RAINFLOWER

The Science of Catching Rain

A Student Whitepaper on the Mathematics Behind the

Rainwater-Collection Simulator

Written for students in grades 9–12

How four green leaves, a little geometry, and one rule about rainfall add up to a glass of clean water.

Contents

1. What This Paper Is About

Clean drinking water is not equally easy to reach everywhere in the world. In many places it rains heavily for part of the year, yet families still struggle to store enough safe water. The Rainflower is a small device, shaped like a potted plant, that catches rainwater on four leaf-shaped paddles and funnels it down into a container. It is designed to be beautiful enough to keep on a balcony or in a courtyard, and useful enough to matter.

Alongside the physical device there is an interactive simulator: a web page where you can change things — the size of the leaves, how many leaves there are, the tilt angle, the city, how much it rains — and immediately see how much water the device would collect. This whitepaper explains the science and the mathematics running quietly underneath that simulator.

Our goal is not to hand you a finished formula to memorize. It is to build the reasoning up slowly, so that by the end you could re-derive every number the simulator shows and — just as importantly — you could argue with it. A good model is honest about what it does not know, and we will point out those places clearly.

> **Before you read on**
>
> Open the simulator in another window if you can. This paper is written to be read with the tool nearby. Every time we derive a formula, change that value in the simulator and watch the result move. Reading about a model and playing with a model teach different halves of the same idea.

2. The Big Picture: Turning Rain Into a Number

Let us look at the whole journey, from sky to glass, before zooming in on any single step. When rain falls on the Rainflower, four things decide how much water ends up stored:

1. How big the leaves are.
2. How they are tilted toward the falling rain.
3. How much rain actually falls where the device is.
4. How much of that caught water survives the trip into storage — some always splashes or leaks away.

The simulator combines these into a single chain of multiplication. In plain words, before any symbols:

```
water collected  =  catching area  ×  rainfall  ×  efficiency
```

Almost everything else in this paper just carefully unpacks what each piece means, why they multiply, and where the numbers come from. Let us take them one at a time.

3. Rainfall: What Does “265 Millimeters” Actually Mean?

Weather reports describe rain in millimeters. You might hear that a city gets “265 mm of rain in August.” That feels strange at first. Rain is a volume of water, so why measure it with a ruler, in millimeters of length?

Here is the key idea. Rainfall is measured as a depth: if all the rain that fell simply stayed where it landed and did not soak in, run off, or evaporate, it would form a layer of water. The depth of that imaginary layer is the rainfall. So 265 mm of rain means every flat surface out in the open collects a sheet of water 265 mm deep over the whole month.

> **The one rainfall rule you must believe**
>
> **1 millimeter of rain = 1 liter of water on every 1 square meter of flat ground.**
>
> This single fact is the bridge between weather and water. Everything the simulator computes rests on it, so it is worth proving to yourself.

Why one millimeter over one square meter is exactly one liter

Picture a square on the ground, 1 meter by 1 meter. Let rain fall on it until the water is 1 millimeter deep. The shape of that water is a very thin box (a rectangular slab). Its volume is length × width × height:

```
V = 1 m  ×  1 m  ×  1 mm
```

To multiply these we must use the same units. One millimeter is one-thousandth of a meter, so 1 mm = 0.001 m. Then:

```
V = 1 m × 1 m × 0.001 m = 0.001 cubic meters
```

A cubic meter of water is 1000 liters — that is the definition of the liter, one-thousandth of a cubic meter. So 0.001 cubic meters is exactly 1 liter. The rule is not a coincidence or an approximation; it falls straight out of how the metric system was built. That is one of the quiet gifts of metric units: the water math comes out clean.

Where the simulator's rainfall numbers come from

The simulator focuses on Bangladesh, a country with a dramatic monsoon season and a real need for household water solutions. For each city, the monthly August rainfall was gathered from several independent weather sources and then averaged, because no two sources agree exactly. The table below shows the built-in starting values. Notice the last column: the honest spread between the lowest and highest source. Dhaka's sources ranged from 106 mm all the way to 337 mm — a reminder that “average rainfall” is a summary of messy, variable reality, not a guarantee.

City	Avg August rain (mm)	Rainy days	Storm rate (mm/hr)	Source range (mm)
Dhaka	265	15	12	106 – 337
Chittagong	570	20	16	414 – 774

City	Avg August rain (mm)	Rainy days	Storm rate (mm/hr)	Source range (mm)
Sylhet	530	17	18	308 – 641
Cox's Bazar	620	21	17	single source
Khulna	330	16	12	300 – 350
Rajshahi	340	18	13	340 – 345
Rangpur	480	22	14	480 – 484
Barisal	380	20	14	335 – 425

Every one of these numbers is a starting point, not a fixed truth. In the simulator you can drag the rainfall slider to any value. That is deliberate: a model you cannot question is a model you cannot trust.

4. Catching Area: Why a Tilted Leaf Catches Less

The rainfall rule tells us how much water lands on a flat square meter. But the Rainflower's leaves are not lying flat on the ground, and they are certainly not one square meter each. So we need two things: how big is a leaf, and how does tilting it change how much rain it catches?

The size of a leaf

Each leaf is roughly an ellipse (a stretched circle). The simulator offers three standard sizes and also lets you slide smoothly to any size up to 100 square centimeters. Here are the three presets:

Leaf size	Length (mm)	Width (mm)	Surface area (cm^2)
Small	90	32	16.3
Medium	120	42	28.5
Large	155	55	48.2

The medium leaf is the reference: it matches the real leaf on the 3D model of the device. When you slide to a custom size, the simulator keeps the leaf's shape and simply scales it, which is why length and width grow together rather than one at a time.

The important twist: rain falls straight down, but leaves are tilted

Imagine holding a paper plate flat, facing straight up at the sky. It catches the most rain possible for its size. Now slowly tilt the plate. As it tilts, the raindrops — which fall almost straight down — see a smaller and smaller target. When the plate is nearly vertical, like a wall, rain barely lands on it at all. The plate has not changed size. What changed is the size of its shadow on the ground.

Key insight

> Falling rain does not care about a leaf's true surface area. It only cares about the leaf's **projected area** — the size of the flat shadow the leaf would cast if a light shone straight down from above.

Finding the shadow with trigonometry

This is where geometry earns its keep. Let the leaf's true surface area be A, and let θ (the Greek letter theta) be the angle the leaf is tilted away from flat. A leaf lying flat has θ = 0°. A leaf standing straight up has θ = 90°. The projected area — the shadow — turns out to be:

$$\text{projected area} = A \times \cos(\theta)$$

The cosine function is exactly the tool for shadows. Here is why, without hand-waving. Tilt a flat strip by angle θ. Draw the side view: the strip is the hypotenuse of a right triangle, and its shadow on the ground is the horizontal side next to the angle θ. From basic trigonometry, the side adjacent to an angle equals the hypotenuse times the cosine of that angle. Apply that to every thin strip making up the leaf, add them all up, and the whole leaf's shadow is its area times cos(θ).

Let us sanity-check the two extremes, because a formula you can test at its edges is one you can trust in the middle:

- Flat leaf, θ = 0°. Then cos(0°) = 1, so projected area equals the full area — a flat leaf catches everything it can. ✓
- Vertical leaf, θ = 90°. Then cos(90°) = 0, so projected area is zero — a leaf standing straight up catches no rain, like a wall in a vertical downpour. ✓

Both match everyday intuition, which is a good sign. In between, cosine slides smoothly from 1 down to 0.

Tilt angle θ	cos(θ)	Fraction of rain caught
0° (flat)	1.00	100%
30°	0.87	87%
45°	0.71	71%
60°	0.50	50%
80°	0.17	17%
90° (vertical)	0.00	0%

This gives a slightly surprising conclusion: to catch the most rainwater, flatter leaves are better. A leaf at 30° catches more than one at 60°. So why tilt the leaves at all? Because a real device must do more than catch water — it has to drain toward the center, shed dust and debris, and stay stable in wind. Steeper leaves drain faster and clog less. The tilt angle is a compromise between catching and draining, exactly the kind of real-world trade-off the simulator lets you explore.

5. Efficiency: The Honest Discount

So far our reasoning has been perfect — too perfect. In an ideal world, every drop that lands on the projected area would slide neatly down into storage. The real world is messier. Drops splash back off the surface. Water sheets over the edges before it reaches the channel. Films of water cling to the leaf and evaporate. Wind blows some of the catch away entirely.

Rather than try to model each of these losses separately — which would need wind speed, surface texture, drop size, and more — the simulator bundles them into a single number called the collection efficiency, written as a percentage. An efficiency of 85% means that, on average, 85 out of every 100 drops that land actually make it into storage. The default is 85%, and you can adjust it.

> **What efficiency is, and what it is not**
>
> Efficiency is a deliberate simplification — a single knob standing in for many complicated, hard-to-measure losses. It makes the model usable without a weather laboratory. But because it is a guess, it is also the number you should treat with the most caution. If the simulator's prediction ever feels too optimistic, the efficiency setting is the first place to look.

Efficiency enters the chain as a simple multiplier. If the geometry-and-rainfall part says a leaf would catch 10 liters in a perfect world, then at 85% efficiency it actually delivers 10 × 0.85 = 8.5 liters. Multiplying by a number less than 1 always makes the result smaller, which is exactly what a loss should do.

6. Putting It Together: The Master Formula

We now have all three pieces. Let us assemble them into the formula the simulator actually uses, then walk one complete example by hand.

For a single leaf of surface area A tilted at angle θ, catching a rainfall depth R, at efficiency E, the water collected is:

```
water = A × cos(θ) × R × E
```

A device has more than one leaf — the Rainflower has four — so we multiply by the number of leaves, N. And if you deploy several devices, D of them, we multiply again. The full expression is:

```
total water = D × N × A × cos(θ) × R × E
```

It looks like a lot of symbols, but every one is something you now understand. Reading it left to right: how many devices, times how many leaves each, times how big each leaf is, times how much the tilt shrinks the catch, times how much rain falls, times how much survives the trip. A chain of honest multiplications.

A worked example, step by step

Let us compute the water one device collects in a Dhaka August, using the default settings. Our inputs:

- Leaf size: medium, so $A = 28.5\ \text{cm}^2$
- Number of leaves: $N = 4$
- Tilt angle: $\theta = 45°$, so $\cos(\theta) = 0.71$
- Rainfall: $R = 265$ mm
- Efficiency: $E = 85\% = 0.85$

Step 1 — Fix the units. Our rainfall rule is written in meters and square meters, so we must convert the leaf area from square centimeters to square meters before combining. There are 10,000 square centimeters in a square meter, so:

$$A = 28.5\ \text{cm}^2 \div 10{,}000 = 0.00285\ \text{m}^2$$

Why this matters: mixing cm^2 with a rule written for m^2 would make the answer wrong by a factor of ten thousand. Unit care is not busywork; it is the difference between a cupful and a bathtub.

Step 2 — Shrink for the tilt. Multiply the true area by cos(45°) to get the projected (shadow) area of one leaf:

$$0.00285\ \text{m}^2 \times 0.71 = 0.002015\ \text{m}^2$$

Step 3 — Count all four leaves. Multiply by $N = 4$ to get the device's total catching area:

$$0.002015\ \text{m}^2 \times 4 = 0.00806\ \text{m}^2$$

Step 4 — Bring in the rain. Now use the rainfall rule. Each millimeter of rain delivers 1 liter per square meter, so multiply the catching area (in m^2) by the rainfall (in mm) to get liters:

$$0.00806\ \text{m}^2 \times 265\ \text{mm} = 2.14\ \text{liters}$$

Step 5 — Apply the honest discount. Finally multiply by the efficiency, 0.85:

$$2.14\ \text{liters} \times 0.85 \approx 1.82\ \text{liters}$$

Result

One four-leaf Rainflower with medium leaves, tilted at 45°, collects about 1.8 liters of water over an average Dhaka August. That is roughly seven and a half glasses of water (at 250 mL a glass) from a single small device — from leaves that together are smaller than a paperback book.

If this number feels small, that instinct is worth keeping. A single small device is a modest catcher. The next two sections are about the two honest ways to collect more: more leaves, and more devices — and one clever finding about which choice uses space better.

7. Changing the Number of Leaves

The Rainflower is built with four leaves, but the simulator lets you explore what would happen with five, six, seven, or eight. Look again at the master formula and find the letter N, the number of leaves. It sits in the chain as a plain multiplier, which tells us something immediately: doubling the number of leaves doubles the catching area, and therefore doubles the water — as long as the leaves stay the same size and angle.

This is called a linear relationship: the output changes in direct proportion to the input. There is no hidden bonus for adding leaves and no penalty; each extra leaf pulls its own weight and no more. The table shows the effect, keeping every other setting at the Dhaka default:

Leaves per device (N)	Water per device, per month	Compared with 4 leaves
4 (as built)	1.82 L	— baseline
5	2.27 L	+25%
6	2.72 L	+50%
7	3.18 L	+75%
8	3.63 L	+100% (double)

Notice the pattern in the last column: +25%, +50%, +75%, +100%. Going from 4 to 8 leaves is a doubling of leaves, and the water doubles too — exactly what a linear relationship promises. You can predict any of these without the simulator: eight leaves is $\mathbf{8/4 = 2}$ times the four-leaf catch, so 1.82 × 2 = 3.63 liters.

An honest note about the 3D model

The real device has exactly four leaves, and the 3D model always shows those four — it never draws extra petals, because a crowded ring of added leaves would misrepresent the actual product. When you ask for more than four, the extra leaves are still counted fully in the mathematics, and a short line beneath the model says so, for example “4 real leaves + 2 simulated leaves.” The five-to-eight-leaf case is a “what if” for exploring the numbers, not a product that ships today. A model should never quietly pretend, so the simulator keeps the picture honest and states plainly where the extra leaves live.

8. More Devices, and the Space They Need

The other way to collect more water is simply to use more devices. In the master formula this is the letter D, and like N it is a plain multiplier: ten devices collect ten times what one device collects. The simulator frames a cluster as “one mother flower plus its children,” a friendly way to picture a family of devices sharing a rooftop or courtyard.

But devices take up floor space, and two devices cannot stand in the same spot. So the simulator also estimates the ground each device needs. When the leaves extend outward, they sweep out a circle. The width of that circle — its diameter — is called the span, and the ground the device occupies is the area of that circle.

The area of the swept circle

The area of any circle is π times its radius squared, where the radius is half the diameter. If the span (full width) is measured across the device, then:

$$\text{footprint} = \pi \times (\text{span} \div 2)^2$$

For a medium-leaf device at 45°, the leaves reach out far enough to make a span of about 278 mm, which is 0.278 m. Half of that is 0.139 m. Squaring and multiplying by π:

$$\pi \times (0.139\ \text{m})^2 \approx 0.061\ \text{m}^2$$

So one device occupies about 0.06 square meters of ground — a little smaller than a standard doormat. Ten such devices, which cannot overlap, need about 0.6 m^2 of floor. The simulator translates these areas into friendly comparisons — doormats, ping-pong tables, parking spaces — so the space cost feels real.

9. A Subtle Question: What Is the “Best” Leaf Size?

Here the simulator reveals something genuinely interesting, and it is worth slowing down for. There are two different ways to ask whether a leaf size is “good,” and they give different answers.

Water per unit of leaf material

Suppose you care about how efficiently the leaf material itself is used — water collected divided by the area of leaf you had to build. Because water collected is directly proportional to leaf area (bigger leaf, proportionally more water), this ratio never changes. A small leaf and a large leaf collect the same amount of water per square centimeter of leaf. In the simulator this figure sits stubbornly flat no matter how you drag the size slider. Doubling the leaf doubles both the water and the material, so their ratio holds constant.

Water per unit of ground space

Now ask a different question: how much water do you collect per square centimeter of floor the device occupies? This ratio does change with size — and it rises as the leaves get bigger. The reason is geometric and rather elegant. The water a leaf catches grows with its area (think of it as growing with length × width, a two-dimensional quantity). But the ground the device sweeps grows mainly with how far the leaf reaches outward (a length, closer to one-dimensional). Because area outpaces reach as things scale up, larger leaves collect more water for each patch of floor they stand on.

Leaf area (cm^2)	Water / month (L)	Water per cm^2 of ground
16.3 (small)	1.04	lower
28.5 (medium)	1.82	↑
48.2 (large)	3.07	↑↑
100 (max slider)	6.37	highest

The takeaway

If floor space is your scarce resource — a small balcony, a crowded rooftop — larger leaves are the more space-efficient choice. They collect more water for the same footprint. This is the kind of insight that only appears when you separate two questions that sound the same but are not: efficient use of *material* versus efficient use of *space*. The simulator surfaces both so you can decide which one matters for your situation.

10. From Liters to Glasses: Making the Number Human

A number like "1.82 liters" is precise but hard to feel. To make results meaningful, the simulator translates liters into everyday quantities. Each translation is just a division — splitting the total water into equal, familiar portions.

Glasses of water

If one glass holds 250 milliliters (0.25 liters), then the number of glasses is the total water divided by the size of one glass. For our 1.82-liter result, converting to milliliters first:

$$1.82\ \text{L} = 1820\ \text{mL}, \quad \text{then} \quad 1820\ \text{mL} \div 250\ \text{mL} \approx 7.3\ \text{glasses}$$

People given a day's drinking water

Health guidance often suggests a person drinks on the order of eight to twelve glasses of water a day. The simulator lets you set both the glass size and the glasses-per-day, then multiplies them to find one person's daily need, and divides the collected water by that. Because you control both inputs, the model stays internally consistent — change the glass size and every downstream count updates with it, so the parts never contradict each other.

Why these conversions are honest

Every "human" number — glasses, bottles, people, days — comes from dividing the same carefully-built water total by a portion size you can see and change. Nothing new is invented in the translation. If you distrust a friendly figure, you can always trace it straight back to the liters, and the liters back to the geometry and the rain.

11. What the Model Does Not Know

A trustworthy model wears its limitations openly. Here are the main ones, so you can read every result with the right amount of salt.

- **Efficiency is a single guess.** Real losses depend on wind, surface texture, drop size, and how the device is built. The 85% default is reasonable, not measured. Treat predictions as estimates, not promises.
- **Average rainfall hides variation.** A month's rain does not arrive evenly. One enormous storm can overflow a small container while the monthly average looks calm. The simulator computes totals, not the timing of individual storms.
- **Filtering and storage losses come later.** The model estimates water caught, not water made safe to drink. Real systems lose a little more to first-flush diversion and filtering, which the simulator does not subtract.
- **Leaves are treated as clean flat catchers.** Dust, leaves, bird activity, and partial clogging all reduce real catch. The projected-area model assumes an unobstructed surface.
- **Five-to-eight-leaf flowers are hypothetical.** The real device has four leaves, and the model always shows four; higher counts change the math and appear as a labeled note under the model, not as extra petals in the picture.

None of these flaws makes the model useless. A good estimate, clearly reasoned and honest about its edges, is far more valuable than a precise-looking number you cannot check. The purpose of the simulator — and of this paper — is to let you follow every step, question every input, and build your own judgment about when rainwater harvesting makes sense.

12. Closing Thought

You started with a weather report — a number of millimeters — and you can now follow it all the way to a glass of water on a table. Along the way you used a definition of the liter, one fact about metric units, a right triangle, the cosine function, the area of a circle, and a handful of careful multiplications and divisions. No step required anything beyond high-school mathematics, yet together they describe a real device that could help a real family.

That is the quiet power of applied mathematics: ordinary tools, used carefully and honestly, add up to something that matters. Now open the simulator, change a number, and see if you can predict the result before it appears. If you can, you understand the model. If it surprises you, you have just found your next question.