

Preface

We ain't dry. We just leakin'.

—Janet Millington, Australian permaculture teacher referring to a lack of water harvesting and conservation compounding droughts in Australia

You've got to plant the water before you plant the trees." An African water-farmer named Mr. Zephaniah Phiri Maseko told me this. "Create a water plantation by planting the rain," he said. "Plant it here, there, over there, everywhere, so it will germinate everywhere!"

I looked across a diversely vegetated landscape. It was something of a miracle. This area in the dry region of Zvishavane, Zimbabwe, (average annual rainfall 22 inches, or 559 mm) was once highly degraded and eroded. But Mr. Phiri had turned a wasteland into an oasis by controlling erosive runoff, harvesting the rain, and planting it within the soil. He and his family did it by creating a diverse array of water-harvesting



Fig. P.1. Mr. Phiri in the hand-dug reservoir he calls his "immigration center" located on the highest point of his site, where he has a good amount of soil. "Rain, welcome to my country!" he shouts during storms. "Now I will tell you where you will live: in the soil!"

earthworks such as infiltration basins, terraces, berm 'n basins, check dams, diversion swales, and contour plantings throughout their 7.4-acre (3-hectare) site.

Following the simple principles of water harvesting, they began at the top of their watershed and continued all the way to the bottom. Now more water was harvested within their soils than was extracted from them by pumping out groundwater, or by evaporation and plant uptake. They gave the land more than they took. As a result, Mr. Phiri's well levels and



Fig. P.2. Mr. Phiri tending his tree nursery. He gives hundreds of trees a year to fellow community members to vegetate the watersheds, build water-absorbing soil, and grow more resources. "People must plant the water before they plant the trees," he says. Water is planted with water-harvesting earthworks.

those of his immediate neighbors began to rise slowly. Erosion was in check, soil was accumulating, fertility was increasing, and the family's farm could now support the family for the long-term. Scarcity had been turned into abundance.

As I walked around Mr. Phiri's land, I felt excited and hopeful. Here was a living, thriving example of a site, stewarded by people, that was improving with time! Progress was happening without degrading the lives or environments of others! For too long I had observed too many gardens, yards, farms, neighborhoods, ranches, and communities degrading with time. Many appeared to be doing great on the surface, but when I looked more closely I realized they were consuming more resources (water, energy, time, money, soil fertility) than they were producing. They were taking more resources from their local economies, ecosystems, and communities than they gave back.

So it was in my hometown of Tucson, Arizona. Growth was booming but we had contaminated our aquifer, depleted groundwater supplies, run our rivers dry, and killed countless springs and wells. Then we took water from other regions using elaborate canal, pump, and water-right buyout schemes at great financial and environmental cost to feed our constantly growing demand for water. Tucson was killing itself—or at least its water resources and those of others. And everyone who lived in Tucson—everyone who drank, irrigated, built, bathed, and washed with water—was part of that problem. But I didn't want to contribute to the problem. I wanted to leave. I wanted to run.

"If we run from our problems, they follow us," Mr. Phiri said, when I told him of my dilemma. "But if we root ourselves and face our problems we solve them."

I then realized the concepts and the strategies Mr. Phiri had used could easily be replicated or adapted elsewhere, such as my hometown. I excitedly returned home, rooted myself, and adapted Mr. Phiri's concepts and strategies in my yard, at my clients' sites, and in neighborhood projects, all with wonderful results.

At our Tucson, Arizona homes (receiving 12 inches or 305 mm of average annual rainfall), each year my brother, sister-in-law, nephew, and I now typically harvest about 100,000 gallons (378,500 liters) of rain and runoff in the soil of our shared 1/8-acre (0.05 ha) urban oasis and surrounding public right-of-way. We've been consuming just 20,000 gallons



Fig. P.3. Matt Weber kayaking his flooded neighborhood street in Tucson, Arizona. The bulk of the rain falling on the city's private and public landscapes (where it would be a free resource) is quickly drained to the streets and storm drains, where flooding is a costly liability.

(75,700 liters) of municipal water a year to meet our household needs and provide water to our washing machine, which serves as a community greywater-harvesting laundromat (see our story in Real-Life Examples in chapter 12). Though I've since set up my home to meet 95% of its domestic (indoor) water needs from rain harvested off just 400 square feet (37 m²) of roof (see chapter 5 in Volume 1 for more). Ninety-five percent of the landscape's, orchard's, and garden's water needs are supplied by a combination of harvested rainwater and greywater, which consists of recycled "wastewater" from all household drains except the toilet. Our once-barren lot is now a lush landscape that produces 15% to 25% of our food, passively heats and cools the home, enhances urban wildlife habitat, and has won numerous awards for water conservation and artistry.

This book documents a diverse array of successful sites where passive water-harvesting earthworks serve as the foundation of thriving landscapes. You can accomplish similar successes at home and beyond by simply building on the skills you already have and using common sense. Mr. Phiri had only a 6th grade education when he taught himself to harvest the rain. Now his work at home, in his community, and throughout southern Africa inspires a new generation of water harvesters. The key to Mr. Phiri's success (and mine) was following eight principles of successful rainwater harvesting, and three ethics.



Fig. P.4A. The Santa Cruz River in Tucson, Arizona, looking southeast from Sentinel Peak in the early 1900s. Note the meandering, flowing river and the rich sponge of vegetation throughout the watershed (especially where the native tree forests have not yet been replaced by agricultural fields). Such a watershed absorbs more rainfall than it drains. Water moves more slowly and consistently through the forested watershed and the meandering waterway.
 Courtesy of Arizona Historical Society/Tucson BN 203, 274



Fig. P.4B. The same stretch of the Santa Cruz River in 2017. Note the dry, channelized riverbed and how much of the watershed's vegetative sponge has been replaced with pavement, buildings, or bare compacted earth. The watershed now drains more rainfall than it absorbs. During storms, flooding water erosively rips through the watershed and straightened river channel unchecked to cause flooding problems downstream. And summer temperatures are rising due to the heat absorbed within the exposed pavement and bare soil.

EIGHT PRINCIPLES OF SUCCESSFUL RAINWATER HARVESTING

1. BEGIN WITH LONG AND THOUGHTFUL OBSERVATION

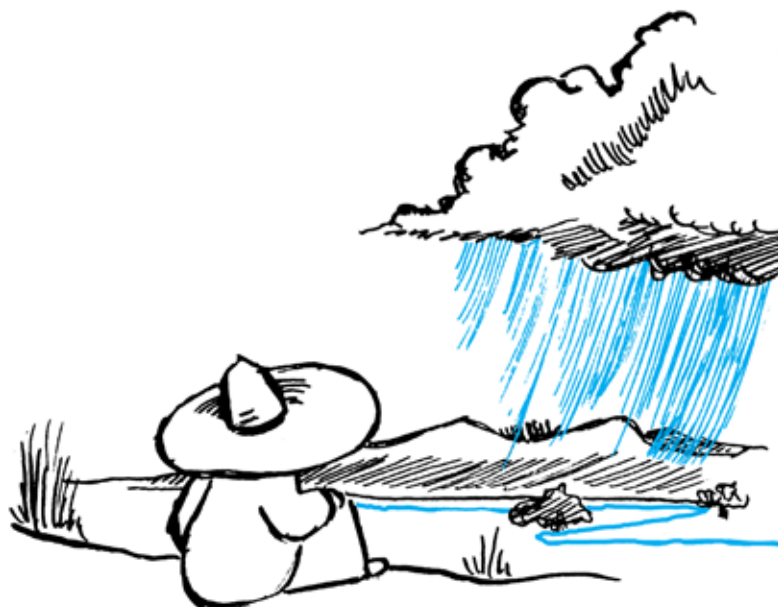


Fig. P.5. Observe where the water flows, where it collects, where it drains away, and where it drains from. This informs you of your resources and challenges. What is working? Build on that. What is not working? Change it.

2. START AT THE TOP (HIGH POINT) OF YOUR WATERSHED AND WORK YOUR WAY DOWN

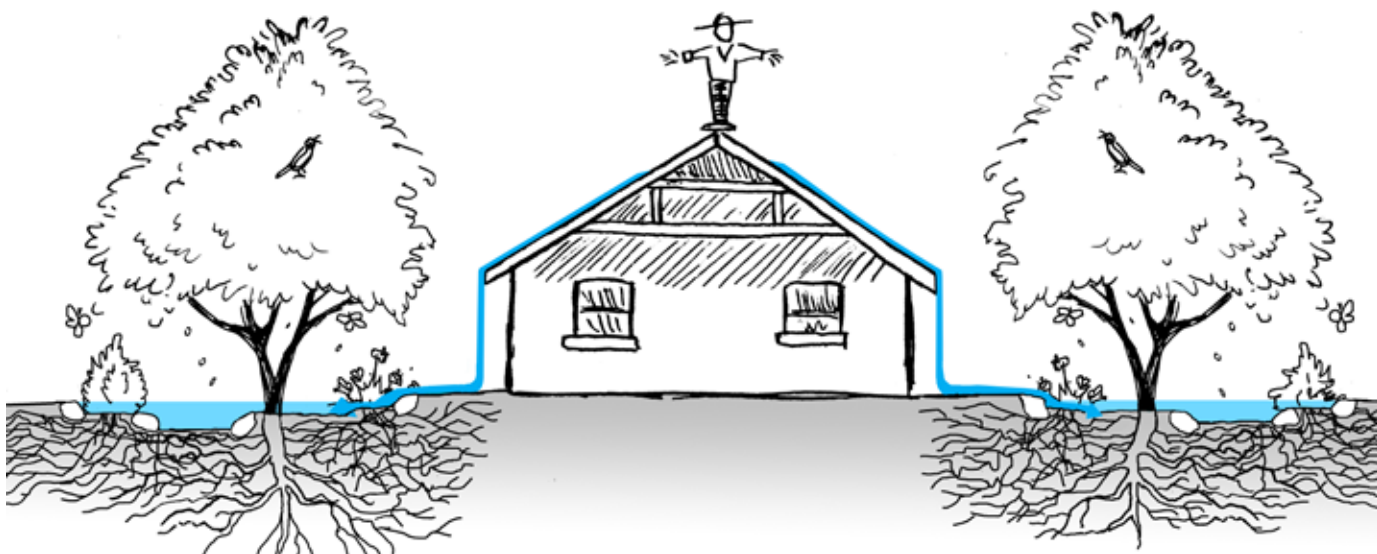


Fig. P.6. It is easier to harvest water high in the watershed than low in the watershed because the volume and velocity of flow is less, and more manageable, at the top. And you can then use the free power of gravity to distribute the harvested water to areas downslope.

3. START SMALL AND SIMPLE

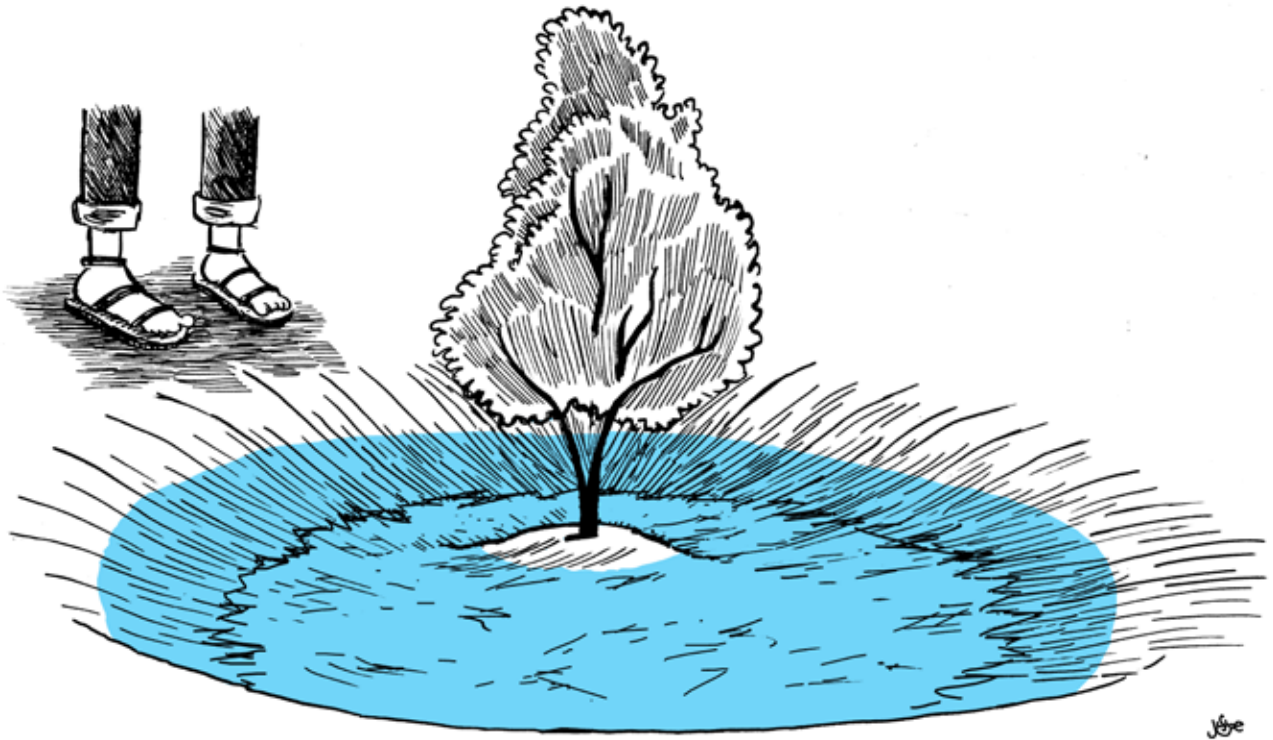


Fig. P.7. Small, simple systems of appropriate scale are easier to create and maintain than complex, extensive systems so starting small and simple makes it all more fun. As an added benefit, large numbers of small earthwork structures distributed throughout a watershed will be far more effective at hydrating the land than a small number of large-scale earthwork structures in just a few areas of the watershed.

4. SLOW, SPREAD, AND INFILTRATE THE FLOW OF WATER

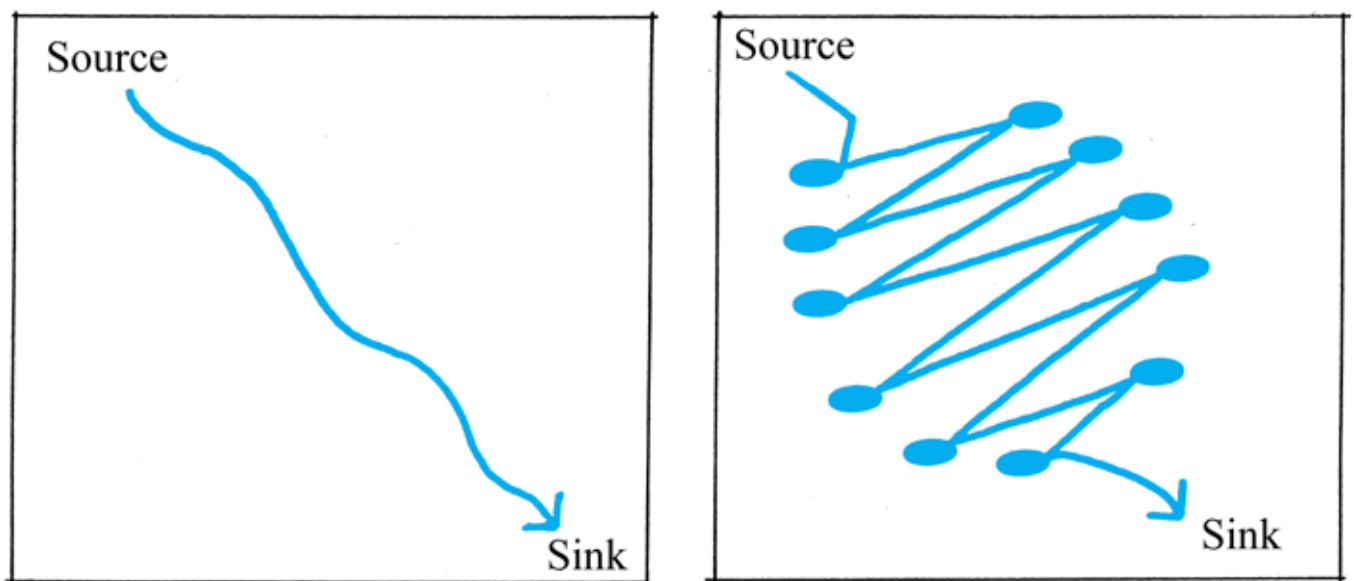


Fig. P.8. Left side is rapidly dehydrating the landscape. Right side is effectively hydrating the landscape. Zig-zag and calm the flowpath of water to reduce destructive erosion and increase the time and distance the water flows. This will increase infiltration into the soil from source (high point) to sink (low point). This practice achieves waterspread throughout the watershed.

5. ALWAYS PLAN AN OVERFLOW ROUTE, AND MANAGE THAT OVERFLOW AS A RESOURCE

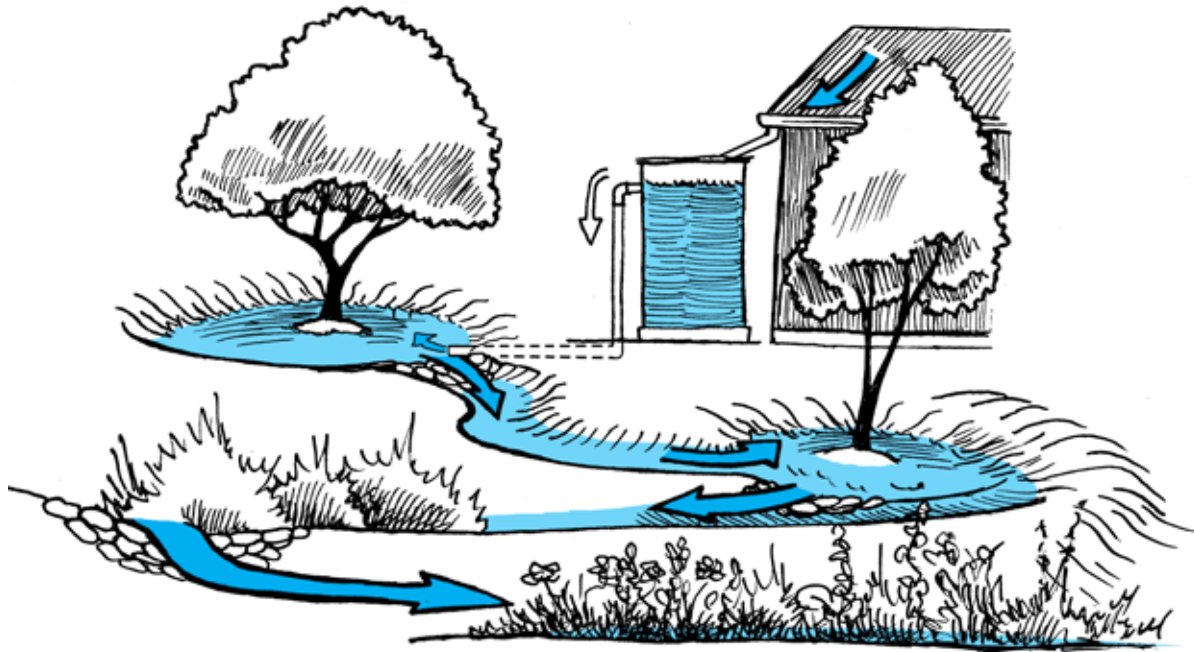


Fig. P.9. You can't turn off the rain once your water-harvesting earthworks and cisterns are filled up, so always be prepared for overflow. In this case, cistern overflow water is designed to fill a nearby, vegetated earthwork, then overflow to the next earthwork, and the next, as it passively irrigates sheltering vegetation. The zig-zagging flowpath also follows the fourth principle—slow, spread, and sink. Arrows denote runoff flow.

6. CREATE A LIVING SPONGE

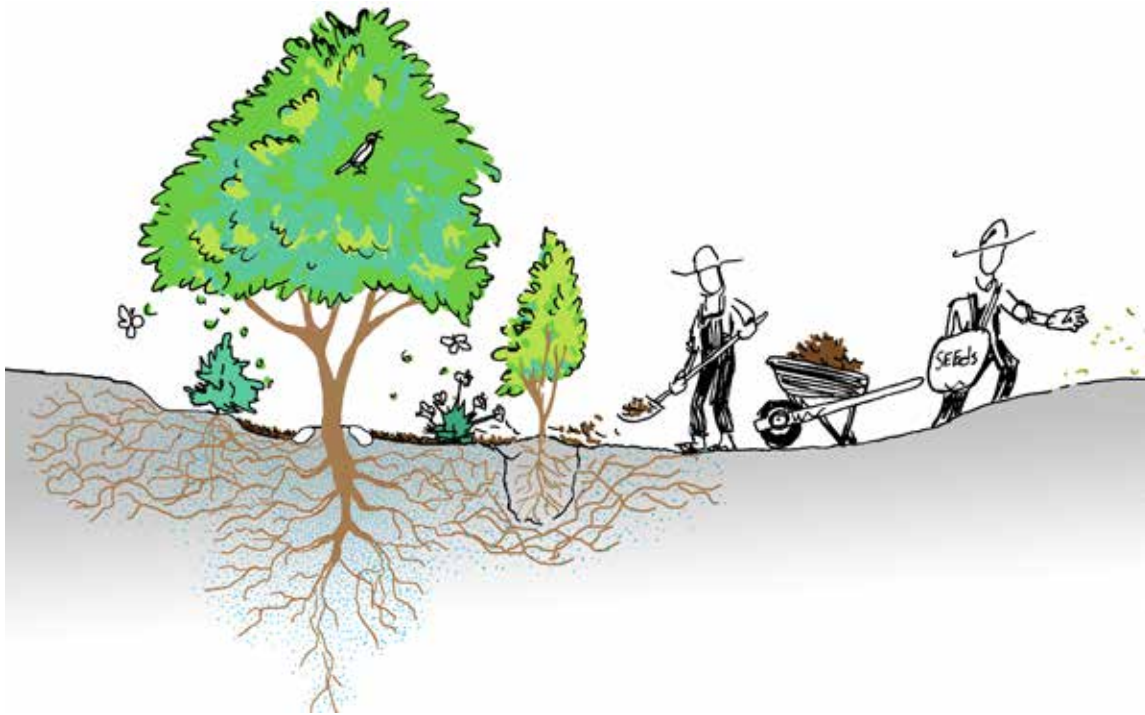


Fig. P.10. Maximize planting of climate-appropriate vegetative groundcover, spread organic mulch over the surface of the soil, and encourage more beneficial life within the soil to create a “living sponge” that uses harvested water to grow more resources. As roots expand and soil life increases, the soil's ability to infiltrate and hold water steadily improves.

7. DO MORE THAN JUST HARVEST WATER

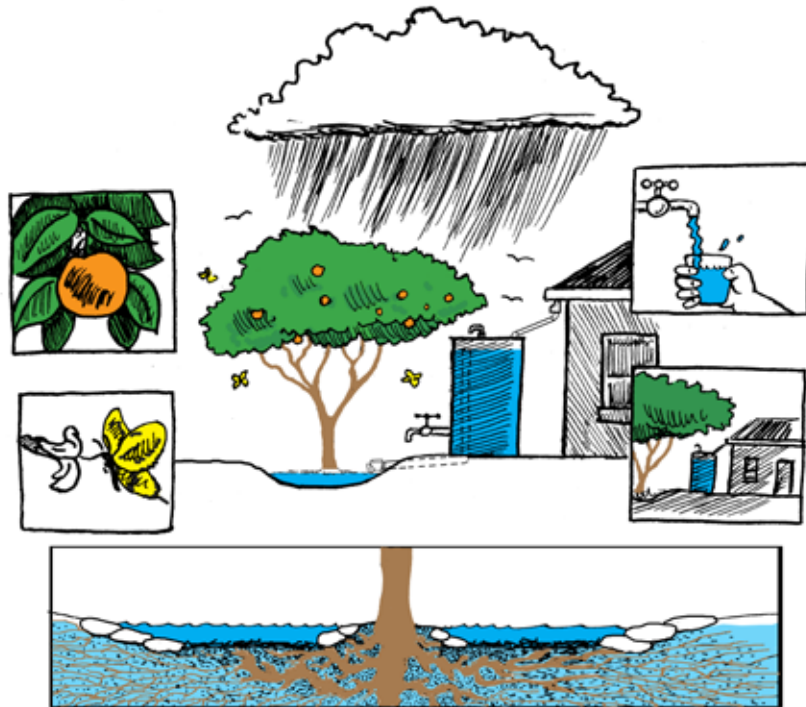


Fig. P.11. Maximize beneficial relationships and efficiency by “stacking functions.” For example, cisterns and earthworks provide high quality irrigation water and serve as on-site stormwater control strategies. In turn, rain-irrigated vegetation and above-ground cisterns can passively shade and cool the east and west sides of buildings in summer, while the plants also clean our air, produce food, create wildlife habitat, and add beauty to our lives.

8. CONTINUALLY REASSESS YOUR SYSTEM: THE “FEEDBACK LOOP”

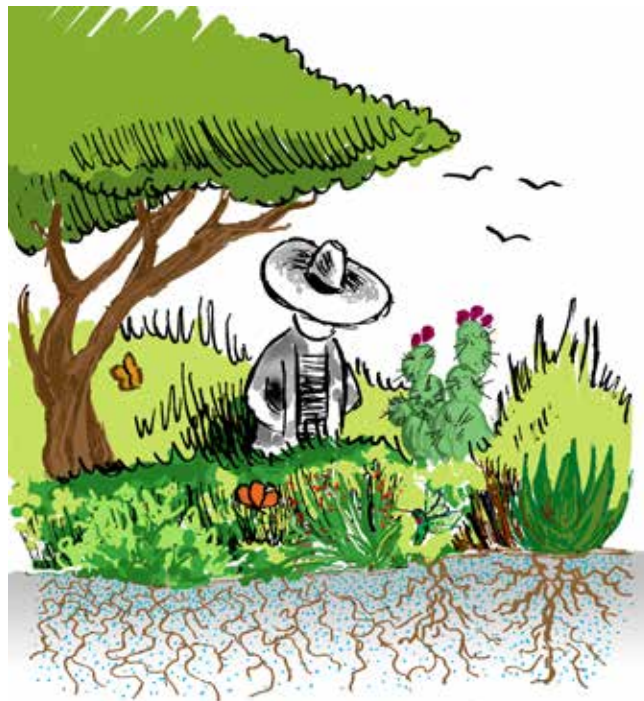


Fig. P.12. The value of long and thoughtful observation extends throughout the life of your system. How is the land responding to your work? How are your strategies performing? What still needs to be addressed? Make any needed changes using all the principles to guide you.

WATER-HARVESTING ETHICS

The following three ethics further increase the benefits of water harvesting on your site and well beyond. They are the ethics of permaculture,¹ a methodology of integrated, sustainable design based on natural systems.

1. The CARE OF THE EARTH² ethic reminds us to care for all things living and nonliving, including soil, water, air, plants, animals, and entire ecosystems. As Bill Mollison states in *An Introduction to Permaculture*, “It implies harmless and rehabilitative activities, active conservation, ethical and frugal use of resources, and ‘right livelihood’ (working for useful and beneficial systems).”³
2. CARE OF PEOPLE⁴ directs us to strive to meet our basic needs for air, water, food, shelter, education, fulfilling employment, and amiable human contact in ways that do not hamper or prevent others from doing the same. We do not exploit or disregard others for our own gain. Nor do we destroy the environment that supports us all. Instead, we sustain a basic quality of life that improves our environment while enabling others to do the same.
3. REINVESTMENT OF SURPLUS TIME, MONEY, AND ENERGY⁵ to achieve the aims of people and earth care encourages us to extend our influence and surplus energies to help others attain the ethics in their own life and work. This helps us all because it strengthens the greater communities in which we all live.

These principles and the ethics are the core of successful water harvesting. They apply equally to the conceptualization, design, and implementation of all water-harvesting landscapes. You must integrate *all* the principles and ethics—not just your favorites—to realize a site’s full potential. Used together, they greatly enhance success, dramatically reduce mistakes, and enable you to adapt and integrate a range of strategies to meet site needs. While the principles and ethics remain constant, the strategies you use to achieve them will vary with each unique site.

For a thorough introductory description of water-harvesting principles and ethics and to read Mr. Phiri’s full story, see Volume 1, chapter 1 of *Rainwater Harvesting for Drylands and Beyond, 3rd Edition* (Rainsource Press, 2019).

WHO THIS BOOK IS FOR

This volume (the second of a 3-volume set) guides you to harvest water in earthworks in a safe, productive, sustainable way in new and existing landscapes. You will learn how to harvest rainwater, stormwater runoff, and greywater within landscape and garden soil using simple earthworks. Earthworks are simple earthen structures that help reduce outdoor water consumption, decrease water bills, control erosion, enhance soil fertility, grow living air conditioners, support regenerative local resource production, and create a system that gets better with time as it helps enrich the larger ecosystem. Earthworks help you achieve maximum effectiveness for the least effort and cost while adapting strategies to your site, whether it’s urban, suburban, or rural, big or small.

You can choose the best combination of earthworks and variations described here to address the unique conditions of your site, and you can develop new strategies based on what you learn. This book tells and shows you *how to do it* and provides inspiring case studies to teach you and motivate you so you *will do it*. The descriptions are detailed and well-illustrated, so they’re easy to follow, and will be useful to backyard gardeners, do-it-yourself and professional landscapers, landscape architects, planners, designers, students, farmers, ranchers, engineers, teachers, community activists, and others.

Dryland-appropriate strategies are emphasized because that’s where the need is greatest (see box P.1). Many strategies are based on indigenous traditions that allowed people to survive and thrive in drylands for thousands of years. Yet water-harvesting principles and many of this book’s strategies are universally applicable—both wet and dry climates experience drought and flooding. Rainwater harvesting reduces the impacts of dry seasons, droughts, and floods, buffering our lands from changing climates and climatic extremes by making the land more resilient.

Box P.1. Drylands: A Definition

Drylands are typically defined as areas of the world where potential average yearly moisture loss (evapotranspiration) exceeds average yearly moisture gain (precipitation). Evapotranspiration is the combined measurement of water loss to evaporation and transpiration.⁶ Transpiration is the loss of moisture from plants to the air via the stomata within their leaves.

More than 16 billion acres (6 billion ha), 47.2% of the Earth's land surface, is dryland. A fifth of the world's population lives in dryland habitat.⁷ Normal dry seasons can last six months or more. Droughts can last for years.

Industrial and conventional agricultural sectors consume and contaminate the bulk of our fresh water resources.⁸ In contrast, this book focuses on intensive, small-scale strategies ideal for homes, neighborhoods and communities in urban, suburban, and rural settings. We begin work at the top of our “watershed of influence” where we can more easily influence what happens and directly observe and benefit from the results. This makes it easier to implement and maintain the strategies and to more quickly realize their potential. It also leads to less dependence on consumptive industry and agriculture. As you gain experience and success you will become an example, and your watershed of influence will naturally grow. You begin to plant *seeds of abundance*—rather than scarcity—well beyond your site.

HOW TO USE THIS BOOK AND VOLUMES 1 AND 3

The three volumes of *Rainwater Harvesting for Drylands and Beyond* create a series on how to conceptualize, design, and implement integrated and sustainable rainwater-harvesting systems. I strongly recommend everyone read Volume 1 to get a detailed understanding of water harvesting principles and ethics in the context of integrated sustainable design. Volume 1 puts all three volumes in context. It shows you how to assess your site so you can conceptualize and design truly efficient and productive *integrated* systems that do far more than harvest rainwater.

Volumes 2 and 3 describe the specific techniques you need to undertake the general strategies presented in Volume 1. Volume 2 focuses on earthwork techniques that passively harvest rainwater and greywater within the landscape. Volume 3 will focus on roof catchment and cistern systems.

Real-Life stories of people creating, implementing, maintaining, and living with water-harvesting landscapes and systems frame all three volumes. The scale and context varies, but they all illustrate principles in action. You can adapt these ideas to the scale and context your site requires.

VOLUME 2: WATER-HARVESTING EARTHWORKS

The *Introduction* to this volume defines earthworks, explains why you should use them, and shares an inspiring story of how water harvesting brought abundance to a once-dying community.

Chapter 1 is a quick reference guide providing tips on assessing a site's water flow and slope. A comprehensive table summarizes and compares all the earthwork strategies described in later chapters. Use this table to find the right earthworks for your needs, then jump to the appropriate chapters to learn more. Be sure to read the important cautions contained in this chapter. Go on to further tips on earthwork placement and selection including information on bountifully efficient oasis zones and how to live within your site's water budget.

Chapters 2 through 11 address individual earthwork strategies, defining them, and outlining where to use them and how to implement and maintain them. Tips and examples help you integrate these earthworks into your site so they do more than harvest water. All of these chapters end with stories illustrating how real people in real places have used these techniques—so if you love stories go to the end of each chapter first!

Chapter 12 illustrates how to integrate greywater harvesting within rainwater-harvesting earthworks to keep the landscape thriving in dry seasons and turn “wastewater” into a resource.

The *Epilogue* ties together what you have learned, and gives you a parting vision.

Separate appendices at the end of this book provide specific information about simple tools for

measuring slope and placing earthworks, calculations for sizing earthworks and estimating building material volumes, a recently simplified and legal kitchen sink drain-water-harvesting system, and additional resources for water harvesting and permaculture.

Uplifting case studies illustrate how people have transformed their sites using specific water-harvesting strategies and combinations/hybrids of techniques and how you can do likewise.

EVOLUTIONS AND ENHANCEMENTS IN THIS SECOND EDITION

Researching, writing, and massively revising this second edition has reenlivened my water harvesting passion, practice, learning, and inspiration and increased my admiration even more for its many diverse practitioners. These practitioners helped me evolve my abilities and understanding, resulting in significant improvements to this new edition. In a virtuous cycle, publication of the first edition allowed me to travel the world, meeting many of these practitioners and cross-pollinating ideas and strategies as I taught and learned from others. But you don't need to write a book or travel the world to accomplish this, just start where you are.

Along with many other people, I started harvesting water in my own back yard. We learned first hand from our successes and our mistakes—which we figured out and fixed. This prepared us to expand into new contexts when we saw the need and opportunity. We evolved and grew even further by seeking out those who pushed aspects of their practices beyond our own.

In my life and in this new edition, I focus on seeking out and developing unique ways to collaborate with the natural, living systems that shape and enable the thriving life on this planet to help maximize natural growth and potential. This book aims to help you collaborate with living systems as well. To that end, I've reduced and removed more intensive strategies that are less collaborative with life and more dependent on imported materials (for example, wire-wrapped gabions) and replaced them with more nuanced, synergistic, and easier to build strategies that use on-site materials (for example, one-rock dams that allow vegetation to grow through them to anchor and expand the structures, see chapter 10).

Box P.2. Advantages of Rainwater and Its Harvest with Earthworks

- Water flows downhill, so earthworks are ideal for harvesting rainwater *and* all other free on-site waters (street runoff, greywater, AC condensate, evaporate cooler bleed off, etc.)
- Rainwater (and hail, sleet, and snowfall) is delivered to us free of charge, eliminating the need for costly distribution systems
- Rainwater is the highest-quality source of irrigation water
- Rainwater is salt-free and can help flush plant-damaging salts from the root zone in alkaline soils
- Rainwater is a natural fertilizer containing sulfur, beneficial microorganisms, mineral nutrients, and nitrogen
- Rainwater harvesting reduces utility bills
- Rainwater harvesting reduces flooding by reducing flow to streets and storm drains
- Rainwater harvesting reduces nonpoint-source pollution of stormwater
- Rainwater harvesting provides a water source when well, surface, or municipal water is contaminated or unreliable
- Water harvesting helps utilities reduce summer peak demands for water and reduces the volume of wastewater that needs to be treated at water treatment plants
- Water harvesting is fun, and it'll get you dancing in the rain!

To enable you to see in a new way, almost 500 photographs and illustrations are now in color, half of which are new or significantly revised. In addition, dynamic new strategies and stories illustrate natural collaboration, including...

- Irrigating thriving landscapes at residential sites with rainwater- and greywater-harvesting earthworks that double as on-site stormwater controls (chapters 2 and 9)
- Dramatically increasing dry-farming yields using indigenous innovations that “plant the rain” in Syria,

Box P.3. Comparing Earthworks and Tanks

CHARACTERISTICS	EARTHWORKS THAT PLANT THE RAIN	TANKS THAT TANK THE RAIN
Water uses	Provide large quantities of high-quality rainwater to garden and landscape	Provide water for drinking, washing, fire control, and supplemental irrigation. Water quality will vary with catchment surface, tank construction, screening, and maintenance. Rainwater has very low hardness.
Water collection areas	Can collect water from roofs, streets, vegetation, bare dirt, greywater drains, air conditioner condensate, etc.	Need a relatively clean collection surface (typically a metal, tiled, or slate roof) located higher than the tank.
Water storage capacity	Very large potential to store water in the soil and vegetation	Storage capacity limited by the size of the tank
Cost	Inexpensive to construct and maintain. Can build with hand tools, though earthmoving equipment can speed up the process.	Much more expensive than earthworks to construct and maintain. Cost varies with size, construction material, above- or below-ground placement, self-built or prefab, etc.
Location	Do not locate within 10 feet (3 m) of wall or building foundation. May be difficult to use in very small yards with adjacent large roofs.	Can locate within 10 feet (3 m) of wall or building foundation, but you should be able to walk around entire tank to check for, and repair, leaks. Tanks increase water-storage potential in very small yards.
Time period water is available	Water available for limited to extended periods after rainfall depending on soil type, mulch, climate, and plant uptake	Water available for extended periods after rainfall depending on catchment and tank size plus water use
Maintenance	Earthworks work passively; require some maintenance after large rainfalls	Maintenance required, must turn valve to access water and may need pump to deliver water
Erosion control	Very effective for erosion control	Can assist with erosion control
Greywater collection	Very effective at harvesting greywater from household drains	Not appropriate to harvest greywater in tanks due to water-quality issues. Never store greywater in a rainwater tank.
Water quality impacts to environment	Pollutants in greywater and street runoff intercepted & bioremediated in the living soil stay out of regional waterways	Less impact than earthworks to the broad environment
Impacts on urban infrastructure and flooding	Can capture large volumes of water, reducing need for municipal water, stormwater drains, and stormwater treatment, and decreasing flooding	Can capture low to moderate volumes of water, reducing demand for municipal water, stormwater drains, and stormwater treatment, and decreasing flooding
Groundwater recharge	Can directly recharge shallow groundwater or indirectly recharge groundwater by reducing or eliminating need for its extraction	Not an efficient use of tank water

Burkina Faso, Niger, Ethiopia, Zimbabwe, Mexico (chapters 3, 4, 6)

- Turning “wastes” into resources including forming broken sidewalk rubble into artistic water-harvesting terrace walls and porous pavement (chapters 4 and 8)
- Bringing back grasslands with the hoofs of intensively herded animals and the fertility of their dung and urine (chapter 6)
- Planting junk mail to hydrate the soil and revegetate the land (chapter 7)
- Changing policy, building codes, and building practice to enable more effective, less-costly systems that rejuvenate local ecologies and economies rather than draining them (chapters 8 and 12 and appendix 3)
- Reviving pasturelands and urban neighborhoods by harvesting runoff from dirt roads and paved streets to create vibrant water-absorbing greenbelts, reduce road maintenance, and counteract the urban heat-island effect (chapters 8 and 9)
- Harvesting liquid water using frozen water by shaping snow berms to harvest snow melt (chapter 9)
- Daylighting once buried creeks and rivers to create local and international destinations of renewal and celebration (chapter 9)
- Regenerating lost wetlands, surface water flows, and groundwater tables with simple water-spreading strategies (chapters 9 and 10)
- Creating innovative designs and installations in which water flow and soil life do the bulk of the work for you by using new principles based on natural patterns of water and sediment flow, soil life, and human behavior (chapters 10 and 12)

DECIDING HOW BEST TO HARVEST YOUR WATER

Despite the many advantages of water-harvesting earthworks (box P.2), they may not be the only water-harvesting strategy to meet your site needs. Tanks/cisterns may also be desirable. How you plan to use your harvested water determines how best to harvest your water (box P.3).

LANDSCAPE OR GARDEN USE

If you plan to use harvested water (including rainwater, runoff, *and* greywater) for landscape or garden use, begin harvesting water in the soil using *earthworks*. Landscapes that harvest water in soil and are planted with low-water-use native perennials can typically subsist on rainfall alone once vegetation is established. However, storing water in cisterns gives you the option of applying supplementary irrigation in dry times, especially if a vegetable garden or less hardy non-native vegetation is planned.

POTABLE USE AND WASHING

If you plan to harvest water for potable use and washing, harvest rainwater in tanks, but do not forget the soil. (See Volume 1 for overall guidance, and Volume 3 for specific cistern information.) Direct overflow from the tank, greywater from your house, and runoff from the general landscape into water-harvesting earthworks. The more water you can effectively harvest and hold in the soil, the less supplemental cistern irrigation will be needed.

MATCH THE QUALITY OF WATER BEING HARVESTED TO THE STRATEGY USED TO HARVEST IT

Runoff from clean roofs constructed of metal, slate, or tile, or coated with elastomeric paints approved for rainwater collection systems, is the cleanest and most appropriate water to store in cisterns for domestic consumption and watering vegetable gardens. This runoff can also be harvested directly within earthworks. Stormwater from dirtier surfaces such as earthen slopes, streets, or sidewalks should be directed not to tanks, but to trees and shrubs in earthworks. Household greywater should be directed to and utilized within mulched basins planted with trees and shrubs. Do not store greywater in tanks. Instead, direct greywater directly to mulched and vegetated earthworks.

Keep in mind the question, “How do I plan to use my harvested water?” as you read the comparisons of these water-harvesting approaches in box P.3.

If water-harvesting with earthworks is appropriate for your site and needs, read on; the rest of this book shows you how.