Rainwater Harvesting Calculator Description and Algorithm

Caminos de Agua
December 16, 2016
www.caminosdeagua.org

Overview

This online tool allows users around the world to determine the adequate **roof area** and **cistern volume** for harvesting rainwater for their households' **essential water need**. It does so by collecting information from the user including location or monthly rainfall, household size, roof size, and roof type.

If you have any other questions feel free to contact us or checkout our websites in Spanish or English for more information.

Let's start by taking a look at the calculator's inputs.

Inputs

Essential water need & household size

We define **essential water consumption** as water that needs to be both safe and healthy. In most situations, the only water that needs to be safe and healthy is water that people consume. This usually includes water for (a) drinking and (b) cooking. For just drinking and cooking, we use a global average of **5 liters/day** for each person in a household (above the 2.5 to 3 liters/day recommended for survival situations by the WHO).

However, if a user lives in a part of the world where the water contains toxins that can be ingested in other ways – mercury can be absorbed through skin-contact, for example – the assumption of *5 liters/day per person does NOT apply* because people need safe and healthy water for other uses besides drinking and cooking. In this case, this calculator is not appropriate, until we add the ability to enter the per person consumption.

We multiply the **5 liters/day** per person daily consumption the given household size to get liters consumed in the household each day.

Monthly rainfall

This calculator was built to serve the Independencia Watershed region in Guanajuato, México. If a user lives there, they can simply select their region on a map, and the calculator knows their monthly rainfall based on local data from SMN. However, this calculator is also useful outside of Guanajuato or México. If a user can find or approximate their average monthly rainfall, they can enter it and the calculator will still spit out their rainwater harvesting system sizing.

The question arises, why monthly rainfall? Why not daily? Or annual? Average daily rainfall is highly variable. Except for places with monsoon/dry cycles (where it rains almost daily during monsoon season and almost never for the rest of the year) daily rainfall is hard to predict more than a few days in advance and you need hard-to-find data over many years for the average effects to dominate. Annual rainfall, on the other hand, is too sparse of a metric. Simply knowing annual rainfall doesn't help us understand the spread of the rain – does 100% of the rain come on the week of April 17th? Is the rain evenly distributed through the year? Does it mostly sprinkle in the spring, but pours in the winter? Annual rainfall can't answer any of these questions. For this calculator, *we aim to size systems to store enough rainfall in the wetter parts of the average year to sustain their households through any dryer seasons*. Therefore, we use monthly rainfall.

Roof area

We ask users to provide their roof's length and width from which we calculate the roof's area. Area is necessary to calculate the volume of water that may be collected. We define area NOT as the surface area of the roof, but rather the flat projection of the roof on the top of the house. This comes from the assumption that the rain is falling vertically from the sky. This assumption implies that a steeply sloped roof with huge area is identical for capturing rain as an approximately flat roof with the same footprint. If you live in a place with frequent high winds, this assumption may not be valid, so be careful using this calculator if you live in a place with high winds and have a steeply sloped roof!

Roof type

Different types of roof have various water-collection efficiencies. We have listed the three types of roof most common in Guanajuato: (1) concrete, (2) corrugated sheet, and (3) Spanish tile. These roofs have the following respective efficiencies: (1) 0.85, (2) 0.9, (3) 0.8 liters collected for each liter fallen. For example, this means that if 100 liters fall on a concrete roof, the maximum that you can collect is 85 liters. If your roof is not listed here, please choose the least efficient (Spanish tile) for a conservative estimate or get in touch with us and we can do a bit of research and add your roof type.

Next, we'll take a look at the different outputs the calculator provides.

Outputs

Annual water need

Your household's annual water need. Calculated by multiplying **5 liters/day** times the **number of people in your household** by the **number of days in the year** (365).

Minimum roof area

The minimum roof area is the area of roof required to meet your household's essential water use for the entire year, based on the average year's rainfall. If this minimum is smaller than your actual roof, you're good to go!

Minimum cistern volume

This is the minimum volume of a cistern required to collect 100% of the water coming off of your **minimum roof area**. This volume of cistern will provide adequate safe and healthy drinking water – when combined with biological post-treatment – for the user's household for the entire average year.

Your current annual maximum water collection

The amount of water your household can collect off of your current roof in a year. This is calculated by month by month using the algorithm detailed below. Then the months are summed together.

Note: sometimes this number could be larger than your **annual water need**, *without meeting that need*. This could happen with an uneven rain distribution through the year (for example if most of the rain comes at the end of the year, even though you end the year with an excess, you may not have had enough rain earlier).

Your current roof area

This is the area of your specified roof. Again, as mentioned in the **roof area** section above, this is the projected area on the top of the house. Please see that section for more details. **Actual roof area** is calculated, perhaps obviously, by multiplying together the roof's length and width.

Required cistern volume using your current roof

This is the minimum cistern volume a household would need to collect 100% of the water that's coming off of their **actual roof area**. If the **actual roof area** is much larger than the **minimum roof area** then this number is not terribly important. But if their roof is too small to collect adequate water (**minimum > actual)** then this provides a decent starting point.

For the algorithm we use to calculate the above quantities, take a look at the next section and the following example.

Algorithm

Once it has all the inputs, the calculator does two calculations: the **current roof area calculation** and the **minimum roof area calculation.** Both calculations use the same algorithm for calculating cistern size. We'll call this the **rain-to-collect algorithm.** Let's take a look at this algorithm first:

Rain-to-collect algorithm

Arguments: household size, daily per-person consumption, roof area, monthly rainfall, roof efficiency.
Returns: cistern volume.
Algorithm: Starts in the month that begins the rainy season (we use June if you're in the Independencia watershed, otherwise the calculation begins during your rainiest month) and first calculates the household's monthly use and the monthly collection from equations (1) and (2) respectively:

$$Consumption_{householdMonthly} = Consumption_{individualDaily} \times People \times Days_{month} \quad (1)$$

$$Collection_{month} = Rainfall_{month} \times Area_{roof} \times Efficiency_{roof} \quad (2)$$

where the subscript “individual” refers to the average individual in the household, “month” indicates “per month” and “household” means “for the entire household for the month.” The efficiency in equation (2) depends on the type of roof used. With the monthly household collection and consumption, we then calculate the inventory, the amount of extra water stored at the end of the month, with the following equation:

$$Inventory_{month} = Collection_{month} - Consumption_{month} \quad (3)$$

Note that this assumes that there is no water collected during the previous month. For each subsequent month, we follow the same process, but to calculate inventory, we include the extra inventory from the previous month, calculating inventory with:

$$Inventory_{month} = (Collection_{month} - Consumption_{month}) + Inventory_{month-1} \quad (4)$$

This allows each household to account for how much water they save during the rainy season(s) and how much they deplete their reserves during the dry season(s). The cistern volume that the algorithm returns is the maximum inventory value. In other words, the maximum liters of water that a household will ever need to store at the end of a month.

This algorithm can be applied to any roof or household size and is the fundamental algorithm underlying our calculator. For the specifics of how we apply it to real households, please see the following two sections and the example.

Current cistern volume calculation

To calculate the actual volume of a cistern required to collect 100% of the rainwater that strikes a household's roof, we apply the above algorithm (see **rain-to-collect algorithm** section) with the user's entered household size and roof area.

We want these households to always have a supply of safe, healthy water, which means we never want their cisterns to go dry. During an average year (which this calculator is based on) if a monthly inventory is ever zero, this implies a dry cistern. If the cistern is never dry, then the provided roof size should be adequate to support the household's essential water use on the average year. Otherwise, it is too small.

In the case where the actual roof is too small: we provide the user with one of the following two numbers: The cistern volume could be (1) the volume returned by the algorithm or (2) the maximum number of liters that the house could collect on the rainiest month, assuming they don't use any. We always provide the greater of these two numbers to the user, because often when the provided roof is too small, option (1) yields a volume that is impractically small.

Minimum cistern volume calculation

To calculate the minimum volume required for a cistern (and the associated minimum area required by a roof), we begin with a roof of 1 square-meter. Using that, and the rest of the user-specified arguments, we calculate the required roof size. Then we check the inventory. If the inventory is 0 anywhere (i.e. the cistern goes dry at some point), we increment the roof surface area by 1 square-meter (from 1 to 2, from 2 to 3, from 3 to 4, etc.) and re-calculate the inventory and cistern volume. Once the cistern stays full year round (inventory is never 0 liters), we've achieved the minimum surface area of roof. The corresponding cistern size is the minimum cistern volume required. For an example of how the

calculator follows this algorithm to calculate a minimum tank size, see the following section.

Example calculation (minimum-size)

Start with 1 m^2 of roof area.
Calculate the amount of water collected in June (the 1st month of the rainy season in Guanajuato), based on location and roof size and type. **(A)**
Calculate the amount of water used in June, based on number of people. **(B)**
Subtract: (A) – (B) = Inventory, amount of water stored in June. **(C)**

Move to July:
Calculate the amount of water collected in July, based on location and roof size and type. **(D)**
Calculate the amount of water used in July, based on number of people. **(E)**
Subtract: (D) – (E) = Inventory, amount of water stored in July, from July rainfall only. **(F)**
The inventory at the end of July is (C) + (F). **(G)**

Move to August:
Calculate the amount of water collected in August, based on location and roof size and type. **(H)**
Calculate the amount of water used in August, based on number of people. **(I)**
Subtract: (H) – (I) = Inventory, amount of water stored in August, from August rainfall only. **(J)**
The inventory at the end of July is (G) + (J). **(K)**

Continue this process through all the months. Once you reach December, return to January. We begin in June at the beginning of the rainy season in Guanajuato, México, so that the cistern has a chance to fill completely before the winter's dry season.

Remember, this is all based on a 1 m^2 roof area. After you've completed all 12 months, you have an inventory at the end of each month [for example, (C), (G), and (K)] . If any of these are 0, your cistern will go dry during the average year. NOT GOOD! That means that 1 m^2 of roof isn't enough to support your needs.

Increase the roof area to 2 m^2 and repeat the entire above process. If 2 m^2 still isn't adequate, increment the roof size again (to 3 m^2) and repeat! Continue this process until your roof is sufficient to support your family on the average year (i.e. all twelve inventories are non-zero). This roof size is your **minimum required roof area**.

To calculate your **minimum cistern volume**, go back through your list of the inventories at the end of the twelfth month. Take the maximum value from that list. This is the **minimum cistern** volume, the cistern volume required to capture 100% of rain that falls on your minimum required roof area, to support your household's drinking and cooking water needs *during the average year.*

Enjoy your own harvested safe and healthy water for drinking and cooking – after any biological treatment step!