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Introducing 100-Fold Gardens: Wicking Beds for High-Density Planting of Vegetables Where Water is Scarce

By Dawn Berkelaar and Tim Motis

Network member Lance Edwards works in Zimbabwe. He told us about using and promoting inexpensive, water-conserving planting beds that he calls 100-fold gardens. These are a type of "wicking bed"; they are lined with plastic so that water pools at the bottom in a reservoir. From there, water moves up towards the plants' rooting zone. 100-fold gardens are a way to maximize vegetable production on raised beds.

Lance learned about wicking beds online, but the ones he saw were primarily built above ground and used expensive containers and other materials. Proponents recommended potting soil to fill the beds. Lance began experimenting with local materials to reduce the cost of the beds. He did not want to have to purchase expensive containers or soil, so he decided to dig the beds 30 cm into the ground. That way, the ground would serve as the container, and they could sieve the soil from the hole and use it as the growing medium; it ends up being a fine growing medium that remains friable and that wicks water and nutrients well. Lance and his colleagues use the rocks and other large objects that were left in the sieve as part of the filler for the bottom of the beds (Figure 1). They also dispose of old tin cans, bottles, broken glass, bones, etc. in the bottom part of the beds. Beds are 2 m x 2 m in size, with a 1 m walkway between beds.

100-fold gardens in Zimbabwe.
Source: Lance Edwards

Lance told us, "I have put about 150 of these 100-fold gardens into rural communities, and people have loved them. I've found them to be especially well-received and looked after by people who struggle to get water: the elderly, single moms, etc. They quickly see the value of the gardens and really take good care of them. One nice thing is that we can put it right next to their home and they can use their grey water in these gardens. By contrast, most of the gardens tend to be away from the homes, down in the river beds in the rural areas, and it makes it much more difficult for people to secure them and take care of them."

100-fold gardens are extremely efficient in their use of water (Table 1), making them an excellent option for dry areas or dry times of the year. They do not have to be watered as often as conventional garden beds, so they are also a good option for situations in which daily watering is not possible. 100-fold gardens are less suited to areas with high rainfall; flooding is a problem without adequate drainage, and large influxes of water make it more difficult to feed nutrients to the plants.

Table 1. How wicking beds prevent water loss that occurs when supplying water to the soil surface.

Sources of water loss with surface irrigation*		Mechanism by which wicking beds prevent water loss
Runoff		The reservoir keeps water in the wicking bed. Some rainfall or surface-applied irrigation water could run off the top of the bed. Mulch helps with this, as well as watering from below by adding water through the irrigation pipe.
Leaching		The plastic liner blocks drainage past the bottom of the reservoir.
Evaporation		As long as the growing layer is not too shallow, the surface remains dry, minimizing evaporation.
*The extent of water loss varies with irrigation method. For example, losses are much less with drip irrigation than with watering cans or overhead sprinklers.		

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100-fold gardens offer many benefits:

Versatility. 100-fold gardens can be constructed in areas where the soils/ conditions are otherwise not favorable.

Water conservation. 100-fold garden beds conserve water, because no water travels down past the plastic layer. Water management is simple, with known quantities applied at known intervals. Mulching prevents soil surface evaporation. Because water is added below the plants, and is filtered through soil before reaching plant roots, grey water can be used for irrigation.

Nutrient management. Nutrients can be easily managed, because they remain in the reservoir and are never leached into the ground. Mulch keeps the soil soft and friable. Lance recommends urine as a primary source of fertilizer; he adds a 1:5 mixture of urine and water through the irrigation pipe. The urine never contacts the above-ground portion of the plants, allaying concerns about disease. It is out of sight and underground, making the use of urine as a fertilizer more socially acceptable than it might otherwise be.

Minimal labor. After the initial labor of setting up the garden beds, little labor is needed. For example, weeds are minimal because a heavy layer of mulch on top means almost no weeds grow; also, plants receive water from below ground through their roots, so fewer weed seeds near the surface receive the moisture they would need in order to germinate.

Sunlight. The design also means that plants have good access to sunlight on all four sides and good light penetration to the center of the bed.

Figure 1. Incorporating fill material into water reservoir of a 100-fold garden. *Source*: Lance Edwards

Convenient design. The size of each garden bed means it is easy to protect. For example, simple hoops can be made to span the bed to protect against intense sun, cold and insect movement. The size also means individual beds can be quickly constructed. An initial bed can be in production while additional beds are constructed, and earnings from the first beds can be used to pay for subsequent beds.

Plants can be spaced quite densely in a 100-fold garden. Lance suggests spacings similar to those on Mel Bartholomew's square-foot gardening planting chart. Be sure to plant seeds or transplants deep enough for the seeds or roots to contact moist soil. If you use stakes or trellises to support tall or vining plants, do not push them all the way to the bottom of the wicking bed, or the liner might puncture.

Lance commented, "In line with Mel Bartholomew's recommendations, I tend to suggest that people grow leafy greens in 100-fold garden beds. We plant these crops densely, but as the plants grow, people pick the leaves and naturally thin them. I do not suggest that people plant things like cabbages in these gardens, because they grow so big--the number of cabbages you could plant in one of these beds is low compared to something like collards."

Lance added, "I also do not promote tomatoes for these beds, because tomato plants get very big and take up a lot of room. Instead, I suggest that people plant tomatoes in a similar way, but that they use the principles of the 100-fold garden in 20 L buckets and plant a tomato plant in each bucket. It works well, and the nice thing about one of these is that a person can place it anywhere in their yard or garden where it can get adequate sunlight, and they can place it far away from other crops for disease prevention."

Instructions for how to construct Lance's 100-fold gardens are found in a newly available *ECHO Technical Note* (TN). The TN also includes information about how wicking beds work. In brief, water molecules are polar, with a positive charge on one end of each molecule and a negative charge on the other end. The positive end of one water molecule is attracted to the negative end of the next, making water molecules slightly "sticky." Attractive forces between water molecules and soil particles mean that, to varying degrees, water molecules in soil resist the downward force of gravity (through something called soil water tension) and wick upward through soil pores (through capillary action). For water to wick upward, the water and soil must be kept in constant contact. 100-fold beds have about 30 cm of soil above the reservoir, which is within a range that allows for good capillary action.

ECHOES FROM OUR NETWORK

Literacy and Agriculture

by Dawn Berkelaar

Several years ago, in a meeting, an ECHO staff member wondered aloud about the importance of literacy as it relates to agriculture. We received feedback from a few network members on this topic; their thoughts are shared below.

How does literacy affect openness to change?

Miriam Noyes, working in Congo with her husband Ed, commented "I am working on writing a literacy component into an agriculture project right now, upon invitation. People in development are very intrigued with the fact that it is educated, literate (the two are not necessarily inclusive) women who are most open to change, whether in the area of family planning, agricultural practices, health, etc. Uneducated, illiterate women are most likely to fear change and cling to ancestral tradition, as they see it. And they tend to decide and act as a group by largely invisible, not classically logical processes. Literate change agents tend to have difficulty entering these modes of thought to communicate effectively with uneducated, illiterate women."

What is the cost of adding literacy training to an agricultural development project?

Financial cost: Noyes also commented on the costs of literacy. “The problem with including literacy classes in a development program, though, is that it takes significant time and money and is not directly related to the goals of the program. It can be seen as an unacceptable diversion with unproven dividends—even though higher-level classes, where classes can read material together and discuss it, are perfect venues for the dissemination of information in a community, whatever the subject matter. The UN estimated that teaching literacy required an investment of $10 per person. It is probably a good estimate, which we get around only by largely volunteer work. We have estimated that it takes a minimum of a year of fairly concentrated classes to make an illiterate person functionally literate.”

Minimum time commitment: Noyes went on to share, “In this project I have been asked to write for, they are only willing to invest six months [of project time] in literacy. It might be enough time, though, for permanent reading clubs to get introduced into the village, to serve the agriculture project's goals of disseminating the information they want to share, and bringing the women to a place where they decide to implement specific actions as a group. In terms of literacy, these clubs could serve to conserve and consolidate the women's reading skills, increase their vocabulary in diverse subjects, and help them to comprehend things that they read—major functional literacy goals.”

Is literacy necessary for success in agricultural projects?

Joann Noel works in Tanzania in the area of literacy, mostly with church planting pastors and their wives. She wrote, “I have been involved in literacy ministry here since 2014. I help train teachers mostly within our church planter course. Keep in mind our church planter families plant churches in areas where there is no church. Quite often this is in a remote place. Most of my experience has been working with adults who can read, [teaching them] to teach other adults who cannot. But I also have spent time helping teach four men and two women who could not read.”

Noel commented that she does not believe literacy is necessary for successful agricultural development. She said, “I do not think [people] necessarily need to be literate to learn new skills such as good agricultural practices. I know there is group thinking here. But the group can also help each other remember. I am not opposed to encouraging reading skills obviously; I just do not think we have to wait for people to be literate to move ahead. [As an example, my husband] Mike teaches Bible story telling. In a 45-minute session, he teaches people how to learn a story almost word perfect. Readers and non-readers alike are able to do this. Time is spent engaging the story so that in the end the students see how it applies to them. In the end they own it because they have invested time and effort.”

What are some obstacles to incorporating literacy into agricultural programs?

Challenges women face: Noel believes literacy is important, and shared several obstacles to literacy, especially for women. “My personal opinion is that Tanzanian women may have more desire to learn to read than [Tanzanian] men. Our numbers support [this opinion;] there tend to be more women in the class than men. But it is more difficult for women to find the time to devote to class or study. From the perspective of a teacher I will use one of the illiterate women I taught as an example. We were in an ideal situation. I gave her lessons one on one. She lived very close to the classroom. There was no charge for lessons. I only required she bring her own notebook and pencil. But she has many children to feed, water to haul, animals to tend and outside work to do. After a few months she gave up. I truly believe the reason she stopped coming to class was because her husband pressured her to remain home. By the way, he had been agreeable to the arrangement in the beginning.”

Potential lack of confidence in learning: Noel added, “Another reason I believe she stopped [coming to class] was a new reason I have been made aware of just recently for [some] illiterate people, and that is their belief that they cannot learn. If it is [reinforced] by others, this falsehood becomes their reality.”

Lack of trained teachers: Noel highlighted the importance of training, stating, “Perhaps the greater challenge is placed on finding teachers with a heart and passion for teaching. If a teacher sees this as a ministry opportunity to serve, then money is not necessarily required.”

Noel also commented on challenges faced by women who want to teach. She shared, “My helper has observed that [Tanzanian] women have more of a heart to teach. Here again, female teachers in Africa have a unique challenge. Depending on their tribe it [varies] how long they stay at home after delivery of a child. We have two very capable, devoted teachers who recently had babies. They stopped teaching for months! No provision has been made for their students to continue learning as far as we know. The solution seems to be to find another teacher. But the possibility remains the same that the teacher, if she is a woman who gets pregnant, will need to stop teaching. I suppose if [teachers] coordinated their efforts, there could be coverage [through a maternity leave situation].”

Realities faced by farmers: Sometimes agricultural realities make learning a challenge. Noel shared, “A very big problem [faced by] our teachers and students alike is drought and hunger. Nobody is coming to class if there is no food to eat. But by the same token, if there are crops to plant or crops to harvest, people will be missing from class. My helper made a suggestion that I want to seriously consider: he said to encourage the teachers to only hold classes during the months of June through October. His thinking is that people will be more free [to attend classes]. [Also,] with no rain, classes can be held outside. This would be a solution to a big problem we face in the bush, of no facilities.”

Is literacy a cause or effect of agricultural development?

When looking online for information about literacy and agriculture, I did not find many references to the topic; for example, the executive summary of a 2006 Unesco publication on literacy (*Education for All Global Monitoring Report: Literacy for Life*) does not mention agriculture in relation to literacy. The closest reference in that document is a comment that, generally speaking, literacy levels are lower in rural areas.

However, I found an article by Barnes, Fliegel and Vanneman (1982) called “Rural Literacy and Agricultural Development: Cause or Effect?” The authors summarize three historical stages regarding the role of literacy in development. In the 1950s, literacy was viewed as a "transforming force." In the 1960s, the role of literacy was not seen as quite so crucial. The authors write, "[Several studies during the 1960s] highlight the fact that, although literacy definitely can benefit farmers, developmentally relevant information can be transmitted in a variety of ways so that non-literates can achieve the same ends." The authors also point out that literacy education can leave learners with "information and perspectives which are not conducive to development." During the 1970s, literacy came to be seen as one of many "causes" of development, one that helps people access helpful information. Though literacy might not transform people, it can have an indirect effect on adoption of agricultural practices.

In their research, Barnes *et al.* tried to "determine whether literacy is one of the causes or the effects of agricultural development." They specifically wanted to know what impact literacy had on agricultural productivity. Over the ten years between 1961 and 1971, "the proportion of literates in the rural population of India's districts increased by 5 percent during the decade." (Barnes *et al.* 1982). Agricultural production also increased--in terms of total production (of the 12 most common crops), production per unit of land, and production per worker. However, according to the authors' analysis, "literacy does not cause increases in agricultural production or productivity." Upon further analysis, they determined that "the short-term effect of increases in production on literacy...is actually negative" but that "the exclusively long-term effect of production is definitely positive." They concluded that "agriculturally productive regions provide a conducive social and economic environment for the long term growth of rural literacy….[and] agricultural development may be one important way to increase the standard of living in rural areas which may in turn result in the long-term increase in 'human capital.'"

Now it's your turn

In your work with smallholder farmers, have you seen connections between literacy and agriculture? We would love feedback from more members of our network! Please let us know by emailing echo@echonet.org.

References

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Photo Essay: FMNR Restores Termite Harvesting as Poultry Feed in Talensi, Ghana

A document by Samuel Abasiba and Joshua Adombire, Talensi FMNR Project, World Vision Ghana

Over the past 35 years, Farmer Managed Natural Regeneration (FMNR) has restored forests on millions of hectares of land in at least 24 countries. FMNR has also had some surprising results. For example, the introduction of FMNR in the Talensi District of Northern Ghana has boosted farmers' local poultry production. Traditionally, farmers in that district collected termites and fed them to their poultry as an important protein source. Over the years, frequent bushfires destroyed termite colonies, leaving farmers without an accessible protein source. But with the introduction of FMNR, bushfires are much less common and termites have returned to the area. A document by Samuel Abasiba and Joshua Adombire, both with World Vision Ghana, describes the changes and includes step-by-step instructions for harvesting termites for poultry feed. The method is used to harvest small-sized termites in the genus *Microtermes* (some kinds of termites are best avoided, either because they are poisonous or because they are prone to bite and kill chicks).

For more about the surprisingly widespread effects of FMNR, view the photo essay and this short video from World Vision Australia.

FROM ECHO'S SEED BANK

Earthbag Houses for Storing Seeds

By Tim Motis

Patrick Trail, an ECHO Asia staff member, compiled a picture-based guide for constructing earthbag houses for seed storage in Asia. Earthbag houses have been used by multiple seed banks in Asia as an alternative to more costly conventional structures. At this writing, construction of an earthbag house at ECHO in Florida is also underway. Content below is drawn from insights gleaned at both ECHO locations.

Figure 2. Earthbag house at ECHO in Thailand. *Source:* ECHO Asia Staff

INTRODUCTION

What is an earthbag house?

An earthbag house consists of a roof over walls made of grain bags filled with soil. The bags are stacked in layers along the perimeter of a foundation or pad, with space left for a door. Then the stacked bags are plastered over with mud (Figure 2).

What are some advantages of earthbag houses?

Earthbag structures are made from local, inexpensive materials. An ECHO earthbag house in Thailand was built at a cost of 750 USD (Trail *et al.* 2019). The simplicity of earthbag houses means that people with little or no construction experience can quickly learn the necessary skills. Earthbag houses are strong, but are also flexible enough to resist earthquakes (Geiger and Zemskova 2016). The walls are durable, non-toxic, and resistant to fire and insects.

Why are earthbag houses good for seed storage?

In the warm tropics, temperature and humidity tend to be high and can fluctuate widely. Under such conditions, seeds deteriorate due to premature germination, rotting, insect pests, and rapid metabolism of food reserves.

Seeds maintain viability best when they are kept consistently dry and cool. Vacuum sealing (to exclude humidity) or desiccants (to absorb moisture) can help keep seed moisture low. However, these technologies do not address temperature.

Earthbag houses stabilize storage temperature in comparison to outside air. An ECHO earthbag house in Thailand reduced average maximum air temperature from 44°C (outside) to 28.5°C (inside the earthbag house); minimum temperatures increased slightly from 10°C (outside) to 11.5°C (inside the earthbag house) (Trail *et al.* 2019). Underground storage is another way to moderate temperatures, but seeds in an aboveground structure are easier to access than buried containers or underground bunkers would be.

How does an earthbag house work?

Earthen walls have high thermal mass, which means they absorb and transfer heat or cold. In warm climates, the exterior walls absorb heat during the day. With earth walls at least 30 cm thick, it takes about 12 hours for that energy to move to the interior of the structure (Hunter and Kiffmeyer 2004). At night, the walls stop absorbing heat as the outside temperature drops. The walls release heat at night, keeping the inside temperature warmer than that outside. Lightweight materials used for the roof (straw/thatch) and placed between the ceiling and roof (rice hulls or plastic bottles) have low thermal mass, so they do not absorb and transfer heat well. They are, however, good insulators. Insulating materials block transfer of heat to the interior of the building. The properties of the walls, roof and ceiling work together to moderate against extreme temperatures.

What are the limitations of an earthbag house?

Humidity inside an earthbag house can be high if outdoor humidity is high. Disease-causing fungi proliferate at or above 65% humidity. If the humidity inside an earthbag house is high, keep the seeds in sealed containers. Earthbag houses work best where it cools off at night; they are less effective if day and night time temperatures do not differ much. In hot climates, an earthbag house will not keep temperatures as low as can be achieved with air-conditioning or refrigeration, but the improvement over ambient conditions will still be significant.

SITE SELECTION

Select a site based on project needs. For example, choose a place that is accessible to those managing the seed collection. If possible, build the earthbag house near trees or other structures that provide protection from the sun. Avoid low-lying areas that could easily flood. To reduce labor and hauling costs, build where suitable soil and other materials are easily accessed.

MATERIALS AND DESIGN

Materials vary with design choices and with what is available locally. Below are a few guidelines to consider for the main structural components of an earthbag house:

Foundation

Pick-axes and shovels are needed for digging a trench around the perimeter; the trench will be filled to form a footer for the walls of the earthbag house. Note that the shape of the foundation determines the shape of the structure. A round design maximizes structural strength and requires the least amount of materials (Toevs 2019). Whatever shape you choose, Geiger and Zemskova (2016) recommend digging the trench 60 cm wide by 60 to 90 cm deep (down to the subsoil). Fill the trench with rubble/gravel, with the largest rocks at the bottom of the trench.

Options exist for the floor. If you choose a concrete floor, you will need to build a pad with cement, sand, and rebar. The perimeter of the pad—on which the walls are built—rests on the footer, with the remainder of the pad supported by packed earth or gravel. In this case, the foundation consists of a concrete pad and footer. Concrete readily absorbs moisture and dries out more slowly than soil. To prevent the pad from absorbing ground moisture, plastic is needed as a moisture barrier between the ground and cement.

In a dry climate, you might make the floor simply of compacted earth or gravel. In that case, the foundation would consist simply of the footer.

Walls

Walls are made mainly of soil with enough clay to stick together and harden (10% to 30% clay according to Stouter 2011). On page 14 of *Earthbag Building in the Humid Tropics*, Stouter (2011) explains how to test the soil for the right texture and moisture; for example, if a ball of soil shatters when dropped 1.5 m, the soil needs more clay and water. Too much clay in the mixture is also a problem. A mixture with more than 40% clay could result in unstable walls due to excessive shrinking and swelling (Toevs 2019).

Sift the soil as needed, to remove rocks and debris. At ECHO Florida, we used a mixture of 20% clay with 80% sand. At ECHO Asia in Thailand, we used 60% soil (estimated to have equal parts clay and fine sand) and 40% rice hulls. The rice hulls (and alternative lightweight materials such as volcanic rock) provide insulation, to reduce the amount of heat stored and radiated back inside the building. This is recommended for areas where temperatures stay high day and night. Rice hulls also resist rot and insect attack. Keep in mind that the mixture of soil and any lightweight material needs to be strong enough to bear the weight of the walls and roof. To test the strength of the mix, Stouter (2011) recommends filling an earthbag with moistened fill, tamping it, and then allowing it to dry for 1-2 weeks; a 25 cm span of earthbag should be able to support a 54 kg person.

Bags are another significant component of the walls. Usually, grain bags of various types and sizes are used. Geiger (2019) suggests bags that are roughly 46 cm X 76 cm. The bags must be strong enough to hold the weight and shape of the walls during construction, but their long-term strength is not critical, since the earth inside them will harden and the bags will be covered with plaster. Polypropylene bags are a good option, because they do not tear easily.

Other materials are needed for the walls: barbed (four point) and non-barbed (16-gauge thickness) wire, wood for a door and doorframe, and plaster. Mud plaster can be made from the same soil that is used to fill the bags. Stouter (2011) discusses plaster options in more detail (see references section). Tools required for wall construction include wire cutters, a tamping tool (this can be made from cement if needed), a leveling device such as a bubble level, and buckets for filling bags with soil.

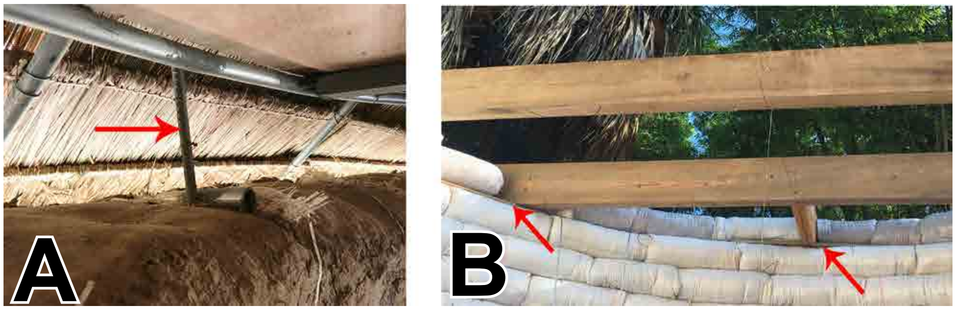


Figure 3. Structural support for the roof and ceiling of an ECHO earthbag house in Thailand (A) and Florida (B). In Thailand (A), a plywood ceiling rests on metal bars welded to rebar pylons (an example of one is indicated by the red arrow) hammered into the top of the earthen wall. In Florida (B), wooden joists rest on plywood (indicated by red arrows) inserted between two bags. *Source:* ECHO Asia staff (A) and Tim Motis (B).

Ceiling and roof

Joists and rafters are needed to support the ceiling and roof, respectively. These can be made with bamboo, wood, or metal. In many earthbag houses, ceiling joists rest on a cement beam that is built on the top layer of bags. The ceiling support structure of ECHO's earthbag houses rests directly on the walls (Figure 3). We suggest plywood for the ceiling. For insulation on top of the ceiling, pile local materials that are unlikely to mold, such as used/empty plastic bottles, or rice hulls (used by ECHO in Thailand; can be bagged to keep them dry). A thatched roof is often made using straw (Figure 3).

CONSTRUCTION STEPS

1) Build the foundation and place the doorframe

A solid, level foundation (Figure 4) supports the entire structure and helps maintain a uniform wall height. As mentioned in the materials and design section, this involves a gravel-filled trench for a footer, with walls resting on the footer or on a concrete pad.

At ECHO in Florida and Thailand, the foundation consisted of a footer and concrete pad. This approach is useful in locations that receive a lot of moisture during the monsoon rains. For ECHO's Florida earthbag structure, we laid plastic between the ground and cement pad/floor, and also between the surface of the floor and the first layer of earth bags. The second moisture barrier was added as an extra precaution to make sure that any moisture absorbed by the concrete pad cannot wick up into the bottom layer of earth bags. With the foundation in place, construct the doorframe and place it on the foundation.

Figure 4. Foundation of earthbag house at ECHO in Asia. *Source:* ECHO Asia staff

2) Fill bags with soil

Fill the bags about two-thirds full of soil. By not filling the bags completely full, they will be more workable when placed on the foundation. The empty space also means bag material will be left at the top end; this can be folded over or stitched shut with wire, to keep soil from spilling out.

NOTE: If you are building an earthbag house without a cement pad as part of the foundation, consider placing several layers of double-bagged gravel above the footer. This will protect the bottom of the structure against water erosion that could otherwise destroy earthen walls. Earth-filled bags can then be stacked on top of the gravel-filled bags.

3) Stack earth-filled bags on the foundation

Place bags around the perimeter on top of the foundation, one layer at a time (Figure 5). To maintain a true circle as the walls are built, tie a string or rope to a center pole (Figure 6), cut or mark it to indicate the desired distance from the center to the inside edge of the wall, and place each bag so that the inside edge is always the same distance from the center. For accurate measurements, keep the string level when measuring. For each layer of bags, first put all the bags in place and then tamp them so they are flat and level (Figure 7); the bags will lock into place as they push against each other (Toevs, 2019).

Figure 5. Placing an earth-filled bag on earthbag house wall. *Source:* ECHO Asia staff

We placed barbed wire between each layer of bags (Figure 8). The wire provides an interlocking matrix that holds the bags together, both between layers and within layers. We used bricks to hold two strands of barbed wire in place while we stacked the bags for each layer (Figure 8A). At ECHO in Florida, we tied pieces of 16-gauge rebar tie wire to each strand of barbed wire (Figure 8B), at intervals of 35-45 cm. The ends of these non-barbed wires, extending

Figure 6. Pole for measuring distance of each bag from the center of a circular earthbag house. *Source:* Cody Kiefer

Figure 7. Tamping bags to form walls of an earthbag house. *Source:* Cody Kiefer

Figure 8. Barbed wire (A) and rebar tie wire tied to barbed wire (B) for interlocking earthbag wall components. Photo C shows a piece of sheet metal used to prevent bags from catching on the barbed wire during placement. Source: Cody Kiefer

6-8 cm on either side of the wall, were used to fasten chicken wire/stucco mesh to the interior and exterior walls (see step 3). To keep the bags from snagging on the wire as we were positioning them, we placed a flat, smooth piece of sheet metal over the barbed wire (Figure 8C). Once the bag was in place, we slid the metal out, allowing the bag to be pierced and thereby caught hold of by the barbs.

The doorframe tends to be held in place by the weight of the bags pressing against the sides. In ECHO's Florida structure, we placed pieces of wood (Figure 9A) adjacent to the doorframe on each side, between every third layer of bags (Figure 9B); these served as points of attachment for added stability.

Add layers of bags until the desired height is reached. The ECHO earthbag house in Florida is about 2 m tall, which allows most people to be in the structure without having to stoop to keep their head from touching the ceiling. Geiger and Zemskova (2016) state that the ratio of wall height to wall thickness should not be more than 8. The Florida earthbag house, which has not been plastered as of this writing, has a wall thickness of 30.5 cm. With a 200 cm wall height, our height to thickness ratio before plastering is 6.6 (200 divided by 30.5).

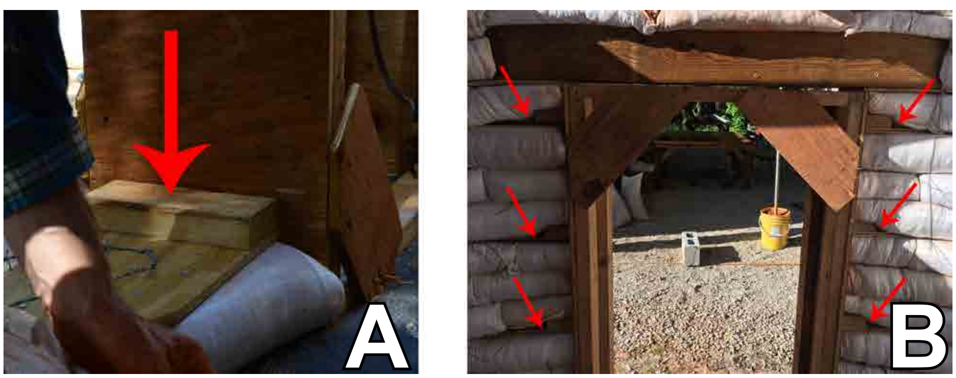


Figure 9. Wooden anchor (A), between every third layer of bags (B), to which the doorframe was attached. *Source:* Cody Kiefer (A) and Tim Motis (B)

Figure 10. Bamboo (A) and metal (B) as options for rafters. Note rice hulls placed on top of plywood ceiling for insulation. *Source:* ECHO Asia staff

4) Construct the roof with an insulated ceiling

Figure 10 shows bamboo (10A) and metal (10B) rafters. Bamboo is likely more available than metal framing or lumber, but the latter two options are more permanent. In Florida's subtropical climate, untreated bamboo lasts for about two years, whereas bamboo treated to resist decomposition and insect attack lasts as long as conventional lumber (20-30 years) when under the protection of a roof (Toevs, 2019; see Bielema 2017 for information on treating bamboo). Make the rafters long enough for an overhang that will shield most of the exterior wall surface from the sun and rain. Secure the ceiling—using nails, screws, or wire— onto joists made with wooden poles, cut lumber (Figure 3B), bamboo (Figure 10A) or metal (Figure 10B). Place insulation material on top of the ceiling (Figure 10B), and secure thatch to the rafters (Figure 3A).

5) Plaster the walls

Once the walls and roof are built, cover the walls with plaster. At ECHO Asia, we made plaster by adding water to the same soil/rice hull mixture that we used to fill the bags (Figure 11). In Florida, since our soil for plaster only had 20% clay, we applied that plaster to chicken wire/stucco mesh attached to the walls, so that it would stick better; this step would be unnecessary if the clay content in the soil used for plaster is closer to 30-35% (Toevs, 2019).

CONCLUSION

Consider an earthbag structure for stabilizing seed storage temperature in areas where air conditioning and refrigeration are not feasible. ECHO staff in Asia have found earthbag buildings to be especially helpful for community seed banks in need of low-cost, sustainable storage space. Temperature control with earthbag storage could be combined with vacuum sealing (Bicksler 2015) to also reduce humidity,

Figure 11. Mixing plaster to cover the walls of an earthbag house. *Source:* ECHO Asia staff

thereby extending the life of seeds. See the References and Further Reading sections below for much more information and detail on earthbag construction.

References:

Bielema, C. 2017. Bamboo for Construction. *ECHO Technical Note* #92.

Bicksler, A. 2015. Bicycle Pump Vacuum Sealer for Seed Storage. *ECHO Development Notes* 126:1-2.

Geiger, O. 2019. Step by Step Earthbag Construction. EarthbagBuilding.com. Website accessed 16 July 2019.

Hunter, K. and D. Kiffmeyer. 2004. *Earthbag Building: The Tools, Tricks, and Techniques*. New Society Publishers.

Geiger, O. and K. Zemskova. 2016. Earthbag Technology – Simple, Safe and Sustainable. *Nepal Engineers' Association Technical Journal* XLIII-EC30 (1):78-90.

Stouter, P. 2011. Earthbag Building in the Humid Tropics: Simple Structures 2nd edition. SCRIBD.

Toevs, E. 2019. Personal Communication.

Trail, P., Y. Danmalidoi, S.M. Pler, A. Bicksler, and B. Thansrithong. 2019. Low-Cost Natural Building Options for Storing Seeds in Tropical Southeast Asia. *ECHO Asia Notes* 38:6-8.

Further reading

More on the cost of earthbag houses:

Haft, R., H. Husain, A. Johnson, and J. Price. 2010. Green Building in Haiti.

Actual costs vary with size and design choices. Haft et al. (2010) reported a cost of $2,168.95 USD for an earthbag house in Port-au-Prince, Haiti. Appendix B of the book *Earthbag Building* (Hunter and Kiffmeyer 2004) provides guidance in determining cost of labor and materials. A seed storage structure does not need windows, which reduces cost in comparison to a home.

General information:

Hart, K. 2018. *Essential Earthbag Construction: The Complete Step-by-Step Guide* (Sustainable Building Essentials Series). New Society Publishers.

BOOKS, WEB SITES, AND OTHER RESOURCES

NOW AVAILABLE!

Second Edition of *Restoring the Soil*: How to Use Green Manure/Cover Crops to Fertilize the Soil and Overcome Droughts

Book authored by Roland Bunch

Smallholder farmers around the world face some of the harshest growing conditions globally, yet they produce the majority of the world's food. Soils in these areas often lack nutrient and water holding capacities, due to erosion or poor soil structure. These obstacles can be staggering for farmers who depend on soils to sustain their crops for home and/or market production.

Bunch stated the following about soil health options for smallholder farmers:

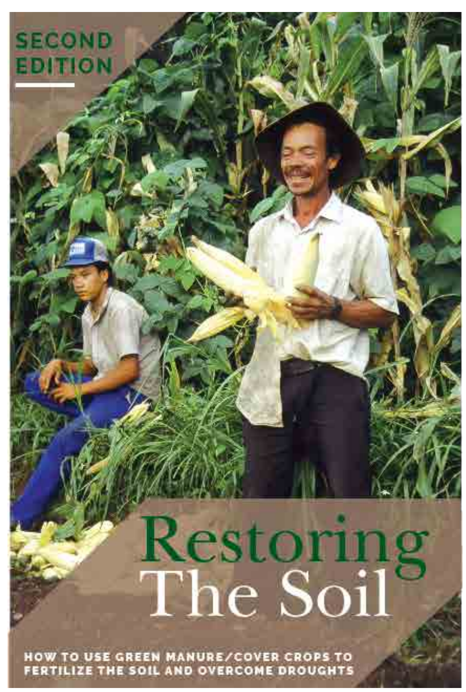
> Now that fallowing has largely died around the world because of population pressures on the land, the only feasible way smallholder farmers can save their soils from eventual degradation is by using green manure/cover crops [gm/ccs]. Composting the soil enough to maintain fertility on just one hectare of land would take months of work, and smallholder farmers do not have enough animal manure to do the job. Synthetic fertilizers often cost more than the value of the increased yield they produce when used on degraded soils or in droughty climates, and cannot provide benefits beyond supplying plant nutrients.

Roland Bunch has worked in agricultural development for more than 42 years in more than 50 nations of Latin America, Africa and Asia. He has done consultancies with the Ford Foundation, Cornell University, CARE and the top non-governmental organizations from Canada, Great Britain, the Netherlands, Germany and Switzerland, as well as the governments of Guatemala, Honduras, Swaziland and Vietnam. In 1982, he published the best-selling book *Two Ears of Corn, A guide to People-Centered Agricultural Improvement*.

Starting in 1983, Bunch began investigating the use of plants that are particularly good at fertilizing the soil, which are now called gm/ccs. Together with an independent group of agronomists in southern Brazil, he spearheaded the effort that successfully put this technology on the agenda of development organizations around the world. Bunch has also collaborated with ECHO since 1983.

Bunch has been nominated for the Global 500 Award, the End the Hunger Prize of the President of the United States, and the World Food Prize.

Roland Bunch's second edition of *Restoring the Soil* explains how gm/ccs can double or triple smallholder farmers' basic grain yields, fix more nitrogen than any smallholder farmer will need, provide up to



80% protection against droughts, provide high-protein food for the farm family, produce dry-season fodder for animals, produce tons of firewood, and sequester more atmospheric carbon at less cost than any other process we know of.

Part 1 of the book describes benefits and limitations of gm/ccs, common misconceptions, and common mistakes made in using them. It discusses how gm/ccs relate to soil improvement, tropical agriculture, and climate-smart practices. Part 2 leads the reader through a unique, incremental decision-making process for selecting which of 117 gm/cc systems have the most potential for success in their setting. Figure 12 shows a portion of one decision tree; each number is accompanied by commentary in the book. Figure 13 shows an example of a system.

To order your own copy of *Restoring the Soil*, Second Edition, please visit the ECHO bookstore website. For questions about ordering, please contact ECHO at +1 (239) 543-3246.

This is a great opportunity to learn from a world-renowned expert how to increase the health and resilience of soils around the world!

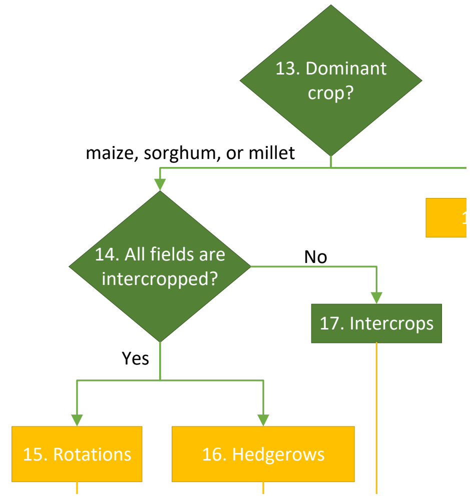


Figure 12. A portion of one decision tree used to help readers select gm/cc systems throughout Bunch's book. The book includes commentary about each entry on the decision tree.
Source: Restoring the Soil, Second Edition

S4. Dispersed shade/gliricidia. Proven. Honduras and El Salvador. Tens of thousands. The original gliricidia-based dispersed shade system, called "quesungual," was developed by smallholder farmers in southern Honduras and eastern El Salvador, where gliricidia is native. Through the years, they allowed gliricidia trees that volunteered and were well-spaced to grow in their fields. In this way, they eventually had fields with gliricidia trees spaced at an average of about 8 m distance. As a result, soil fertility decreased much more slowly over time.

Figure 13. An example of a system description box with its accompanying image.
Source: Restoring the Soil, Second Edition

UPCOMING EVENTS

ECHO Florida Events:
Location: ECHO Global Farm, USA

Seed Saving & Banking
September 16 - 20, 2019

26th Annual International Agriculture Conference
November 19 - 21, 2019

ECHO East Africa Events:

Best Practices Improving Nutrition and Sustainable Agriculture in Highland Areas
November 26 - 28, 2019
Hilltop hotel in Kigali-Remera (TENTATIVE), Rwanda

Best Practices to Improve Nutrition and Livelihoods in Pastoralist Areas
March 2 - 4, 2020
Uganda

ECHO Asia Event:

Agriculture & Community Development Conference
October 1 - 4, 2019
Chiang Mai, Thailand

PLEASE NOTE: At ECHO we are always striving to be more effective. Do you have ideas that could help others, or have you experimented with an idea you read about in *EDN*? What did or did not work for you? Please let us know the results!