The Basics of Rainwater Harvesting for Drip Irrigation: Our Experience

A Manual Created by the Vlahi Nature School

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Introduction

Rainwater harvesting – *"the collection, storage, and reuse of rainwater"* - is an ancient water resource management practice used throughout the world.[1] The United Nations Environment Program describes it as, "the most economical and surest way of providing water for drinking and sanitation even in the remotest areas."[2] It is a practice that, while simple, can provide tremendous environmental, social and economic benefits.

As a key goal of the Vlahi Nature School is to demonstrate sustainable living, we chose to implement a rainwater harvesting system. The purpose of this manual is to describe the steps we took to plan and implement the system. Our hope is that this manual, combined with other available resources, will provide you with the knowledge needed to implement your own rainwater collection system.

To learn more about rainwater harvesting, including the benefits and examples of different systems throughout the world, please see our Powerpoint presentation, *Harvest the Rain*.

Thank you for reading and please do not hesitate to contact us for more information on rainwater harvesting!

Our rainwater harvesting system:

1) *Collection surface (roof)*
2) *Delivery system (gutters / piping)*
3) *Storage Reservoir*
4) *Outlet for water (not visible)*

[1] http://www.nkba.org/green/glossary.aspx
[2] UNEP manual

1. Is it Appropriate?

"Is it appropriate for me?"

This is the first question to ask yourself about rainwater harvesting.

Rainwater harvesting often proves to be an excellent solution to water resource problems. However, there are costs and challenges associated with it and these must be considered thoroughly before planning or implementing a system. It is always recommended to do thorough research and consider all alternatives for your water resource needs before committing to any option.

What follows is a summary of the situation and analysis that led the Vlahi Nature School to demonstrate rainwater harvesting and drip irrigation:

In the spring of 2008, the Vlahi Nature School created its first garden. While our design and methods were based on the principles of permaculture, we irrigated the garden using the same canal shared by all locals. The canal is a diversion from the XXXX river and this style of irrigation is typical for most of Bulgaria.

Essentially, gardens are designed so that when the canal is diverted to their plot the water flows through their crop rows, soaks the ground and sends excess water off the property. When finished watering, the owner then physically blocks the canal so that it diverts to an upstream user or carries on downhill.
Irrigation Canal - erosion visible

Almost immediately while using this system, we identified several critical problems. Some of the problems could be avoided by improving the irrigation canal approach, others, however, required a new solution.

1.1 Problem Analysis:

I. **Avoidable Problems**

a. **Conflict**

i. It is best for crops to be watered in the early morning or evening, thus most people want to use the canal at the same time. However, the canal is only sufficient for one person to water at a time. Despite these facts, there is no regulation or schedule for canal use. These facts combine to create frequent conflict.

ii. This could be avoided if a schedule were agreed upon and the water supply expanded. Examples of such schedules exist and the Municipality has loose plans to construct a reservoir. So, conflict over the canal could be reduced.

b. **Erosion caused by the canal**

i. As the river water travels in the canal to reach its users, the water naturally carries earth away with it. Thus, it is constantly eroding a fragile landscape (loose slopes prone to landslides) and often when overflowing it erodes away the village road. This is bad for the natural and social environments.

ii. An option to address this problem would be to enhance the canal by making it out of wood, concrete or pipe. This solution could be viable for the main line, but the many changing diversions might not be suitable for upgrades. Further, there is fear that materials used would be stolen. Ultimately, any upgrade would need to be maintained cooperatively, which is another challenge.

II. **Unavoidable Problems**

a. **Ecosystem damage**

i. As long as river water is diverted for irrigation, the river ecosystem will be impacted negatively. This is especially true in the hottest months when the water level is low. Further, as the river is already under severe stress from pumps and hydroelectric dams, any additional water diverted is significant.

ii. The only way to avoid this impact would be to draw canal water from another source, such as the proposed reservoir. However, this does not eliminate the stress, but merely shifts the stress from the river to the aquifer.

b. **Topsoil Erosion**

i. Although there are ways to avoid erosion caused by the main canal, erosion of topsoil in gardens is inevitable as long as villagers use the current technique. Essentially, they flood their gardens, carrying away valuable topsoil and often leaving unfertile soil or sand.

c. **Evaporation**

i. This style of irrigation leads to a great amount of water loss.

d. **Labor intensive**

i. Maintaining, diverting and controlling the canal is extremely labor intensive, especially for senior citizens.

1.2 Solution Analysis

Considering the variety and complexity of the problems, reconciled with our inability to fund a full solution for the whole community, **we chose to demonstrate rainwater collection for drip irrigation as a solution to the above problems.**

In simpler terms, we decided to install rain gutters to direct the rainwater from our roof to a large plastic reservoir. The water is stored and released to our garden via a drip irrigation system as needed. This system:

1. **Reduces conflict by**:
   - Reducing demand on the canal
   - Presenting a conflict-free model where every person could primarily rely on their own rainwater instead of the collective canal.
2. **Reduces erosion by:**
   - Eliminating the erosion caused by water being carried from the source to the garden. Water is transported from the reservoir to the irrigation hoses via an underground pipe.
   - Eliminating topsoil erosion caused by the current irrigation technique as drip irrigation nourishes the plants roots slowly, drip by drip, and thus does not cause erosion.
3. **Benefits the ecosystem by:**
   - Reducing stress on the river by drawing less water.
   - Reducing damage caused to the river by:
     - Runoff and erosion caused by heavy rains
     - Runoff and erosion caused by irrigation with the canal
4. **Conserves water by:**
   - Almost no water is wasted in the collection of rainwater and distribution of it through drip irrigation. Contrary to canal irrigation, your plants receive exactly as much water as needed exactly where it is needed.
   - By transporting rainwater from the roof to the reservoir to the plants with piping, very little water is lost in transit.
   - Finally, the system saves water by collecting a resource that was otherwise being unutilized.
5. **Dramatically reduces labor input:**
   - To operate a drip irrigation system, you simply open the flow of water with one lever and then open the flow to the individual hoses as needed with individual levers. After the installation there is no digging involved, you simply turn the water flow on and off.
   - The rainwater collection system is maintained with minimal labor. Filters must be cleaned and the system must be inspected, but, again, after installation, the system requires very little labor input.

For all of these reasons, we determined that rainwater harvesting would be an appropriate solution for the Vlahi Nature School. With the analysis completed, we moved on to designing our system.

2. Design, Goals, Resources

Goals: Once you have determined that rainwater harvesting is appropriate, the first step is to *consider the goals for your system.* You may want to collect a small amount of rainwater for decorative flowers, or you may want rainwater to meet all of the water needs for your household. The important task is to determine your exact goals for rainwater harvesting so that you move forward with a clear plan.

Our goal was to collect enough rainwater to be able to irrigate our garden throughout the drier months of June, July and August. Thus, our plan did not include drinking or washing with rainwater, so we were not concerned with maintaining potable rainwater.

This process can be done more precisely by calculating your exact water demand and then designing a system to meet it. If you want advice on this topic, please refer to the more detailed manuals listed in the Appendix.

Resources: Once you have your goal set, you must determine the resources available to meet that goal. We break the resources down into two categories:

1. **Natural**
   a. Clearly, the most important of which is rainfall.
   b. Your potential supply is calculated with the following equation:

      S = R x A x C

   Where: S= Avg. annual supply (m^3)
   R = Avg. annual rainfall in meters
   A = Area of catchment surface (m^2)
   C = Runoff coefficient – a figure used to account for rainwater lost. For a solid roof, typically 0.9 is used.
   c. Essentially, this is your limit. You cannot collect more rainwater than what falls on your collection surface in a year.
   d. On average we receive 1 meter of rainfall per year. Our collection surface is 165 m^2. So, accounting for the run-off coefficient, our maximum on an average year is about 15 m^3, which is our long-term storage goal.

2. **Financial / Material**
   a. Material
      i. In the process of determining what you need, it is good to see what materials you already have available. For example, if you have rain gutters installed, you are well on your way to harvesting rainwater.
      ii. The materials needed will be described in more detail in the following sections.
   b. Financial

i. This is often the other key limiting factor. The most expensive part of rainwater harvesting is the storage device, so your budget will largely determine your storage capacity.
ii. In our case, our goal was to store 15 m^3. However, our project budget only permitted for a 7 m^3 cistern. While not ideal, systems can always be easily expanded as budgets permit.

Design: Your final design will thus likely be a compromise between your goals and available resources.

3. Gutters: Catch the rain

Assuming you have a collection surface (roof), the first thing that must be considered is rain gutters. These are what concentrate, collect and deliver the rainfall from your roof. Therefore, they are essential if you want to efficiently harvest rainwater.

If you do not have gutters, then there are a few key considerations. First, you should plan your downspouts to be as close to your cistern as possible. This will ensure that the connection is simple and that rain is efficiently delivered. Second, the gutters should slope very slightly towards the downspout. This increases efficiency and reduces the chance for pools of water to form, which prevents insects from accumulating in your gutters.

In the event that you already have gutters and downspouts not planned for rainwater collection, modifications will likely have to be made. For example, if your house has four downspouts, it might be wise to close two or three of them and then use piping to direct the remaining downspout(s) to the cistern (as opposed to running pipes all around the building to one cistern).

Our steel gutters and primary downspout

We chose steel gutters that are readily available and most frequently used in Bulgaria. The major pros of these gutters are their strength and affordability. However, they are prone to corrosion and require welding to be properly connected.

There are many options for gutters, ranging from handmade to very expensive. For more details on gutter types, selection, sizing and specifics please refer to the manuals listed in the Appendix.

4. Cisterns: Store the rain

Perhaps the biggest consideration for any rainwater harvesting project is the reservoir, cistern or storage vessel:
Our cistern, insulation layer and foundation

The options for storing rainwater are limited only by your imagination and budget. While most people opt for an above-ground, pre-fabricated cistern like ours above, any sort of system that holds water can be used. With that in mind, here are the key categories:

1. Above-ground or underground:
   a. Cisterns can be above ground or built into the ground.
   b. The advantage to above ground storage is that you have natural pressure at the tap and it is generally less work. On the other hand, above-ground storage is exposed to the elements, meaning you must consider both heat damage, the possibility of freezing or cracking and accidental damage.
   c. Underground storage is usually not as susceptible to the elements (if it is deep enough it will both stay cool and not freeze). However, if the water is underground you will need a pump of some kind to use it (unless the underground storage was uphill from the point of use).
2. Handmade or Pre-fabricated
   a. The differences here are quite predictable. Pre-fabricated cisterns are the easier solution, however they can be more expensive than hand-dug or hand-built cisterns (depends on labor/material costs).
   b. Handmade cisterns are more customizable, but custom cisterns can also be very expensive.
3. Materials
   a. Cisterns can be fabricated from a variety of materials. Here is a list of commonly used materials. Each has its own pros and cons, details of which are available in the manuals referenced in the Appendix.
   Plastic; Steel; Earthen; Concrete; Clay; Wood.

<u>Placing the Cistern:</u>

Regardless of your intended use for rainwater, the placement of your cistern is a key consideration. Here are some major factors to plan:

1. Slope:
   a. If possible, locate the cistern at an elevation higher than where the water is needed. The more you utilize gravity, the less you rely on pumps and additional energy.
   b. Our cistern was placed in a way that the bottom of the cistern is at an elevation higher than the highest point in our garden. This enables our drip irrigation system to operate without a pump.
2. Exposure to elements:
   a. Especially in the case of plastic cisterns, you must find a way to guard it from direct sunlight. This prevents the plastic from degrading and protects your investment.
   b. If you live in a climate with consistent below freezing temperatures, you must also prepare to either drain the cistern in the winter or insulate/circulate it enough to not freeze.
   c. Generally, it is wise to hide the cistern for aesthetic reasons as well as to prevent it from being punctured by accident.
3. Foundation / Insulation
   a. For any above ground cistern you must first have a stable, level foundation. When designing a foundation, be sure to consider your plans for concealing and/or insulating the cistern.

b. In our case, we had a concrete foundation installed. This was the preferred method as the reservoir is located close to a steep decline.
c. To protect the cistern from the cold that will be absorbed by the concrete, it is wise to have a layer of insulation between the foundation and the cistern. Again, it is crucial to protect your plastic cistern as much as possible.
d. In the above picture of our cistern, you can see our concrete foundation and insulation layer.

Final Considerations:
Whether your cistern is custom built or manufactured, ideally there should be **at least three outlets** for water:

1. On the very bottom of your cistern there should be an outlet that can completely drain out all water. This is useful for cleaning, repairing, etc.
2. 20-30 cm above the first outlet should be the primary outlet. The water at the very bottom of the tank is dirtier and may contain bacteria, so an elevated tap provides access to better quality water.
3. Finally, you need an overflow outlet in case the rains exceed the capacity of your tank. An uncontrolled overflowing cistern could cause damage to the system or its foundation. Thus, it is important to control the flow of excess rainwater.

Catching rain in a 200 liter barrel from our second downspout. The barrel was overflowing in 5 minutes!

5. First-flush diversion and filters: Keep it clean!

In between rains, your roof or catchment surface will inevitably collect dust, leaves, droppings or other elements that you do not want in your cistern. Further, stored water attracts insects and critters of all kinds which can contaminate your collected rainwater. Thus, when making the connection between your gutters and cistern, it is very important to implement measures that prevent these problems.

First-Flush Diversion:
To address the first issue, we chose a simple method known as “first-flush diversion.” As you can see in the picture below, rain will not divert to the reservoir until the down pipe is filled with water. This way, the rainwater that is dirty after “washing” the roof collects in the down pipe, not the reservoir.
First-flush diversion

The pipe has a slow drip which enables it to be primarily self-cleaning. At the bottom there is plug that can be removed
for a complete cleaning of debris.

The exact amount you should divert depends on many factors. The two main things to consider are the goals for your stored water and your local site conditions. So, for example, if your collection surface does not get very dirty and your only goal is irrigation, then the first-flush may be simply to keep your tank clean. However, if your collection surface is often covered with leaves, birds, dust or soot and you want to collect

rainwater for drinking, then you should divert a substantial amount. It all depends on your situation.

Beyond volume, you can also take extra measures to ensure your tank receives as clean water as possible. In the first-flush system, you can install a "floating-ball" in the pipe that will rise as the pipe fills. Thus, when the pipe is filled, the ball creates a seal which prevents the clean water from mixing with the dirty diverted water. There are many options, both manufactured and handmade for first-flush diversion. All of the manuals listed in the Appendix address this topic.

Filters:
Stored water attracts insects, reptiles, animals and many other things that will contaminate your rainwater. To keep them out while letting rainwater in you need to install and clean filters.

We have filters at 3 points, all of which are to prevent access to stored water – both in the tank and in the first-flush device.
Unless the connection from your gutters to your tank is sealed, it is absolutely critical to have a screen barrier on the opening of the tank. This filter should be sized to prohibit mosquitoes and must be regularly cleaned.
Rainwater passing through our screen filter into the cistern

We have also installed a filter in between our rain gutters and the first-flush diversion. The purpose of this filter is two-fold. First, it prevents any larger objects such as leaves from accumulating in our first-flush diversion. Typically, coarse filters are placed in rain gutters to prevent this kind of accumulation. However, if a filter is blocked in your gutters, it is very difficult to clean. Thus, we chose to have the primary filter closer to the ground.

Second, this filter prevents any insects or reptiles from accumulating in the first-flush diversion pipe. We noticed that in between rains, if we did completely empty the pipe, bugs would accumulate. The filter solved this problem and ultimately keeps the filter on the tank cleaner.

Finally, as discussed in the previous section, we have placed a small screen filter on our overflow outlet. Again, the purpose is to prevent insects like mosquitoes from entering the tank.

Final Note:
If first-flush diversion and several filters seem like a lot of maintenance, it is wise to consider the alternative: a cistern full of dirty water, hazardous insects and dangerous bacteria. Cleaning a few filters is **much** easier than cleaning the whole tank and **much better** than losing a season's worth of collected rainwater because of contamination.

Since this is the trade-off, ensuring the cleanliness of the water in your tank is a crucial consideration.

Rainwater passing through the filter into the first-flush diversion

6. Outlets: Control the rain!

Once you have clean water in your tank, then it's time to use it! Finally, after all that planning and building, you can finally "control the rain!"

As stated above, our goal for collecting rainwater was to use it for irrigation. To facilitate this we purchased and assembled a professional drip irrigation system. This system is essentially a series of pipes and hoses. Two buried pipes (reservoir to filter; filter to irrigation rows) deliver the water from the cistern to the irrigation row outlets. The outlets – each with its own on/off lever – then carry water to the specially designed drip irrigation hoses that water the garden. Due to the placement of the cistern, even the highest rows can be irrigated without the use of a pump.

To learn more about drip irrigation, it is best to contact a distributor or someone with experience using this technology.
Trench dug for the pipe that connects the cistern to the irrigation hoses

Irrigation row outlets – connected to buried pipe – drip irrigation hoses not attached. Each row has its own on/off lever.

Here you can see the pipe from the reservoir connected to the filter; the filter then connects to a horizontal buried pipe; from this buried pipe come the outlets which then connect to the drip hoses (visible)

7. Final Considerations

Final Considerations:
Although it has been mentioned indirectly, in every step you must consider your local climate conditions. They will determine how much rain you have, the length of your dry season and what kinds of extreme weather you must prepare for. The cold can destroy almost every part of your system if water is left to freeze and direct sunlight can drastically shorten the life of any above-ground plastic parts. Like anything, if you want the system to work and to last, it must be maintained and well-managed.

The last point to make about harvesting rainwater for drip irrigation is that there is no one way to do it and you must adapt your system to your situation. If you want to drink your rainwater, you will need a very different system than the one outlined above. Or, if you don't want to store rainwater, but simply direct it, then you will need to focus more on landscape architecture. Every system, like every situation, will be different.

Conclusion:
Rainwater harvesting, when done appropriately, is a powerful tool for people and the planet. With a small upfront investment, it can solve many water resource problems while saving energy. However, if implemented poorly or mismanaged it can create a serious

health hazard and waste precious resources. That said, while we have covered the basics, if you are interested in harvesting rainwater, you are advised to find as much information as you can on these topics. A good place to start is the resource list on the next page.

Taking control of your water resources by harvesting rainwater is very rewarding. If you live in a water-stressed community, you can feel more secure knowing that you have a renewable reserve of this vital resource. And, after all the work you put in to implement your system, you may find that rainy days are now a cause for celebration!

Finally, if you have any questions, please contact us at the address provided above. Of course, it's even better if you stop by to ask us in person by paying a visit to the Vlahi Nature School!

The Vlahi Nature School

Appendix: Resources for Further Reading

- Luong, T.V.*Harvesting the Rain: A Construction Manual for for Cement Rainwater Jars and Tanks.* UNICEF East Asia and Pacific Regional Office. Bangkok, Thailand: 2002. Accessed at: http://www.unicef.org/eapro/activities_3703.html
  - This free manual explains step-by-step how to make low-cost hand-made rainwater collection systems. It thoroughly explains different options for tanks and gutters, as well as provides technical specifics. Emphasizes low-cost.

- Raw, David. "DIY Guide to Healthy Rainwater Tanks." ABC Tasmania: 2007. Accessed at: http://www.abc.net.au/tasmania/stories/s1402901.htm; Download manual at: http://www.abc.net.au/tasmania/stories/David_Raws_m1343991.pdf
  - An excellent, short, free document on how to modify your rainwater harvesting system to ensure that it is clean and healthy. Excellent visual descriptions.

- Texas Water Development Board. *The Texas Manual on Rainwater Harvesting, 3rd Edition.* Austin, Texas: 2005. Accessed at: http://www.twdb.state.tx.us/publications/reports/RainwaterHarvestingManual_3rdedition.pdf
  - This free manual goes into great detail about every step involved in rainwater harvesting. It is recommended as on of the best guides on the topic. Includes calculation rubrics, diagrams, costs and many examples of rainwater harvesting.

- United Nations Environment Programme. *Rainwater Harvesting: A Lifeline for Human Well-being.* UNEP and the Stockholm Environment Institute, Nairobi, Kenya: 2009. Accessed at: http://www.unep.org/Themes/Freshwater/PDF/Rainwater_Harvesting_090310b.pdf
  - This manual is less technical and focuses more on the relationship of rainwater harvesting to ecosystems and social environments. Provides excellent insight into the importance of rainwater harvesting, potential drawbacks, and examples of rainwater harvesting from around the world.

- Waterfall, Patricia H. *Harvesting Rainwater for Landscape Use*. University of Arizona Cooperative Extension: 2006. Accessed at: http://www.azwater.gov/dwr/Conservation/files/Harvesting_Rainwater.pdf
  - A free manual with a focus on harvesting rainwater for irrigation. Includes a focus on landscape architecture not present in other manuals. Also provides many worksheets for calculating supply and demand, as well as many images of creative rainwater harvesting techniques.

- Worm, Janet and Van Hattum, Tim. *Agrodok 43: Rainwater Harvesting for Domestic Use*. Agromisa Foundation and CTA, Wageningen, The Netherlands: 2006. Accessed at: http://www.agromisa.org/agrodoks/Agromisa-AD-43-E.pdf
  - Thorough manual on rainwater harvesting. Several examples of low-cost tank construction methods, explanations on the development and design process, as well as information on calculations, system maintenance, etc.