from the system. For example:

- Shift a crop pattern to align with the contours of the land
- Add a half-moon shaped berm around the base of an existing high-value tree
- Integrate a secondary crop near an existing main crop
- Us locally adapted seeds

## 3. Start at the top (highpoint or source) and work down

Begin at the top of the site to maximize energy efficiency and the effect of gravity, as well as to harness essential water resources and nutrients for optimal plant, tree and animal production. For example:

- Slow water down higher uphill to keep it from eroding further downslope
- Create an aquaculture system high up on a site to provide high value fish manure in the water for crop irrigation downslope
- Move an animal enclosure upslope of crops to allow nutrients in the water to cascade into the growing areas
- Plant perennial fertility-building plants such as leguminous trees upslope of field crops to contribute to the fertility needs of the main crops

Photo: Brad Lancaster, ***www.HarvestingRainwater.com***

***Water runoff from the roof fills the pond (top left) that provides water to the cows who produce manure, which flows down to fertilize the crop fields.***

### 4. Slow, spread, and sink the flow of water and nutrients

Nature uses many strategies to slow, spread, sink and store valuable resources for best uptake by life. When systems no longer have this function, there is a loss of plant diversity and health, a loss of nutrients through erosion, and less overall water for plant production. Create conditions in the soil for long-term storage of water and nutrients, and to eliminate the loss or underuse of these resources. For example:

- Build water harvesting structures like swales, dams or rock check dams high in the landscape to allow water and nutrients to sink into the soil as a reserve for future plant usage
- Use the contours of the land as a guide for crop and tree plantings
- Use water-flow-spreading structures like one-rock check dams on-contour

### 5. Grow natural resources

Grow resources to decrease input costs and dependency on off-site resources. For example:

- Plant leguminous trees for perennial, high-value woody mulch, shade, wind protection, fodder, and a rich nitrogen fertilizer
- Plant nitrogen-fixing ground cover to protect soil, provide fodder, and to feed the soil's nutrients
- Grow a well-designed living fence, consisting of a mix of plants that contribute to the system. This provides structure, food, and fertility to the system, and will be regenerative as it enhances itself with each growing season.

### 6. Place every resource for energy efficiency

Consider the energy requirements for the system and the energy available within it, and then identify ways to adjust the placement of resources to maximize energy efficiency. For example:

- If a farmer has a cow, consider placing the pen above the field on the slope. Add an on-contour swale between the fields and the pen to spread out the manure flows to let gravity, rather than labor, disperse and deliver the nutrients to the fields.

## 7. Locate and use each resource so that it provides several benefits to the farming system

With the placement of each technique and resource, ensure it provides more than one benefit to the system. For example:

- Integrate a swale or on-contour berm to help slow, spread, and sink water into the farming system. The swale, a resource in this example, provides multiple benefits: it captures nutrients from upslope sources; creates a small site for growing perennial, fertility-building trees and shrubs to feed the soils; reduces erosion; hosts crops that need higher levels of moisture; and serves as a level path to a field.
- Plant nutrient-contributing trees to the west side of a dryland field. Prune the trees at the beginning of the rainy season to create high-value mulch for the farming system. Then, as the dry season approaches, the tree's leaves will regrow, along with new branches that provide valuable shade from the intense westerly sun.

## 8. Ensure critical functions in the farming system are supported in several ways

For each critical function identified during the site assessment, ensure that there are multiple sources of supply or access. For example, if building or maintaining healthy soils is identified as a critical function:

- Practice alley cropping with main crops and nutrient-fixing trees for ground cover, such as Desmodium intortum sweet clover (Melilotus alba), pigeon pea (Cajanus cajan), velvet bean (Mucuna pruriens), cowpea (Vigna family), or lucerne (Medicago sativa)
- Use animal manures, which are high in organic matter
- Save local wastes like crop residues that others may discard
- Collect leaf drop from forests
- Extract organic matter from ponds or lakes
- Use wind and water traps to deposit organic matter on the site

## 9. Change a problem into a benefit

Identify and use the unique conditions of the site, such as slopes or sun exposure, as opportunities rather than constraints. For example:

- Use the different microclimates on the site to grow specific plants that succeed better in one place than another, e.g., tomatoes, sunflowers and herbs on a dry site, and lettuce, kale, and other leafy vegetables on a cooler site
- Turn crop residue (typically seen as a waste and burned) into high-value organic matter and mulch through the process of slow-composting
- Use animal and human urine (diluted with ten parts water) to enrich the soil[33]

Photos: Brad Lancaster, ***www.HarvestingRainwater.com***

***Using once erosive road runoff (left) as a benefit (right).***

## 10. Continually reassess the system using the feedback loop

Once the site design is implemented, reengage the four steps and the RD design principles to see what is working well and what is not. Observing from season to season, and within seasons, highlights whether:

- The soil structure and fertility is improving
- Plants perform well and are productive in comparison to the previous year's crop or to their neighbors' crops
- The growing season is extended or not
- More or less pests, weeds, or other negative influences are present

## Techniques to Improve Soil Health

There are many techniques and combinations of techniques that can be used to create ideal conditions for soil organisms to thrive and result in a robust soil food web and healthy soils. To take maximum advantage of site-specific conditions and natural resources, farmers should look at their soil from a whole-farm perspective, as well as in specific locations, and then choose and combine the appropriate techniques for each situation.

The decision of where and how to combine techniques will depend on site-specific elements. For example, it may be ideal to plant leguminous trees in a water-harvesting swale above the farmer's crop to provide mulch, a windbreak, nutrients, and evaporation protection for harvested water. Then, as time goes on, the swale can be linked with a goat path along the side of the site to capture the water flow, high in nutrients, from the goat manure. With the swale upslope of the planting area, water and nutrients will slowly sink and move downslope, creating a stable water source for plants.

Local innovations, such as the adaptation or creation of a new technique specific to the farming system, should also be encouraged and shared; these innovations are often overlooked by field agents who are more familiar with standard techniques.

Below is a table of agricultural techniques that help build soil health. It is not an exhaustive list, but rather a useful subset and should be considered together with those presented in the water management module. See also Techniques Tip Sheet.

| Techniques to Improve Soil Health | | | | |
|---|---|---|---|---|
| **What it is** | **Benefits** | **Where to use** | **Cautions** | **Variations** |
| **COMPOSTING** | | | | |
| Decayed organic material used as a plant fertilizer. | Adds organic matter to the soil and improves soil fertility.<br>Increases soil moisture-holding capacity.<br>Helps suppress weed growth.<br>Improves crops' resistance to pests. | Particularly useful for home gardens.<br>Also useful for field crops, but producing sufficient quantities is a challenge. | Keep compost moist, particularly in hot and dry areas.<br>Keep compost covered or in the shade and be sure to water it. | Hot compost<br>Compost tea<br>Vermi-compost<br>Cold compost<br>In large fields, copy nature by layering organic materials (manure, dry leaves, green mulch, etc.) to create conditions for humus creation. |

| Techniques to Improve Soil Health | | | | |
|---|---|---|---|---|
| **What it is** | **Benefits** | **Where to use** | **Cautions** | **Variations** |
| **SOIL AMENDMENTS** | | | | |
| Adding locally available materials such as animal manure and bird droppings, charcoal, and dry leaves to soil. | Adds nutrients and organic matter to soil to improve soil biology and structure. | Use in the field for crops. | Be careful not to add too much wood ash, as it affects the soil's pH and can affect the plant's ability to uptake nutrients. | Use a moveable chicken coop to bring manure directly to fields.<br>Build a pigeon house upslope of a field to bring valuable phosphorous from wild pigeon waste. |
| **COVER CROPS** | | | | |
| Planting herbaceous crops (normally legumes) during "off season" in order to protect the soil and boost fertility for the next season. | Reduces evaporation.<br>Increases soil fertility.<br>Reduces erosion. | Use in fields during "off season" (such as in the summer or winter between main crop plantings). | Some cover crops can become weeds if allowed to flower and reseed. | Cover crops can be incorporated with field crops to help boost fertility and growth. If doing so, manage cover crop to ensure it does not compete with field crop for sunlight and water. |
| **CROP PATTERNING** | | | | |
| Patterning crops according to observation of landscape. | Helps protect soil against potential erosion and runoff.<br>Creates water- and nutrient-harvesting opportunities. | Use in any field, garden, or orchard.<br>Taller, perennial crops can be planted to the west to deflect hot, summer afternoon sun or on the windward side to deflect harsh winds. | Plan for the plants' full size at maturity to ensure harvesting access and sunlight access in the future. | Pattern crops along successive contour lines at different heights to enable the capture of water, soil and nutrient runoff to improve production conditions. |
| **IMPROVED FALLOWS** | | | | |
| Planting leguminous trees, shrubs and herbaceous cover crops on land resting from cultivation in order to replenish soil fertility more quickly. | Replenishes soil fertility.<br>Conserves nutrients from one season to the next.<br>Interrupts life cycles of pests and diseases. | Use on land that has been intensely cultivated. | Fallow land left bare could lose soil and fertility to wind or storm water runoff. The more vegetative anchors there are, the less likely soil is to be lost and the more likely it will be gained. | Cut back some legumes for mulch and to release root mass into the soils as food for microorganisms. |

| Techniques to Improve Soil Health | | | | |
|---|---|---|---|---|
| **What it is** | **Benefits** | **Where to use** | **Cautions** | **Variations** |
| **CROP ROTATION** | | | | |
| Rotating crops in a sequence to ensure soil fertility.<br>Mostly used where monoculture is practiced. | Enhances soil fertility and structure.<br>Reduces the incidence of pests. | Particularly for fields where mono-cropping is used, or for farms with declining yields and/or problems with pests and disease.<br>Where inter-cropping or polyculture is practiced, crop rotation may not be necessary. | Sequence crops so that they extract or add nutrients to the soil in a beneficial order (see variations). | Ideal rotation for each growing season would be from a leaf crop (kale, spinach, etc.) to a main fruiting crop (millet, sorghum, maize, tomatoes, etc.) to a root crop (potato, cassava, beet, etc.) to a legume (bean, cow pea, etc.) to a green manure (Desmodium, lucerne, etc.). |
| **INTERCROPPING** | | | | |
| Combining two or more different crops (usually one of them a legume) in the same space, typically parallel to each other. | Improves nutrient recycling and moisture retention.<br>Extends cropping seasons and reduces land areas required for fallowing. | Use with all crops. | Ensure crops are good companions before planting them together.<br>Be sure to choose crops that will not compete with each other. | Alley cropping or hedgerow intercropping, which combines crops with trees of fast-growing woody species.<br>Polyculture, which combines multiple crops (and animals) in the same space. |
| **AGROFORESTRY** | | | | |
| Combining crops with trees of fast-growing woody species, such as shrubs. | Improves soil fertility.<br>Increases soil moisture.<br>Increases tree cover. | Use with staple crops.<br>Depending on the system's needs, choose trees that provide income, human nutrition, perennial fertility for annual crops, fodder, building materials, or firewood. | If shade becomes too dense for crops between trees or hedgerows, prune the trees or hedgerows to allow in sunlight. | |

| Techniques to Improve Soil Health | | | | |
|---|---|---|---|---|
| **What it is** | **Benefits** | **Where to use** | **Cautions** | **Variations** |
| **WINDBREAK** | | | | |
| Placing a line of trees to protect a field from strong winds. | Limits stress that wind puts on plants.<br>Reduces erosion.<br>Creates microclimates.<br>Reduces crop damage and evaporation. | Use on farms where wind is causing stress to plants.<br>Note: A windbreak is most effective up to 10 times the distance of the height of the trees in the downwind zone (for example, if trees grow to 30 feet, the protected area would be about 300 feet.). | Be careful not to make a wind tunnel where wind will move more forcefully through an opening in the windbreak.<br>Stagger a second or third windbreak upwind or downwind of the opening (perhaps for road access) in the original windbreak. | Use trees that can provide fodder, food, firewood, or mulch. |
| **NO – OR MINIMUM – TILLAGE** | | | | |
| Planting in holes, rather than ploughing, to minimalize soil disturbance. | Reduces soil exposure to sun, compaction and wind.<br>Protects from loss of essential microorganisms and moisture. | Use on land used for field crops. | Ensure crop residues used in the soil are pest- and disease- free.<br>It may take time to see benefits if the land it has been tilled for a long time. | Combine with other techniques such as mulching to further reduce need for tillage. |
| **NUTRIENT CASCADING** | | | | |
| Placing nutrient sinks, such as a cow paddock, upslope of a production crop. | Uses gravity to cascade nutrients down slope to the crops, reducing energy requirements. | Use anywhere possible on the farm. | Make sure household health is not negatively impacted when locating animal structures on the farm site. | Consider other external influences such as wind for ideal placement of nutrient sinks. |
| **INTEGRATED PRODUCTION SYSTEMS** | | | | |
| Integrating intensively managed animals into the farming system. | Adds organic matter to the soil in the form of manure.<br>When livestock eat grasses, it | Use in grazing fields. | Do not introduce livestock where they may damage or compact the soil for crop production. | Integrate chicken or pigeon pens into the system. |

| Techniques to Improve Soil Health | | | | |
|---|---|---|---|---|
| **What it is** | **Benefits** | **Where to use** | **Cautions** | **Variations** |
| | releases root matter into the soil to feed soil microorganisms. | | | |
| **MOUNDED OR RECESSED PLANTING STRUCTURES** | | | | |
| Strategically placing plants on mounded structures (such as a berm or bund) or in recessed or sunken structures (such as a swale, pit, furrow or basin) rather than on flat ground. | In dry/ arid areas, recessed structures help concentrate water and nutrients in the root feeder zones, and protect the plant from too much wind and sun.<br>In humid/wet areas mounds help avoid root rot. | Use recessed structures in arid, low-rainfall areas.<br>Use mounded structures in humid, high-rainfall areas. | Plan an overflow route for recessed structures so they are not flooded in heavy rains.<br>Use mulch on mounded structures to avoid erosion. | Can also use recessed structures with organic matter to build soil fertility, including bio-swales, half-moon or semi-circular basins.<br>Tassa/zai pits (planting pits), Katumani pits, Negarim micro-catchments.[34] |

It is important to monitor the impact of different techniques over time and continually adapt them as external influences change. Step 4 of the RD approach provides further information on assessing the impact of soil health techniques.

***Case Study***

The community of Chikukwa Village, Zimbabwe used to suffer hunger, malnutrition, and high rates of disease but, by using farming techniques similar to those in the Resilience Design approach, it has turned its fortunes around. Complementing agricultural techniques used to improve food security, they have built their community strength through locally initiated and controlled programs for permaculture training, conflict resolution, women's empowerment, primary education and HIV management.

Early in the 1980s, Chikukwa Village, a hillside community of more than 5,000 people, suffered from the ill-effects of deforestation, monocrop agriculture and overgrazing. When trees were removed for use by the community the soil started to degrade and eventually the entire ecological system began to collapse. Without trees, the rains no longer sank into the soils and an erosion cycle began. People planted monocrops where diverse forest systems once existed. Soon, the water system collapsed, the springs dried up and the villagers had to go to a river to fetch water and bring it uphill to their homes, gardens and farms. Cholera was frequent in the rainy season, causing a decline in health and more untimely deaths. Soil fertility fell as the topsoil was carried away and the crops were exposed to sun, wind and erosive rains. Both crops and livestock began to suffer from the effects of reduced nutrition and decreased capacity to withstand pests and disease.

Around this time, several community members went to a permaculture design course that used elements similar to those in the resilience design process. They came back from the course with skills to redesign their village and began building community consensus to start the work.

The villagers created a whole community design focused on linking as many site-relevant techniques as possible; increasing biodiversity, and recreating the stability of the previous forest. They used earth-shaping techniques (earthworks), planted legume trees and cover crops, built boomerang berms, began composting and alley cropping, and integrated animals and aquaculture into the farming system. All of these interventions proved highly effective in rebuilding the stability of their community.

Now, more than 30 years later, they have a surplus of food and the people are healthy. Their degraded landscape has been turned into one that is productive, resilient and economically viable.

http://www.thechikukwaproject.com and
http://www.gifteconomy.org.au/files/ChikukwaProject.pdf

# Key Resources for Healthy Soils

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Photo: Adam Bacher, Mercy Corps

# Technical Guidance: Water Management

Photo: Warren Brush, True Nature Design

***Water management in Mazvihwa, the Muonde Trust, Zimbabwe.***

**The aim of this technical guidance** is to help field agents support smallholder farmers to optimize water management. Water is crucial for productive farming systems and the lack of it (or sometimes, too much of it) is often the largest barrier to the overall productivity of farming systems. This module explains how farmers can use water-harvesting techniques to increase the amount of water in the soil during times of adequate rainfall as well as through dry seasons. It also describes techniques that farmers can use to decrease the damage caused by erosion or downstream flooding.

# Key Messages

- **Observing external influences** on the land, such as water and sediment flow, will inform the best way to design a site to manage its water and soils. The better the farmers can see and understand water-flow patterns on the land, the better they can work with them and other natural systems.
- **RD principles guide farmers** to effectively link and use water-harvesting and management techniques. The principles bring together design practices found in successful water management and are crucial for developing more effective and integrated farming systems.
- **Integrating diverse techniques** into the design of farmer's site helps maximize the benefits for the farming system, especially when they are guided by RD principles and linked with the site's external influences. Integration can often lead to new techniques or hybrid techniques that are designed to suit the unique conditions and needs of the site where they are being applied.

# The Importance of Water Management

Water is a vital part of a healthy farming system and is often the largest need in a smallholder farming system. Water management is the control and movement of water to minimize its negative effects and maximize its benefits. The RD approach maximizes the amount of water in to a farming system when needed, primarily by increasing the amount of rain that infiltrates and stays in the soil, and ensuring water ecosystem services are maintained.

The soil can store a lot of water—much more than a smallholder farmer's tank might hold—and the water in the soil is then used by the plants. We can think of the plants as "living pumps" that pump water from the soil into their fruit and canopy, which then benefit the farmer. Using proper water management practices and techniques will enhance both the water resources (including the recharge of groundwater and borehole levels) and fertility of a site, while reducing erosion and downstream flooding.

Water harvesting – the collection storage and use of water - is not simply the draining of rain and runoff. Excessive draining of a site increases the drying of a site, as well as downslope or downstream erosion and flooding. Instead, effective water harvesting directs water away from those areas that do not need it (buildings, roads, paths) towards those areas that do need it (trees, pastures, fields, gardens). Different levels of water needs should also be taken into account: the more water-needy the plants, the more water they should get, and vice versa.  To ensure excess water can flow through–and if necessary leave the system to avoid flooding—an overflow route is always planned and built.

Water harvesting builds on itself. As water enhances soil moisture, more plants and soil life grow and increase the amount of organic matter and fertility within and on top of the soil. This organic matter acts as a sponge and helps to hold extra water, increasing the rate at which the soil can absorb water (helping to reduce or stop downstream flooding) while lengthening the time the soil can hold that water (alleviating the effects of drought).

**How much rain can we capture?**

- 100 mm of rain falling on 1 square meter = 100 liters. This is the same as five 20-liter jerry cans of water.
- Some 60,000 liters of water falls on a 20-meter by 30-meter plot of land in a 100 mm rain. This is equivalent to 3,000 jerry cans of water.
- But the rainfall that runs off a plot of land is lost by the farm.

The more life there is in the soil in the form of plant roots, earthworms and beneficial soil microorganisms, the more water will be available in the soil. Water follows the tunneled paths of these lifeforms and is absorbed by them throughout the soil. Additionally, water acts as a lubricant of exchange. Soil moisture is needed to allow nutrients to pass from dead organic matter to beneficial microorganisms in the soil, then onto living plants and back again.

Rainwater is a natural fertilizer. Rain contains sulfur, beneficial microorganisms, mineral nutrients and nitrogen, all of which are beneficial to plants. Rainwater contains no salts, which are harmful to plants and are common in the soil and groundwater in dry climates. After a rainstorm, plants are greener for three reasons: they received water, they received nutrients, and the rain flushed away harmful salts

Rainwater is the primary water source for groundwater, boreholes, wells, springs, creeks and rivers. If secondary water sources, such as boreholes and ponds, are pumped or drained faster than they are filled, they will eventually dry up until rains can refill them. To ensure that water is available through dry seasons, farmers can improve the water supply of boreholes, wells, springs, creeks, and rivers by sinking or holding more of the rainfall that falls within their soils and vegetation.

The amount of available rainwater is increased by how much runoff adds to it, and decreased by how much runoff takes away from it. For example, 15 mm of rain falls on a farm. Bare dirt areas, such as a sloping road or a gathering area outside a home, will only hold onto half or less of that rain; the rest will drain away. In contrast, sunken, spongy areas below the road or gathering area will hold and sink the runoff, and those areas will receive 15 mm of rainfall *plus* most of the water that ran off the area upslope. The spongy area could receive the equivalent of 30 or 45mm of rain and runoff in a single storm, even if only 15mm falls.

# Water Management and the RD Approach: Practical Application

**The following section demonstrates how farmers can use the four steps of the RD Approach – identify, analyze, plan and adapt – to manage water resources effectively. See Step 1 – 4 of the RD approach for more specific details on the methodology.**

## Identifying Resources and Observing Influences

Every farming system offers unique water-harvesting opportunities and challenges specific to their site and its watershed. Using the RD approach to improve water management, farmers should begin with identifying resources and observing influences as part of the site assessment. From there, they analyze these observations to then select and combine appropriate techniques to harvest more of the available water, and sink it into the soil for improved plant and crop growth.

### Resources

Identify on-site water sources. These could include rainfall, runoff, tanks, water stored in plants, ponds, grey water, springs, creeks, rivers, soil moisture, groundwater, or boreholes. Observe the quality and quantity of these resources and how often they are available.

### External Influences

Commonly seen influences on a given site include sun, wind and gravity. As farmers observe these influences, they should consider what the causes of these influences are and their effects, and how they might channel positive influences into their farming system, and negative influences away from it.

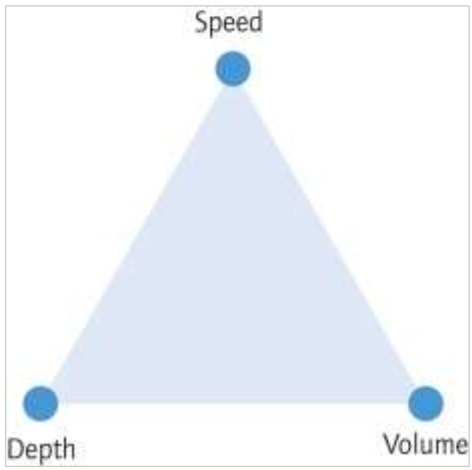
In addition to the three main influences listed below, farmers should also take care to consider other external influences, such boundaries, land uses, wildlife, and man-made influences such as roads, path, noise and theft.

#### *Slope*

Water flows downhill and is always picking up or depositing sediment as it flows across the landscape. Depending on its location a farm is either gaining or losing soil, organic matter and other sediments.

Landscapes that are gaining soil have convex landforms such as alluvial fans, deltas, and depositional bars. These landforms are created where the force of the water's flow lessens, resulting in sediment being deposited out of the water's flow and onto the farmer's site. Eroding landscapes have concave landforms such as gullies or shallow channels formed by the force of water and sediment flowing off the land.

The erosion triangle explains the relationship between water flow and the potential severity of soil erosion or deposition. Three main factors contribute to the levels of soil erosion or deposition: speed, depth, and volume.




***Erosion triangle.***

The greater the speed, depth, and volume of flowing water, the more sediment (soil, organic matter, rock) it carries and the chance of erosion increases. The lower the speed, depth, and volume of flowing water, the less sediment it carries and the chance of sediment being deposited increases.

- **Water speed** increases with a steeper slope; compaction of the soil; lack of vegetation, or lack of other roughness on the soil's surface.
- **Water depth** increases when more of a water's flow is concentrated in a narrower, smaller area or channel.
- **Water volume** increases when water does not infiltrate the soil but remains on the surface, and when the time it takes for a set volume of water to flow from its source to its "sink" or end point decreases. Straightening a meandering water flow would therefore increase the water volume.

In a healthy, stable, natural waterway, the overall speed, depth, and volume of large flood flows are reduced when the water is able to rise and leave the main channel and spread out onto the nearby shallower, wider, vegetated flood plain. When water channels are narrowed and straightened, the speed, depth, and volume of water increases and often results in erosive down-cutting of the channel and water no longer overflows onto an adjoining flood plain.

People and animals create pathways or trails across the land as they walk through it. Over time these pathways often become low spots as feet and hooves dig into the earth. Water flows downhill into the low spots and then adds to the erosive digging down of the path. Such unplanned paths can divert water away from and dry out fields, pastures, and orchards or they may inappropriately direct water towards houses and increase the risk of flooding. Deliberately planning, building, fixing, and maintaining pathways helps people and animals get where they need to go while directing water to where it is needed.

Using their understanding of the three factor–speed, depth, volume–and how they work together, the farmer can assess their site using the following questions:

- How is water and sediment flowing on the land?
- Where does speed, depth, and volume affect water and sediment flow?
- Where are the high points and where are the low points?
- Where is the land eroding? Why is it doing so? (Use the erosion triangle as you think through the answer)
- Where is the land aggrading, or collecting sediment? Why is it doing so? (Use the erosion triangle as you think through the answer)
- Where might the farmer want to reduce the speed, depth, and/or volume of water flow?
- Where might the farmer want to increase soil and water accumulation?

***Overflow routes***

An overflow route should always be planned as part of any rain water harvesting structure. Overflow spillways should have the same flow capacity as a water-harvesting structure's inlet(s). The spillways can be stabilized by making them wide, sloped gradually, and shallow (reducing the force of the water by reducing the flow's speed, depth, and volume), using well-rooted vegetation such as native grasses, and/or tightly packed rock laid only a single rock high (so stabilizing vegetation can grow between the rocks).

## *Sun*

Similar to the process where humans sweat in the hot sun, direct sun on plants, soil, or open bodies of water increases their temperature, which then increases the rate at which they lose moisture to evaporation and evapotranspiration. Shading the soil with mulch and plants reduces evaporation significantly. Plants are unable to uptake hot water as efficiently as cool water therefore the soil (and its water) should be kept cool during the hot months to aid plant growth.

When assessing their site for the influence of the sun, farmers should consider the following questions:

- Where are the hottest, driest parts of the farm, especially in the hottest and driest times of the day and year? Are they sheltered or exposed?
- Are water sources exposed or sheltered?
- Where are plants growing well and where are they suffering the most (indicating soil water levels)?
- Where is natural vegetation growing?

### *Wind*

Too much wind (especially hot, dry wind) increases evaporation from plants, soil, and open water. Windbreaks help reduce the negative effects of the wind and protect downwind fields and plants; these can be made of hardy perennial plant species or be man-made structures. Windbreaks made from of evapotranspiring plant species can additionally help cool, spread, and add moisture to strong, hot, dry winds.

On the farm site, local knowledge of wind patterns should be complemented by observing wind conditions and impact, including tree flagging, wind eddies and direct exposure, and the farmer should consider the following questions when assessing their site:

- From which direction are the winds coming? Are they hot and dry, or cold and moist?
- Does the wind direction change throughout the year?
- How does the wind direction affect rainfall landing on the site?
- Is the wind depositing materials that might be used to reduce evaporation from soils?
- Are their opportunities to add moisture to drying winds through growing wind breaks?

In addition to slope, sun and wind, other external influences to consider are upslope influences such as erosive water flowing off poorly managed adjacent land, water channeled from paths and roads, and pollution moving down with water.

***Example: Reducing erosion and increasing water infiltration***

A farmer suffers from erosion in a crop field downslope from a road. In order to reduce the speed, depth, and volume of runoff flowing through the field, and thereby reducing erosion, he uses a combination of techniques. Because the force of the water is so high, he builds a series of one-rock-high check dams as the water enters his land. He then creates low earthen, brush, rock or vegetative structures on-contour, together with applying mulch and growing more vegetation to slow and spread the runoff flow in the area above the erosion. Together, all these techniques help increase the amount of rainfall that sinks into the soil before it runs off.

## Analyzing the Resources and Influences

Once farmers have observed resources and influences, they can assess the quality, quantity, availability, and accessibility of water resources and the effect of external influences upon them. For example, **rainfall** is good quality water; quantity can be high in a good storm, but it is only available when rain falls. Accessibility depends upon what happens once the rain hits a surface. If it all runs off, it is not accessible; if it is harvested on-site, then it is accessible and for longer periods of time. Comparatively, **grey water** is contaminated from soap and what is washed, so it is not as good quality as rainwater. Quantity is usually much lower than rainfall, but it is available whenever something is washed. If it is thrown onto bare dirt where it evaporates, it is not accessible; if it is directed to sponge-like soil and plants, it will be accessible to those plants and will benefit the farmer though fruit and shade.

Plants grow where there is water, and so their presence shows where water naturally collects, where it is lacking, or how much water is in the soil based on the water needs of the plant (more water-needy plants will only grow where there is more water) and the conditions of the plant (wilted and dehydrated or vibrant and hydrated). Planting crops on-contour within a field helps slow and spread the water flow, making it more likely to drop organic matter rather than take it away. Slowing the water flow and letting more of it infiltrate the soil also enables plants to grow larger and create more organic matter with their roots and leaves. The more organic matter and life there is in the soil, the quicker the water sinks into the soil and the longer the soil holds moisture. Soil with as little as 2 percent of organic matter can reduce irrigation needed by 75 percent when compared to poor soils with less than 1 percent of organic matter.[35] Each 1 percent increase in organic matter gives the soil the potential to absorb and store an additional 16,500 gallons of water per acre, or 233,000 liters per hectare.[36]

Perennial plants used for shading or protecting tend to grow where they are least disturbed, for example along fence lines. During the analysis, farmers should identify places where sections of protective fencing can be placed at right angles to hot, dry prevailing winds with the intention of

Photo: Warren Brush, True Nature Design

***Crops planted on-contour, Zimbabwe.***

planting (or encouraging) hardy windbreak species to grow along the fence in the site design. In addition, farmers should look at the contour of the land to analyze where a fence might be constructed on the contour so that the fence, the soil and the vegetation along the fence all help to slow, spread, and sink more of the water runoff. This will result in benefits to the crops as well as a larger, healthier windbreak.

The placement of road and pathways should also be reviewed to see if there are opportunities to place them perpendicular to drying winds and/or on-contour so the runoff from the road or path is directed to roadside and path-side plants that could grow to help deflect the winds. Alternately, roads and paths could be placed at right angles to the water and wind flows and rainwater-harvesting structures like contour rocks or berms and their plantings could be specifically placed on either side of the fence or road to capture water and grow trees and shrubs.

Questions to consider when analyzing water systems on a site:

- Where on the site does soil and organic matter collect? In rainstorms, does runoff water deposit organic matter in orchards, pastures or fields, or does the runoff take the organic matter away? How could this be improved? Where are the sources of organic matter or rock that could be used to create speed humps and sponges to slow and sink more of the rain and runoff?
- Where on the site is soil eroding? How could vegetative cover be increased to decrease erosion? Could perennial crops be mixed with annuals so there is cover all year round? Could a living and/or non-living mulch help shelter soils?
- Where might planting be done on the contour to slow and sink more water to help grow those plants and better hold mulch in place?
- Is a sunscreen (of sun-loving plants) important to shelter exposed areas from hot afternoon sun? How might this screen be combined with water-harvesting techniques to slow and sink more water for these plantings?
- Is there a straight waterway that cuts through a field, or a straight overflow channel beside a field that might be encouraged to meander and cause more of the flow to sink into the soil? Where might water be diverted from that channel into nearby plants?
- Is there a path or road beside a field or orchard that brings water with it? Could some of the water flowing down a path or road be diverted (and slowed, spread and sunk) into a field to irrigate crops? Could water be diverted to irrigate plants at points along the path that help to shade and shelter the path, perhaps with food-bearing perennial vegetation?
- In a steep, eroding waterway, could stepped pools be created? If suitable rock is available, could one-rock-high check dams or rock-lined plunge pools or Zuni bowls be created? Could the volume of water flowing down the steep waterway be reduced by diverting some of the flow over a more gradual, meandering path?

## How to use an A-Frame to identify the contour of the land:

The A-frame can be a helpful tool for farmers to better understand slope and where they might plant across the slope on a level line (contour) to spread out storm water flowing across the land. Planting on-contour decreases the speed of the storm water flow and infiltrates more of the water into the soil, decreasing the volume of the flowing water. This tool is low-cost and can be constructed using locally-available resources.

After analyzing how water flows on the land and where to put water harvesting structures to best capture it, identify the highest point on the land to begin determining the contours.

At this highest point place one leg of the A-frame on the ground and put a stake or small stick at that point.

While keeping the first leg at the starting point, move the second 180 degrees around the first leg, then move that second leg up or down slope as needed, until the twine rests exactly on the center line. Put another stake in the ground at that point. These first two stakes share the same elevation across the slope and are the beginning of the first contour line.

Keep the second leg at the last marked point on the ground and rotate the A-frame, moving only the first leg, until the next point on the land that centers the twine in the A-frame is found. Mark the third point with another stake. At all times, at least one leg should be at a marked point on the contour line.

Continue this process until a contour line is drawn across the length of the garden site and the other side has been reached. The line that connects all of the stakes in the ground is the contour line.

Continuously assess whether or not the contour line is perpendicular to the slope and follows the site assessment and analysis results of how to best capture the most runoff water.  If the contour line seems to be doing something very different than expected, go back, observe and reassess. Remember, every point on the contour should be at the same elevation.

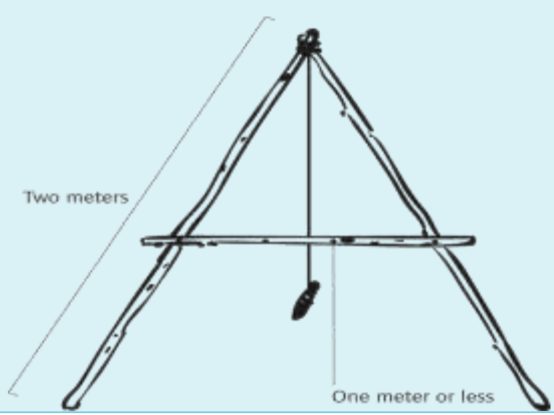


Photo: Elin Duby, Mercy Corps

Photo: Andrea Mottram, Mercy Corps

Photo: Abby Love, Mercy Corps

***Building A-frames in Nepal and Zimbabwe.***

# Designing for Water Management

## Applying Resilience Design Principles to Water Management

After observing and analyzing the resources and external influences of the site and its surrounding areas, use the RD principles as a guiding lens to design the site and choose the most appropriate combination of techniques that will increase overall productivity and resilience.

Below are some examples of how the principles can enhance site design to improve water management and what water-management techniques can be integrated to have the greatest impact. Each principle is illustrated through the story of self-taught water-harvesting master and farmer Zephaniah Phiri Maseko (Mr. Phiri) from Zvishavane, Zimbabwe. His site was severely eroded and unproductive but today it is a productive oasis that has inspired many thousands of people to follow his water management techniques.

Photo: Brock Dolman, reproduced with permission from *Rainwater Harvesting for Drylands and Beyond, Volume 1* by Brad Lancaster, www.HarvestingRainwater.com

***Mr. Zephaniah Phiri Maseko in 2013.***

As Mr. Phiri said:

> *"I plant water as I plant crops. So, this farm is not just a grain plantation. It is really a water plantation."*

To learn more about the work of Mr. Phiri, visit http://www.muonde.org/.

### 1. Observe and mimic healthy and resilient living systems

It is easier to copy and build on what works than to start anew; look at where water naturally flows over the landscape and how it is moving.

In nature, streams with a slope of 4 percent or less spread their energy naturally by meandering, bending back and forth as they flow down a gradual slope. This meandering pattern slows the energy of the flowing water by increasing the distance water must flow to get from the top to the bottom of the waterway. This reduces the steepness of the waterway, increases the time it needs to complete its journey, and in turn reduces the erosive speed of the flow. Meandering also increases the amount of soil in contact with the water flow, allowing more water to sink into the soil to recharge wells, springs and groundwater, and to provide moisture for more plants along the waterway. In contrast, streams with a slope steeper than 4 percent naturally spread energy downwards through step pools. The falling-pooling-falling-pooling effect of step pools stops water from reaching great speed. Greater channel roughness—created by the varied surfaces of the deeper pool bottoms and their shallower spillways, vegetation, and/or rocks of various sizes on the streambed—also reduces stream energy and speed. This natural balancing of water flow can be mimicked in a site design.

**Example:** *Mr. Phiri watched the water flow every time it rained. He saw storm water rush off the mostly bare hill above his farm and carry much of his soil away with it. He noticed that soil moisture would linger longer upslope of rocks and plants than in areas where the water flow went unchecked. Sediment also gathered up there and more vegetation grew. Mr. Phiri copied the set-up that he saw in nature. At right angles to the slope of the hill he created many low stone walls on-contour that slowed and spread the storm runoff before it had a chance to build up to destructive volumes and speeds. The next time it rained, the flow slowed, far less soil was lost below, and soil was even gained on the upslope side of the walls.*

### 2. Start small and simple

When trying to sink water into the soil, several small techniques can often be more effective than one large one. When first applying techniques they should be small-scale and easily managed by the farmer, for example planting tree within or beside a water-harvesting basin. Observe the impacts of these techniques over time, and then gradually incorporate more complicated and larger scale techniques as required.

**Example:** *Mr. Phiri and his family built most of the structures required for water management by hand using local materials such as rock and local, naturally growing vegetation. They spent little money on external materials such as concrete. This enabled them to perform all the maintenance themselves and without incurring on-going costs. Everything was kept technically and mechanically simple.*

### 3. Start at the top (highpoint or source) and work down.

Start at the top where there is less volume and speed. Collect water at high points for easy, gravity-fed distribution.

**Example:** *Mr. Phiri started building his stone walls near the top of the hill then continued downslope to address storm water. Just below the stone walls, runoff was directed to unlined reservoirs. With* *the reservoirs high on his land, Mr. Phiri could then use the free power of gravity to direct his water flow to all points downslope where and when he wanted it.*

### 4. Slow, spread, and sink the flow of water and nutrients

Encourage water to slow, spread, and sink into the soil rather than allowing it to run off the land's surface and contribute to erosion.

***Example:*** *Aside from one water holding tank for a courtyard garden, and another capturing roof runoff for household drinking water, the rest of Mr. Phiri's water-harvesting techniques directed the rain into the soil. He used many techniques to spread water over as much porous surface area as possible, to give the water the most chance of sinking into his land; for example by building contour earthworks, berms and basins, infiltrations basins and increasing vegetation cover and mulch. Once it has sunk in, water gently travels through the soil, not destructively over it.*

*The Phiri family sinks more rainwater into their soils than they take out from their hand-dug wells or boreholes or that comes from their transpiring crops. As a result, their groundwater and well levels have risen. Immediate neighbors have also benefitted from Mr. Phiri's work as the water in their wells has also increased.*

### 5. Grow natural resources

Maximize living, organic groundcover to create a living sponge so the harvested water is used to create more resources, while the soil's ability to sink and hold water steadily improves.[37] Native vegetation—indigenous plants found within 40 km of a site and within an elevation range of 150 meters above or below a site—is generally best adapted to local rainfall patterns and growing conditions, and should be used as much as possible for organic groundcover.

***Example:*** *Rather than buying them, the Phiri family grows many of the natural resources that they use in the farming system. The farm site is a living, vegetation-covered sponge that helps water sink into the soil and pumps soil moisture back to the surface through roots. The vegetation transforms harvested water into fruit, vegetables, medicinal herbs, and grains for people and livestock; shade for home and fields; lumber and thatch for building; fiber for clothes and rope; and fallen leaves that break down and fertilize the soil.*

### 6. Place every resource for energy efficiency

To conserve energy and time, place plantings, buildings, water-harvesting structures and other resources in ways that they can work together and enhance one another.

More water is available where it runs off hard surfaces such as a roofs, roads, or paths. To capture both rainfall and runoff, farmers can create low planting spots linked to various water-harvesting earthworks situated beside buildings, roads, and paths. These spots can be planted with trees to shelter the buildings, roads, and paths that the trees also capture runoff from. Trees that produce food for people, for example fruit trees, should be situated close to living spaces so that wildlife do not poach the fruit. Trees with crops not eaten by wildlife, for example timber trees, can be planted further away.

*Example: It is wise to "plant the water" (bank it in the soil) before planting to eliminate the need to carry as much water to the plants once they start to grow. Mr. Phiri calls his farm a "water plantation" because he uses techniques that encourage rainfall, runoff, and household greywater to sink into the soil. He also plants within or beside low spots in the landscape where water naturally collects. For plants needing more water, he plants them where more water collects. For vegetation needing less water, he plants where water does not collect as readily.*

### 7. Locate and use each resource so that it provides several benefits to the farming system

Good water-harvesting techniques should do more than just hold water. Berms or swales can also act as high and dry raised paths or planting areas for more drought-tolerant plants. Trees within water-harvesting earthworks can be placed to cool buildings; for example, a fruit tree on the west side of a building, located to receive the roof runoff and/or household grey water can shade the building from the hot afternoon sun and also provide food.

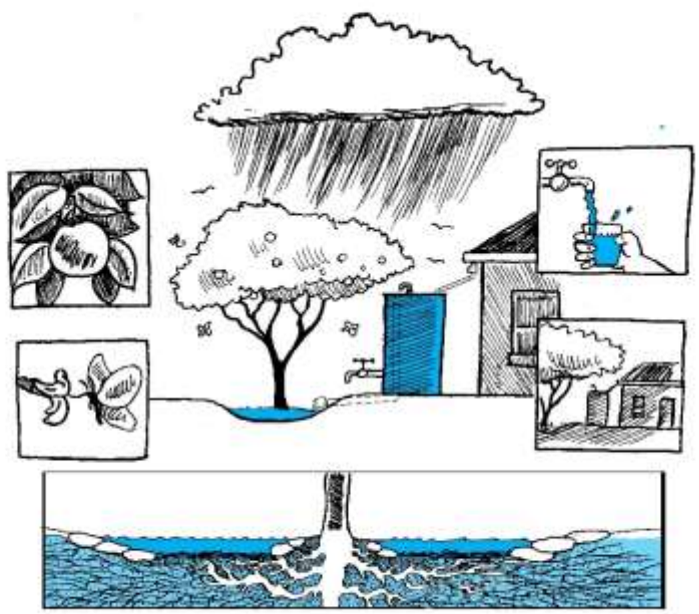


Illustration: Joe Marshall, reproduced with permission from *Rainwater Harvesting for Drylands and Beyond, Volume 1* by Brad Lancaster, www.HarvestingRainwater.com

***A resource within a water harvesting system providing several benefits: shade, stormwater control, wildlife habitat, and food.***

*Example: The Phiri's place their water-harvesting structures so that each performs many beneficial functions and provides more efficiency and productivity for the same amount of effort. The vegetation chosen to harvest rainwater also results in food, dust control, shelter, wildlife habitat, and windbreaks. Windbreaks reduce evaporation of water from adjoining fields and ponds. Fish raised in the ponds feed the family and fertilize the water used in the fields. Check dams, placed on the downstream side of path and road crossings over waterways, stabilize those crossings.*

## 8. Ensure critical functions in the farming system are supported in several ways

For continuous access and availability, ensure that water is harvested in multiple ways.

*Example:* *The Phiri's do not focus on just one or two techniques to harvest water, but instead use dozens of different small and simple techniques throughout their farm. Their water capture techniques include contour plantings of annual and perennial crops; mulching; one-rock-check dams; swales; reservoirs, and a tank that collects runoff from the roof of the house. If one source of water runs dry there would still be multiple others to support the critical function of water capture.*

## 9. Change a problem into a solution

Farmers should be encouraged to view problems as opportunities for change and improvement. For example, overflow from a storm can be re-directed to where it can be a resource and not a flood problem. Design the overflow route so that surplus water becomes a benefit; for example, spread-out overflow can calmly irrigate a field rather than eroding a road or flooding a building.

*Example:* *Many years ago, the government built off-contour drainage swales across from Mr. Phiri's farm and those of his neighbors. The swales helped reduce downslope flooding but also drained and dried the land. As a result, on-farm conditions became drier in the dry season and during droughts, and fewer crops could be grown.*

*Mr. Phiri and his family dug stepped infiltration basins into the bottom of the large swales to catch and sink more water. Any excess not captured by a basin overflowed into the next basin. At the end of the swale, any excess water was released into natural waterways.*

## 10. Continually reassess the system using the feedback loop.

Frequently revisit the site and the site design and observe how it is performing, repair elements as needed, and identify ways to evolve and improve the site design. Use all the principles to prompt questions and new perspectives. Seeking feedback while reassessing and maintaining the site is an ongoing opportunity to learn and improve.

*Example:* *Previously during the dry season, Mr. Phiri used a homemade pump powered by a donkey to draw water from one of his reservoirs to irrigate his crops in an adjoining field. Either he or the donkey had to power the pump. In the wet season, however, the well would overflow fairly directly to the reservoir, and the reservoir would overflow to earthworks below it. The system worked but it could be improved. Thinking both of the* **Slow, spread, and sink** *principle and the* **Change a problem into a benefit** *principle, Mr. Phiri wondered how he could do better. Eventually he redirected the overflow from the well over a much wider area, sending the excess water to fields in drier areas. Surplus water from the fields was then redirected back to the reservoir, achieved through a zig-zag* *pattern of contour and slightly off-contour berm and basins filled with stepped infiltration basins. He also maximized the living groundcover by planting windbreaks with perennial plantings such as mango trees. All these efforts resulted in much greater slowing, spreading, and sinking of the water; more water infiltrated the soil and moved below the surface to and through the root zone of the whole field below. The pump was no longer needed as gravity was now moving the water.*

## Techniques to Improve Water Management

The RD approach is not about finding and promoting one successful technique. Instead, it is about using information gathered from the land, and the people living on that land, to integrate (and eventually create, evolve, or combine) many techniques that together optimize land use and productivity.

Observing and understanding local influences and applying the RD 10 principles will inform the most effective choice and use of techniques. Below is a table of techniques that can be used when designing the water management components of a farming system. It is not an exhaustive list; instead, it highlights a useful subset of techniques to consider. See also Techniques Tip Sheet.

It is important to monitor the impact of the techniques over time, and continually adapt them as resources and external influences change. Step 4 of the RD approach provides further information on assessing the impact of water management techniques

| Techniques to Improve Water Management | | | | |
|---|---|---|---|---|
| **Variations** | **Benefits** | **Where to use** | **Cautions** | **Variations** |
| **VEGETATION** | | | | |
| Plants and plant life in a given area help build, shelter, and anchor soil.<br>Along with living soil, vegetation is the main living element of all earthworks. | Increases water's ability to sink into the soil.<br>Supports soil microorganisms<br>Reduces erosion.<br>Produces food, fiber, wildlife habitat, and more. | Use in watershed from flat areas to slopes, within or beside earthworks, and in drainages if stabilizing banks and not inhibiting water flow. | Locate and space plants based on expected mature size, water needs, water sources, and tolerance to flooding.<br>Keep root crops away from grey water. | Contour plantings<br>Reforestation |

| Techniques to Improve Water Management | | | | |
|---|---|---|---|---|
| **Variations** | **Benefits** | **Where to use** | **Cautions** | **Variations** |
| **MULCH** | | | | |
| Porous organic or mineral materials on the soil (e.g., compost, aged manure, straw, wood chips, gravel). | Increases infiltration rate.<br>Reduces evaporation.<br>Limits soil erosion.<br>Suppresses weed growth.<br>Improves soil fertility. | Use on soil around crops. In drier areas, use a thin mulch layer to help rain penetrate.<br>In wet areas, or with drip irrigation, use thicker mulches to retain moisture. | On slopes, find ways to slow or stop runoff before it comes in contact with mulch, to reduce loss of mulch.<br>Do not use in drainageways. | Cover crops<br>Rock mulch<br>Vertical mulch |
| **TERRACE** | | | | |
| Relatively flat "shelf" of soil built parallel to the contour on sloping land. | Creates a level planting area to intercept direct rainfall and some runoff from upslope to help sink rain into the soil. | Use on land sloped up to 2:1 ratio, 26 degrees, or 48.8% grade.<br>Make it big enough to handle a typical large rainstorm in the area. | Do not use in areas with soils prone to waterlogging or areas with a high water table.<br>Do not use in drainageways. | Terrace with a retaining wall<br>Terrace without a retaining wall |
| **INFILTRATION BASIN / RAIN GARDEN** | | | | |
| Shallow, wide, and level-bottomed hole with gradually sloping sides or banks. | Catches and sinks rainfall, runoff, and/or grey water to store water within the soil. | Use on flat to gently-sloped land.<br>Intercept runoff from multiple or all directions.<br>Make basin large enough to handle a big rainstorm or maximum amount of grey water at one time. | Do not use in areas where groundwater is close to land surface, which could result in standing water.<br>Do not use in drainageways. | Basins around or beside existing vegetation<br>Raised pathways creating basins<br>Sunken garden beds<br>Raised sunken garden beds |
| **CONTOUR EARTHWORKS** | | | | |
| Berm set at a right angle to slope, typically made of soil moved to make an adjoining, upslope basin. | Stops, spreads, and sinks runoff water in the soil. | Use on land sloped up to 3:1 ratio, 18 degrees, or 32.5% grade.<br>Make them large enough to handle a typical large rainstorm. | Try to preserve existing perennial vegetation.<br>Do not use in drainageways. | Boomerang berms |
| **DIVERSION EARTHWORKS** | | | | |
| Berm and basin constructed slightly off the contour. | Gently and gradually moves water downhill and across a | Use to divert water off one surface (e.g., a road) where it is a problem, to another surface (e.g., | Do not use in alkaline soils prone to salt buildup or waterlogging. | Rolling dip or diversion berm |

| Techniques to Improve Water Management | | | | |
|---|---|---|---|---|
| **Variations** | **Benefits** | **Where to use** | **Cautions** | **Variations** |
| | landscape, while promoting infiltration into the soil. | road-side plantings) where it is an asset.<br>Direct overflow from one water-harvesting earthwork to another. | | |
| **ONE-ROCK-HIGH DAM** | | | | |
| Small dam (only one layer of loose rocks) used to slow, spread, and sink more of the water's flow into the drainage bed and banks. | Slows, spreads, and sinks water flow to reduce flooding, reduce erosion, and stabilize land. | Use in small, low-volume, low-speed water channels. Can address eroding gullies, stabilize roads or paths across drainages, and reduce erosion below culverts. Use in temporary water channels. | Placement and correct construction is critical to avoid damage.<br>For vegetation to grow through the rocks and to stabilize the structure, never lay rocks more than one layer high. | One-rock-high check dam<br>Filter dam<br>Brush check dam |
| **ROCK MULCH OR VEGETATED RUNDOWN** | | | | |
| A one-rock-high layer of mulch or perennial vegetation such as grass used to stabilize a sloped, low-energy waterway. | Directs flowing water to a less erosive, more gradually sloping location where it can be more easily and effectively harvested and sunk into the soil. | Use to stabilize overflow spillways carrying water from one water-harvesting earthwork to another.<br>Use to direct falling runoff from a roof to a water-harvesting earthwork<br>Use to control headcut erosion (where a deepening channel erodes or heads upslope toward the 'head' waters) but only on low-energy headcuts like those at the top of upland rills and gullies where calm sheetflow concentrates into more channelized flow. | Rundown must be lower in the middle than on either side to ensure that water flows down the middle of the structure and not around it.<br>Do not use within water channels with moderate- to high-energy flows, such as below headcuts. In those instances consider one-rock-high check dams or a rock-lined plunge pool, if appropriate. | Rock-mulch rundowns for dry areas where vegetation is lacking at the beginning of the rainy season.<br>Vegetated rundowns for areas where rainfall and land management supports year-round vegetative cover of the rundown. Native perennial grasses are typically used. |

| Techniques to Improve Water Management | | | | |
|---|---|---|---|---|
| **Variations** | **Benefits** | **Where to use** | **Cautions** | **Variations** |
| **SHEET FLOW SPREADER** | | | | |
| A level-topped, one- rock-high, crescent-shaped rock mulch structure (where the ends of the crescent point uphill), laid on contour. Only the downstream, largest rocks are anchored into the soil; others are on the soil's surface.<br>Usually built of rocks at least 15 cm in diameter to avoid movement in a water-flow event. | Slows, spreads, and sinks flowing water, and transforms channelized water flow into calmer, shallower, and more spread-out sheet flow. | Use on relatively flat to gradually sloping, alluvial fan-shaped ground.<br>Use where water carries a lot of sediment, so the structure can catch and hold sediment, thus slowing and capturing more water. | Ensure the ends of the structure are higher upslope than the middle of the structure, so water flows through and over, not around it. If water begins to flow around, add more rock on the ends of the structure. | If rock is unavailable, brush can be used with cut ends facing upslope, and staked in the ground with wooden stakes no higher than the brush. Pack tightly together and maximize contact with the soil below. |
| **ROCK-LINED PLUNGE POOL OR ZUNI BOWL** | | | | |
| A rock structure used to control small headcut erosion.<br>It consists of rock-lined step falls in the shape of an arc, leading into a constructed plunge pool where the pooled water spreads the energy of the water falling over the steps. | The pool moistens the soil above, below, and within the structure to sustain growth of more stabilizing, sediment-accumulating vegetation between the structure's rocks. | Use in waterways with small headcut erosion to prevent it from migrating upwards. | Never lay rocks more than one layer high.<br>Length of plunge pool should be 3-4 times the height of headcut.<br>Use one-rock-high dams downstream of the Zuni bowl, to create a second stabilizing pool, a distance of 6-8 times the height of the headcut from its location. | |
| **RESERVOIR** | | | | |
| A pond catching and holding water on top of the surface of the soil. | Provides readily accessible water for irrigation and raising fish in times of no rain. | Place where gravity can freely distribute water to plantings below.<br>Place where water naturally collects, and there is enough clay in | Stock with mosquito-eating frogs, fish, etc. to prevent the spread of disease.<br>Slopes must be gradual enough that | |

| Techniques to Improve Water Management | | | | |
|---|---|---|---|---|
| **Variations** | **Benefits** | **Where to use** | **Cautions** | **Variations** |
| | | the soil to retain water and slow infiltration.<br>Place on gradual slopes where sediment naturally drops out of runoff flow, not on steep slopes where soil is carried away by runoff flow. | people and animals can crawl out of water.<br>The shallower the reservoir, the hotter the water, and the more rapid the evaporation rate, so less efficient in hot and dry climates. | |
| **RAINWATER TANK** | | | | |
| A tank collecting rainwater runoff. | Stores readily accessible water for irrigation or domestic use in times of limited or no rain. | Use to capture runoff from a roof or other clean surface.<br>The cleaner the catchment surface, the cleaner the harvested water.<br>Direct overflow to where it can be used as a resource. | Keep sunlight (which grows green algae) and mosquitoes out of the tank.<br>A filter that keeps insects and other materials out but does not restrict flow is recommended.<br>Overflow pipe/outlet must be as big as the inflow pipe/inlet. | Above-ground tank: gravity can freely move water in and out of tank.<br>Below-ground tank: pump, siphon, or rope-and-bucket needed to access water in tank. |
| **GREY WATER HARVESTING** | | | | |
| Once-used water, such as water from bathing or washing dishes or clothes, which is harvested or used again to irrigate plants. | Cycles or uses water more than once. | Use to irrigate perennial plants close to grey water source.<br>Direct grey water to perennial plants whose edible parts will not come into direct contact with the water, the soap, or what was washed.<br>Avoid using grey water to irrigate low annual plants. | Soils that are too wet for too long become anaerobic and start to smell, so:<br>Direct the grey water to various places, rather than always putting it in the same one.<br>Apply to well-vegetated and mulched areas that will rapidly absorb and use it.<br>Do not put it in a tank because it will go septic and stink. | Grey water directed to mulched and vegetated basins on the surface.<br>Grey water directed to subsurface basins. |

***Case Study***

*The Phiri family farm discussed above has been transformed from a wasteland to a relative oasis by the family's many and diverse efforts to "plant the rain." They now get two or three harvests in dry years when others in nearby communities struggle to get just one, and their wells do not go dry.*

*When the Phiris began to transform their eroding farm they looked at various influences, such as the flow of water and sediment when it rained, and asked themselves, "What effects do these influences have on our farming system?" They observed that vegetation grew where water and sediment slowed and gathered, and the soil degraded where water and sediment washed away.*

*They then asked themselves, "What is the cause of both the good and bad effects of the influences?" They observed that water and sediment slowed and gathered where slopes were more gradual; that flow was more spread out and shallow rather than concentrated and deep; that vegetation or other obstructions slowed the flow; that the soil was more porous and had more organic matter, and that the soil and vegetation were sheltered from excessive sun or wind.*

*They then copied these beneficial influences in their fields, orchards, and around their buildings where they wanted more vegetation and healthier, more vibrant growth. Various techniques described in the table above were used, and their selection and placement informed by the principles.*

*The Phiris also observed that where slopes were steeper, water, sediment, and vegetation washed away from their land; runoff flow was concentrated and intensified; soil was more compact and bare; organic matter was lacking within the soil, and exposure to sun and wind was more extreme.*

*They then decreased the impact of these damaging influences using various techniques and applying the RD principles.*

*The diagram opposite is an illustration of Mr Phiri's land.*

*Key: 1 Granite dome; 2 Unmortared stone walls; 3 Reservoir; 4 Fence with unmortared stone wall; 5 Swale/terrace; 6 Outdoor wash basin; 7 Chickens and turkeys run freely in courtyard; 8 Traditional round houses with thatched roofs; 9 Main house with vine-covered cistern; 10 Open ferro-cement cistern; 11 Kraal – cattle and goats; 12Courtyard garden; 13 Swale; 14 Dirt road; 15 Thatch grass and thick vegetation; 16 Fruition pit in large swale; 17 Crops; 18 Dense grasses; 19 Well with hand pump; 20 Donkey pump; 21 Open unmortared wells; 22 Reeds and sugar cane; 23 Dense banana grove.*

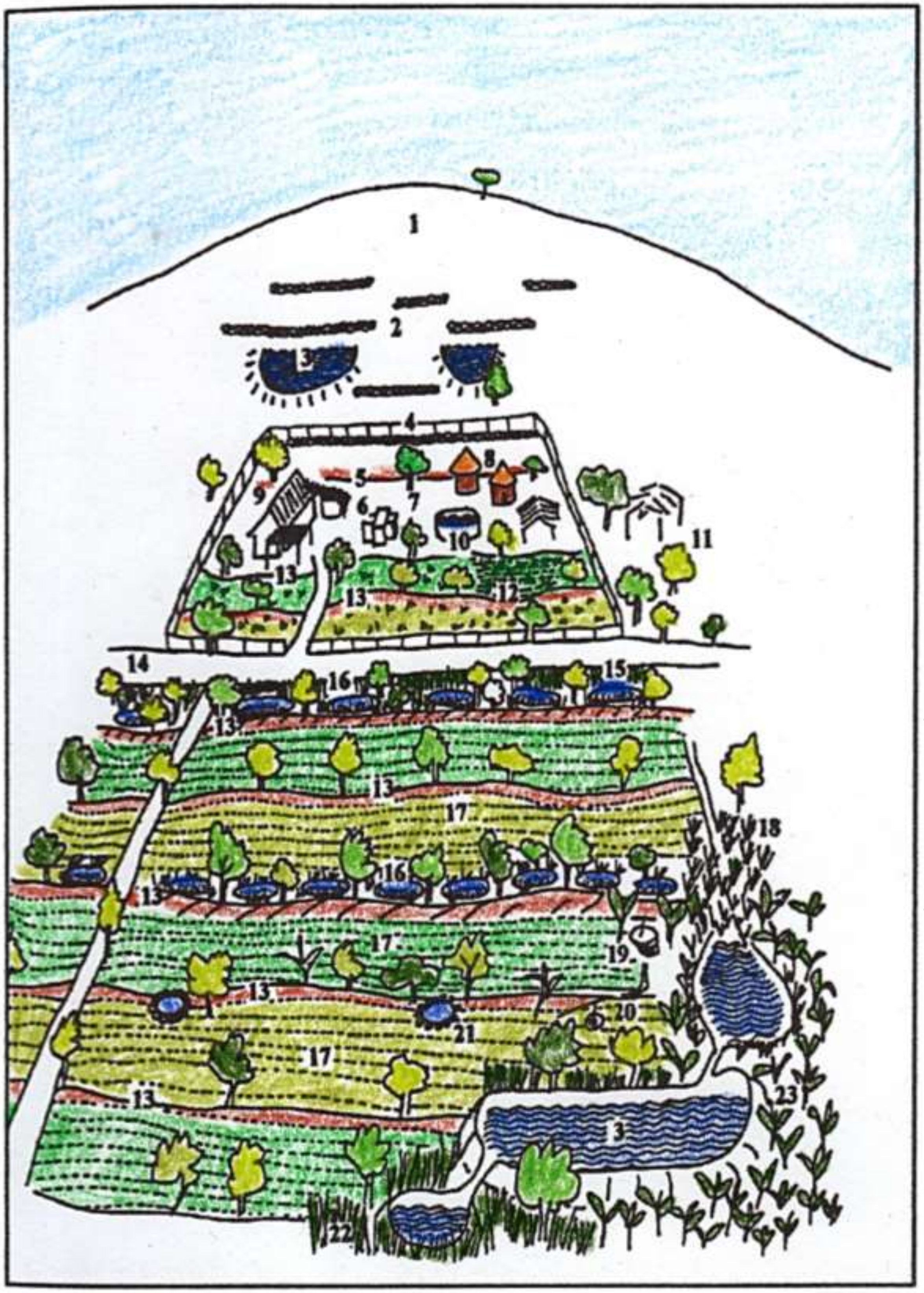



*Illustration: Silvia Rayces, reproduced with permission from* ***Rainwater Harvesting for Drylands and Beyond, Volume 1*** *by Brad Lancaster, www.HarvestingRainwater.com*

***Illustration of Mr. Phiri's farm.***

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# Glossary

**Agroecology**: The study of ecological processes applied to agriculture systems

**Agroecosystem**: A site or integrated region of agricultural production (e.g., a farm) understood as an ecosystem

**Agroforestry**: A land use management system in which trees are planted around or among crops

**Alley cropping**: Planting rows of crops between rows of trees

**Alluvial fan**: Fan-shaped deposits of water-transported sediment (alluvium). They typically form at the base of topographic features where there is a marked break in slope or when water velocity slows

**Aquifer** (including perched aquifer): Underground layer of water underneath water permeable rock in which the water can be extracted using a well or pump

**Berm** (boomerang berm; rolling dip/diversion berm): A small raised barrier of dirt used for protection from runoff water

**Bioaccumulation**: the accumulation of substances, such as pesticides, or other chemicals in an organism

**Biochar**: Charcoal produced from plant matter, which is added to the soil to improve its health

**Bio-intensive agriculture**: An organic agriculture system that focuses on sustainably maximizing output with minimal land

**Biomass**: living matter in a given habitat

**Bund**: an embankment or wall to help direct water flow

**Carbon sequestration**: process involved in carbon capture and the long-term storage of atmospheric carbon dioxide

**Catchment**: the action of collecting water, especially the collection of rainfall over a natural drainage area

**Check dam** (one-rock-high, brush): small, sometimes temporary, dam constructed across a swale, drainage ditch, or waterway to counteract erosion by reducing water flow velocity

**Climate change**: Any long-term change in Earth's climate – its typical or average weather – or in the climate of a region or city

**Climate-resilient agriculture**: An approach related to climate-smart agriculture but has only two main objectives: sustainably increase agriculture productivity and incomes; and adapt and building resilience to climate change

**Climate-smart agriculture**: An approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. The approach aims to tackle three main objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible.

**Compost**: Organic material of a decayed combination of green and brown plants (such as leaves and grass) that is used to improve the soil in a garden

**Compost tea**: A liquid natural fertilizer tea made from decayed organic material and water

**Conservation agriculture**: A set of soil management practices focused around three pillars: minimal soil disturbance, permanent soil cover and crop rotations

**Contour**: A line made up of points that share the same elevation

**Contour terracing**: The practice of creating terraces, or flat shelves of soil, along the slope of the land

**Crop rotation**: practice of growing a series of dissimilar or different types of crops in the same area in sequenced seasons

**Culvert**: a structure that allows water to flow under a road, railroad, trail, or similar obstruction from one side to the other side

**Cycling**: Rotating a series of activities or materials in a consistent pattern

**Decomposing organic matter:** Organic compounds that can be used as food by microorganisms

**Deforestation**: Removal of trees from a forest where the land is thereafter converted to non-forest use

**Degenerative investment**: Starts to degrade or break down as soon as it is made and consumes more resources than it produces. *See* Generative investment *and* Regenerative investment

**Delta**: a landform that forms from deposition of sediment carried by a river as the flow leaves its mouth and enters slower-moving or standing water

**Demi-lune**: A raised water harvesting structure shaped like a crescent moon

**Depositional bar**: the area on the bend of a waterway where sediment accumulates

**Earthworks**: structures created by moving or processing parts of the earth surface including using soil and rock

**Erosion (headcut)**: the process of being eroded by wind, water, or other natural agents leading to the sudden change in elevation or knickpoint at the leading edge of a gully

**Evaporation**: the process of liquid turning into gas due to an increase in temperature

**Evapotranspiration**: loss of water from the soil by both evaporation and transpiration from plants

**Extension services**: application of scientific research and new knowledge to agricultural practices through farmer education

**Fauna and flora**: Animals (including farm and wild animals; those that live in the soil; insect pests; etc.) and plants

**Fallowing**: Farmland left unsown for a period to restore its fertility as part of crop rotation or to avoid surplus production.

**Fodder**: Food, especially dried hay or feed, for livestock.

**Generative investment**: Starts to degrade as soon as it is made, but can be used to make or repair other investments. *See* Degenerative investment *and* Regenerative investment

**Grey water**: all wastewater generated in households or office buildings from streams without fecal contamination

**Gully**: deep ditch or channel cut in the earth by running water after a prolonged rain

**Humus:** the organic component of soil, formed by the decomposition of leaves and other plant material by soil microorganisms

**Manure**: animal dung used for fertilizing land

**Microorganism**: Extremely small and microscopic organisms including bacteria, fungi, protozoa, and nematodes, and some arthropods.

**Minimum soil disturbance**: low disturbance or no-tillage and direct seeding

**Multicropping**: Growing two or more crops on the same piece of land in the same growing season

**Mulch** (including stone mulch): Material added to the top of garden beds to enrich or shield the soil

**Negarim microcatchment :** diamond-shaped basins surrounded by small earth bunds with an infiltration pit in the lowest corner of each

**Nitrogen-fixing**: a process in which nitrogen (N2) in the atmosphere is converted into ammonia (NH3)

**Nutrient sink**: areas where nutrients naturally deposit

**Perennial**: A plant that lives for more than two years. Differentiated from annual or bi-annual

**Permaculture**: An agriculture and design system that integrates human activity with natural patterns to create highly efficient, self-sustaining ecosystems

**Polyculture**: agriculture using multiple crops in the same space, in imitation of the diversity of natural ecosystems, and avoiding large stands of single crops, or monoculture

**Regenerative investment**: Produces more resources than it consumes and can repair, reproduce, and/or regenerate itself. *See* Degenerative investment *and* Generative investment.

**Resilience**: The ability of people, households, communities, countries and systems to mitigate, adapt to and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth (USAID)

**Redundancy**: inclusion of extra practices or techniques that is not strictly necessary to functioning

**Resource**: a source or supply from which benefit is produced.

**Rill**: a shallow channel cut into soil by flowing water

**Runoff**: the draining away of water (and substances carried in it) from the surface of an area of land, a building or structure, etc.

**Sheet flow**: An overland flow or downslope movement of water taking the form of a thin, continuous film over relatively smooth soil or rock surfaces and not concentrated into channels larger than rills

**Smallholder farmer**: A farmer who farms on a small land area, of less than 2 hectares, but often less than 0.5 hectares.

**Soil amendment**: Resources added to the soil to improve its quality and health

**Soil food web**: The community of organisms—from bacteria and fungi, to earthworms and insects—that live all or part of their lives in the soil

**Stone mulch**: *See* Mulch

**Swale**: A ditch or low place on the landscape. When plants are growing in or on a swale, it is often referred to as a *bioswale*.

**Tree flagging**: Brown leaves appear on individual branches throughout the tree crown. This can be caused by insects, disease or weather-related injury

**Water catchment**: *See* catchment

**Watershed**: an area or ridge of land that separates waters flowing to different rivers, basins, or seas

**Wind eddies**: A whirl of air that develops when the wind flows over or adjacent to buildings, mountains or other obstructions. They generally form on the downwind side of these obstructions

# Endnotes

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[5] Climate change refers to any long-term change in Earth's climate—its typical or average weather—or in the climate of a region or city. This includes temperature warming and cooling, changes in a region's average annual rainfall, in a city's average temperature for a given season, in Earth's average temperature, or in Earth's typical precipitation patterns or velocity and timing of winds.

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[17] In permaculture, 'influences' are referred to as 'patterns', i.e., the connection and relationship between things; an ordered arrangement of objects or events in time or in space (they can be seen in everything from nature to numeric sequences to economic booms and busts). For simplicity they are adapted and referred to here as influences.

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[28] A list of principles has been selected from those found in permaculture, agroecology and water harvesting (which were originally derived from observing natural phenomena, influences, successful indigenous agricultural practices and scientific inquiry) for simplification and applicability to the development context. Those wishing to add to this list can do so by visiting the principle lists found in those specific approaches.

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As smallholder farmers face increasingly frequent and intense environmental and economic shocks and stresses, they must adapt their farming systems to provide food and income over the long term. The *Resilience Design in Smallholder Farming Systems Toolkit* helps farmers and those who support them build a more productive and resilient farming system. By adjusting the farm design to work with the surrounding natural systems, farmers can optimize the use of available resources and better respond to external changes over time.