Experiment

Irrigation system with a hygrometer to reduce physical effort and improve water use efficiency

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Results Report

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Prepared in Ecuador

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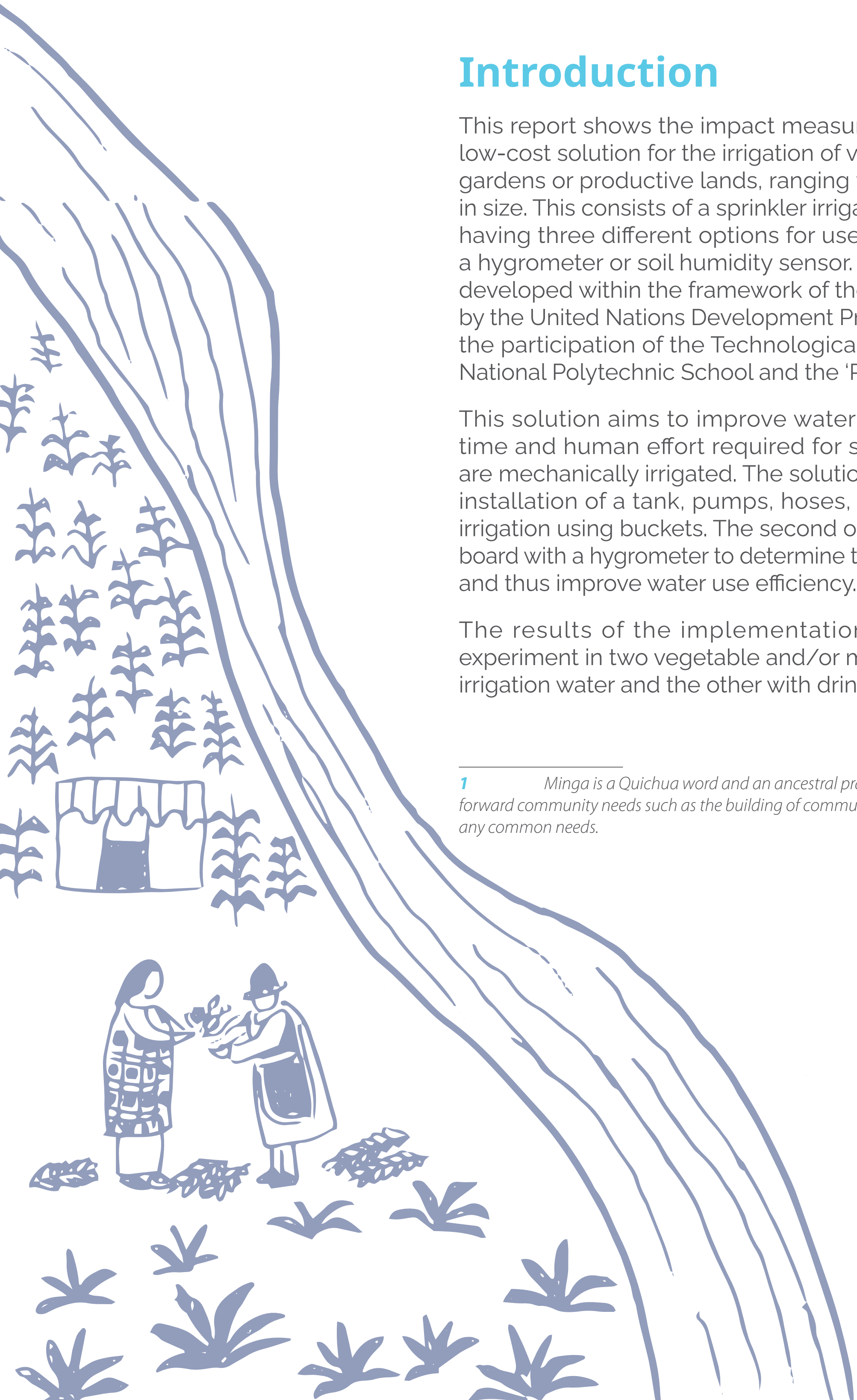

Introduction

This report shows the impact measurement results of an innovative, low-cost solution for the irrigation of vegetable and/or medicinal herb gardens or productive lands, ranging from 100 to 1000 square meters in size. This consists of a sprinkler irrigation system with a control panel having three different options for use: manual, with a timer, and with a hygrometer or soil humidity sensor. The irrigation control panel was developed within the framework of the *Innovation Minga*[1], coordinated by the United Nations Development Program Accelerator Lab and with the participation of the Technological Training School (ESFOT) at the National Polytechnic School and the 'Primero de Mayo' Central Market.

This solution aims to improve water use efficiency and reduce the time and human effort required for situations where crops or herbs are mechanically irrigated. The solution has two components: first, the installation of a tank, pumps, hoses, and sprinklers to avoid manual irrigation using buckets. The second one is composed of a multimodal board with a hygrometer to determine the necessary amount of irrigation and thus improve water use efficiency.

The results of the implementation are presented below as an experiment in two vegetable and/or medicinal herb gardens, one with irrigation water and the other with drinking water.

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1 *Minga is a Quichua word and an ancestral practice consisting of collaborative work to bring forward community needs such as the building of communal ditches, roads, planting and harvesting or any common needs.*

What problems are we addressing?

1. Physical effort

Many small-scale farmers dedicate long hours of manual work to irrigate their crops, as they use buckets and watering cans to pour water onto the plants, one by one. This method is frequently used by agroecological producers who store water in reservoirs, either because they do not have access to water sources or, even when they do have access to a water network, they choose to let the water sit in tanks to remove chlorine. Prior to the intervention, irrigation was done by filling tubs, buckets, and tanks of various sizes to let the water sit and then watering plants using watering cans.

Manual irrigation methods can be physically demanding and time-consuming, therefore, one of the elements of the implemented irrigation system aims to save time and effort. The mechanical component consists of a 55-gallon tank connected to a 0.5 hp pump in one case and a 1 hp pump in another, and water distribution through sprinklers. The chlorine-free water is then transported to the sprinklers through hoses to avoid carrying buckets. Our hypothesis is based on the presumption that if we install this mechanical system, physical effort will be significantly reduced.

MINIMIZING HUMAN EFFORT HYPOTHESIS

- ***H0 (no effect):*** There are no changes in terms of the number of people and time required to irrigate crops with the irrigation system.
- ***H1 (positive effect):*** The irrigation system reduces the number of people and time required for crop irrigation.
- ***H2 (negative effect):*** Once the irrigation system is installed, the number of people and time required for crop irrigation increases.

2. Irrigation Efficiency

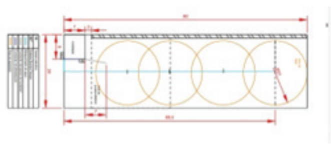
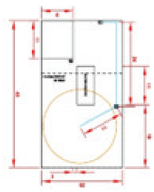
The second element of the irrigation system consists of a multimodal board that controls the sprinkling time, aiming to improve irrigation efficiency. The control panel provides three forms of use. The manual mode allows the user to turn the pump and sprinklers on and off at their discretion. The second one uses a timer to automatically turn off the pump at the time determined by the user. The third one uses a hygrometer that is inserted into the soil and emits signals whenever the soil is moist, turning the irrigation system off. The idea here is to identify the right amount of water that crops require in order to improve water use efficiency. Our hypotheses are presented below. Water use efficiency would also be improved with sprinklers by avoiding losses along the way. Therefore, our hypothesis is based on the presumption that if we determine the irrigation time with a hygrometer, then we would be applying the right amount of water to avoid waste.

IRRIGATION EFFICIENCY HYPOTHESIS

- ***H0 (no effect):*** No change in water use between the irrigation system with hygrometer and the traditional system that consisted of manual irrigation through visual inspection.
- ***H1 (positive effect):*** Water use is reduced when the sprinkling time is used based on the signals emitted by the hygrometer versus the manual irrigation through visual inspection.
- ***H2 (negative effect):*** Increases water use with the sprinkler system with a hygrometer versus the manual irrigation through visual inspection.

Intervention sites (sample)

The sample selection for this experiment was intentional. To compare the results obtained in different contexts, the intervention was performed in two types of land: one flat with access to tap water and the other one sloped with limited access to communal water.

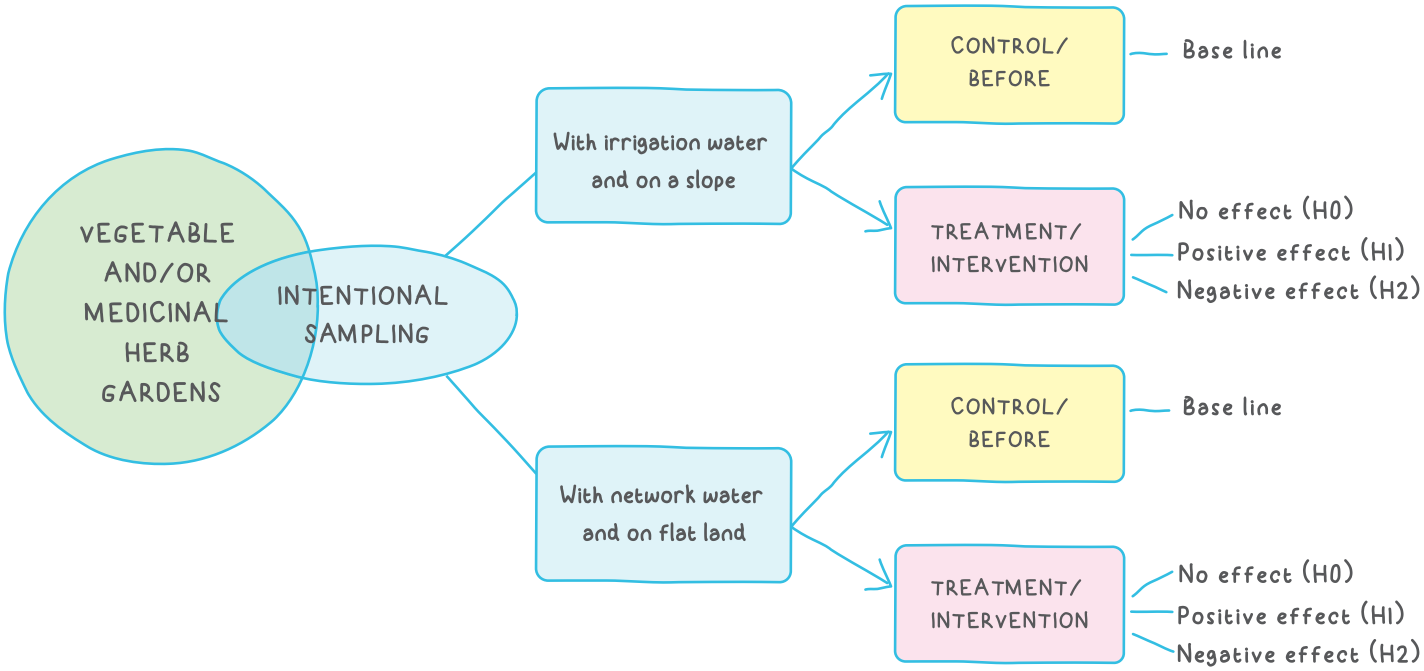
	Parish	M2 cultivated	Elevation	Plan
Land Plot A	Tumbaco	1600	30% (1 hp Pump)	
Land Plot B	Llano Chico	800	Plano (0.5 hp Pump)	

Experiment duration

This experiment was carried out in the month of July, during a dry period, when there was no rain in either of the two areas of land. The solution is oriented towards these months, since during the rainy months (from November to April), irrigation is done occasionally.

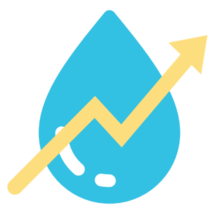
Experiment Design and measurement methods

This is a quasi-experimental case-control study with purpoive sampling.



To measure changes regarding **physical effort,** both in terms of the number of people involved and time spent, a survey with semi structured questions were asked to users at two different times: before and after the intervention. This survey included questions about people, time, and irrigation methods.

The measurement of **water consumption** was done using three data collection methods in order to triangulate the results.



1. Volume - reservoirs measurement: The first one consisted of applying the survey before (monitoring) and after (procedure) the intervention on the number of reservoirs used for one irrigation day.
2. Observational- time and liters: The second method was observational, putting the irrigation system to work and recording the time demanded by the hygrometer and the liters consumed in the main reservoir.
3. Volume reported in water bill: Finally, in the case of the plot with drinking water, we compared cubic meters from one month to another shown in the water bill.

LLANO CHICO INTERVENTION LAND PLOT A

Etelvina Rojas's vegetable and/or medicinal herb garden

Pre-existing Conditions

Water access and availability	Water collection prior to intervention	Water application prior to intervention
Land registered in CONQUITO's urban gardens program. It has access to tap water and electricity.	Use of 33 tanks to collect rainwater in winter or tap water in summer, which is stored for later irrigation.	Manual use of watering cans from the tanks located in three areas of the vegetable and/or medicinal herb garden to the crops.

Etelvina Rojas is a medicinal plant producer from the '1ro de Mayo Central' Market. In addition to selling various fresh products in such market, she produces vegetables using permaculture and organic methods and sells them at farmer's markets

Irrigation method before the intervention

Etelvina has a vegetable and/or medicinal herb garden approximately 800 square meters in size. Prior to the intervention, she irrigated her crops manually. Although she has access to the water network, she did not use hoses or sprinklers because the that water contains chlorine, and she considers it harmful to her products. For this reason, Etelvina collected the water with hoses in a total of 33 reservoirs to let it sit until the chlorine was removed. This work required two people in order to carefully pull the hoses towards the reservoirs without any dragging of hoses damaging the crops. Later, she would proceed to water manually with sprinklers. To reduce the travel distance between the tanks and the crops, Etelvina placed the reservoirs in different strategic points to apply the water by section.

Water management practices

Etelvina recycles household greywater on her crops. She bathes in the vegetable and/or medicinal herb garden with sun-warmed water and washes dishes and clothes in tanks in efforts to foster water reuse. She bathes over the crops that require more water such as citrons and chayotes. To neutralize soapy water, Etelvina rinses it in a second container and adds drinking water to dilute the detergents. Etelvina's reuse of water is a good environmental practice, however, not having a greywater separation system for its reuse through faucets demands a heavy workload. Similarly, another good practice is to irrigate in the late afternoon or very early in the morning to avoid losses due to evaporation.

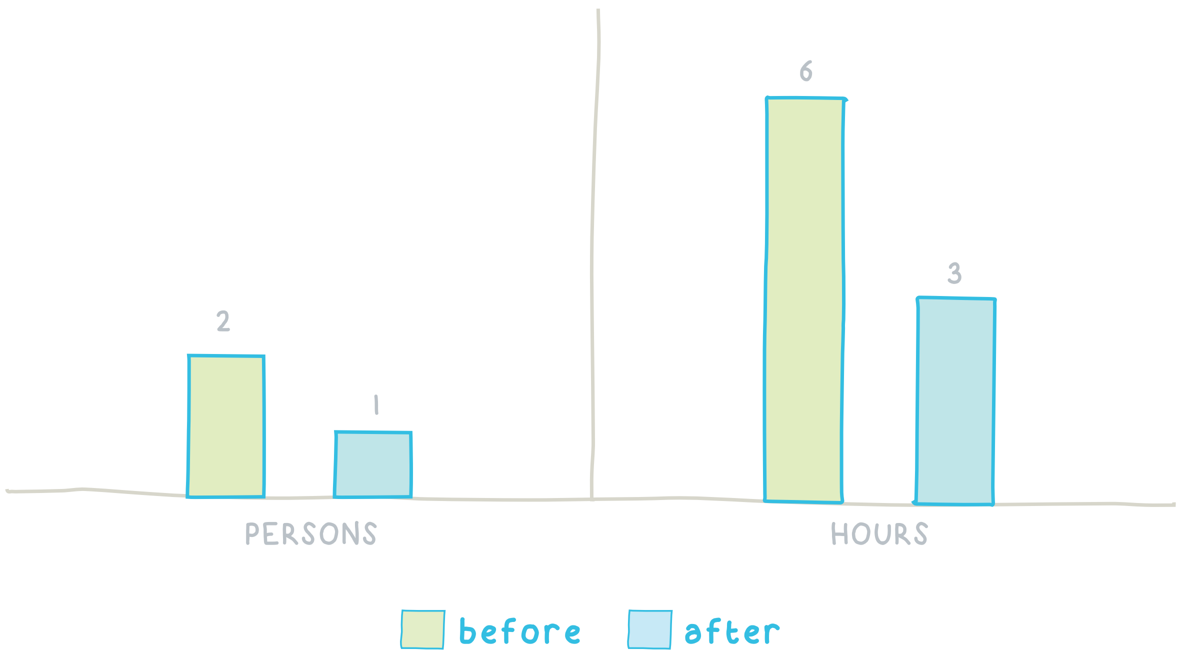
Llano Chico Results

Reduction in physical effort and time

The results obtained in Land Plot A, located in Llano Chico, which does have tap water, are presented below: The effort measurement data was collected by asking the small-scale farmer about the number of people involved before and after the installation of the irrigation system.

Figure 1

Reduction in effort per week



The time was significantly reduced with the installation of a larger capacity tank, hoses, pump, and sprinklers, so we verified hypothesis H1.

Water use efficiency

The measurement of water consumption has limitations due to the difficulty of isolating or controlling variables such as the demand for water intended for purposes other than irrigation. For this reason, we triangulate the results for verification. Likewise, to reduce error in the results, the measurement in this experiment was conducted during the summer season, with July being a month in which there was no rain.

Etelvina commented that prior to the intervention, she used 33 reservoirs to store water distributed as follows:

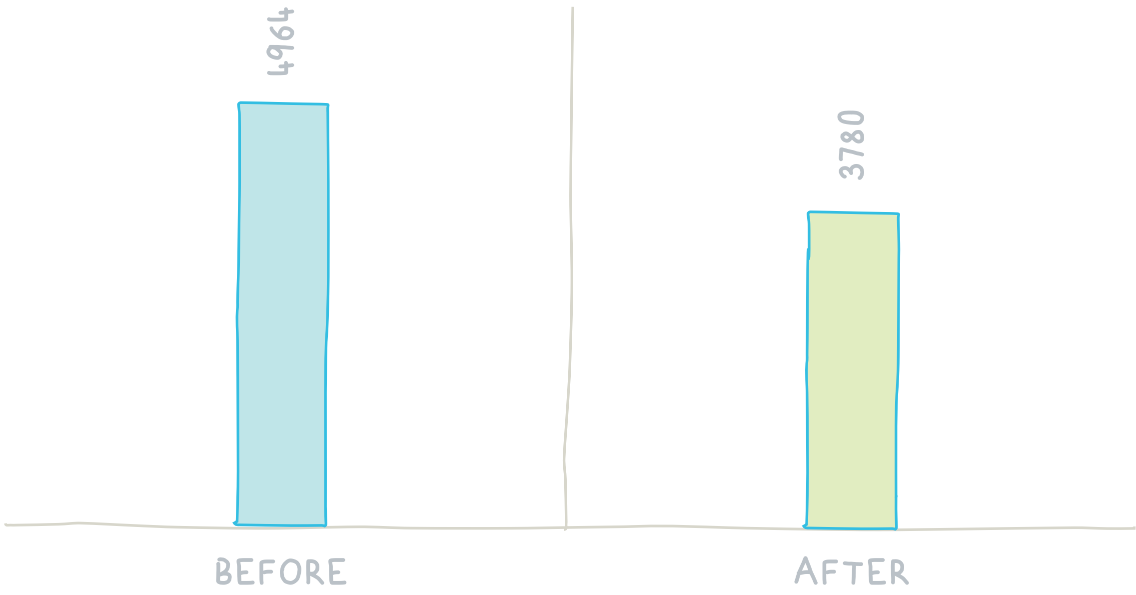
Reservoirs	Quantity	Capacity in liters	Total liters per week
5 tanks of 100 liters	5	100	500
2 large ones of more than 80 liters	2	80	160
10 small 20-liter tanks	10	20	200
10-15 20-liter buckets	15	20	300
tubs that add up to 80 liters	1	80	80
Total liters applied before the inter-vention	33		**1240**

This amount of reservoirs was depleted in one week and distributed over three days; therefore, the calculation of monthly consumption in summer, specifically in the month of July, was about 5 m3 (4964).

With the intervention, we installed a 55-gallon tank to store and dechlorinate water. This replaced many reservoirs and reduced the number of deposits from 33 to 7. The cultivated land is fully irrigated with 1.5 or a maximum of 2 tanks of 55 gallons. The reduction in water consumption is detailed below.

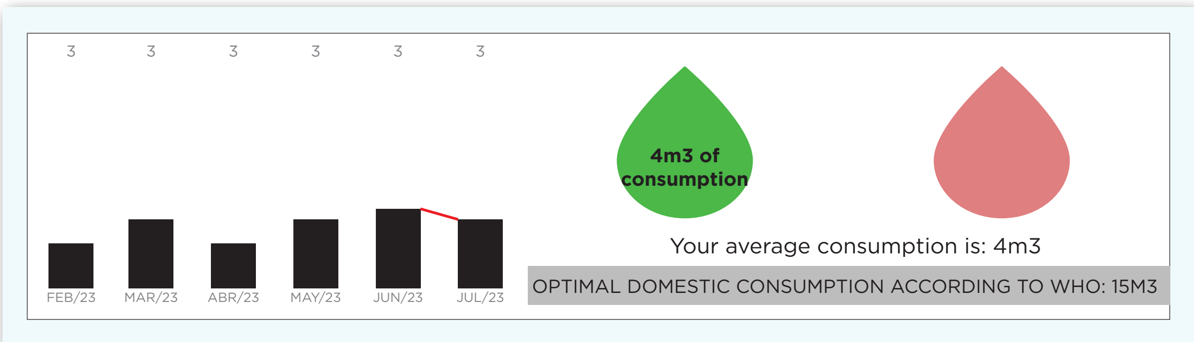
Figure 2

Liters per Month



To verify this data, the water consumption bill was reviewed and, since there is no rain in July, a reduction of 1 cubic meter of water was confirmed during the month of intervention.

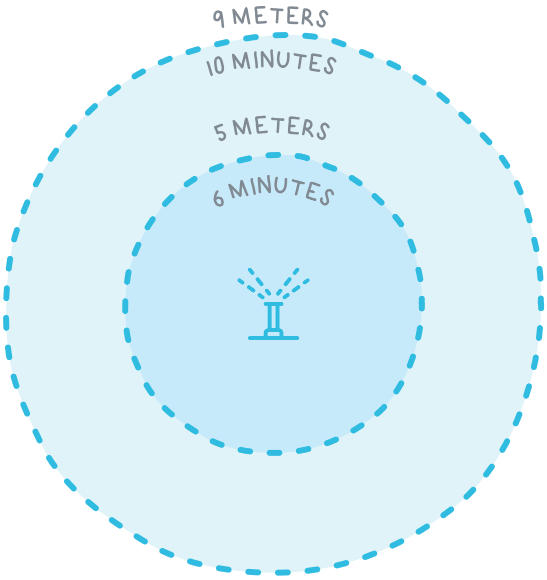
Historic monthly consumption in m3



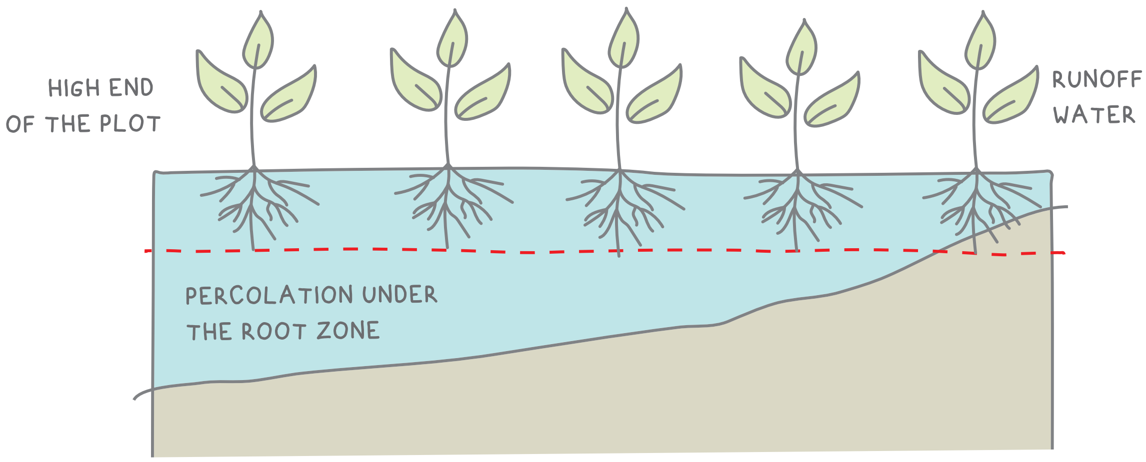
EPMAPS bill

Contribution of the hygrometer

It is important to note that this reduction in water consumption results from use of the 'hygrometer.' The time it takes to send this signal was measured, and this data makes it possible to establish optimal water use criteria for this land. With this data, small-scale farmers can standardize the irrigation time during a dry period, avoiding water excess due to 'over irrigation.' It should be noted that soil moisture varies based on the measurement distance from the sprinkler. The greater the distance, the lower the moisture, which is why it was crucial to take two measurements. The watering time determined by the sensor located 5 meters from the sprinkler is 6 minutes and 10 minutes at 9 meters. We recommend averaging the time to benefit all crops and ensuring a good distribution of sprinklers.



We consider that water use efficiency is due to the hygrometer placed in the soil, which determines the water demand of the crop at an optimal point (just enough) without losses due to deep infiltration that is not utilized by the roots (percolation).



In other words, as the hygrometer provides information that allows us to improve water efficiency, we were able to verify hypothesis H1.

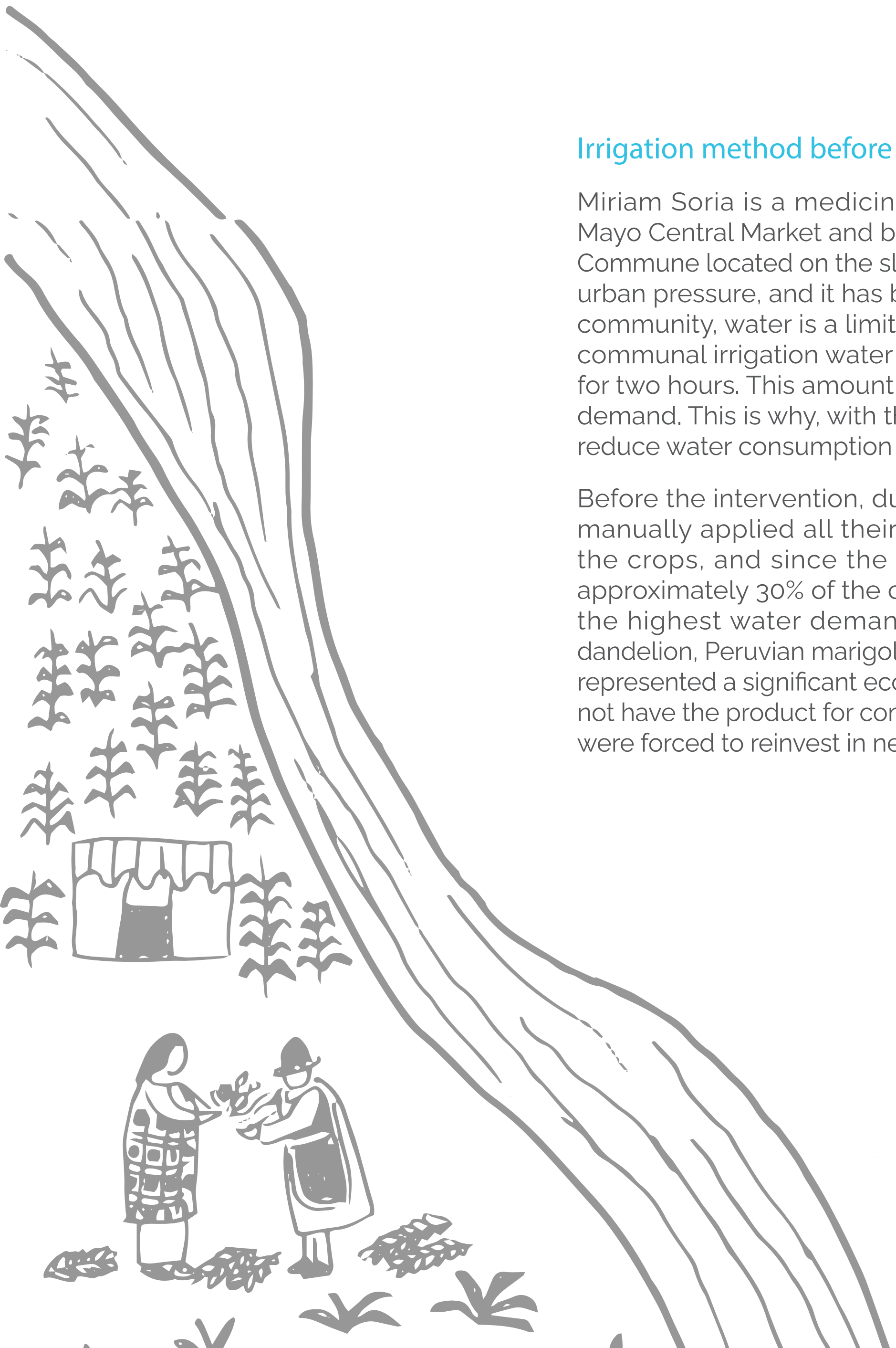
In addition, the sprinkler method also contributes to a better water use efficiency, as it prevents losses due to spills and puddling from the manual method.

tumbaco INTERVENTION Land Plot b

Miriam Soria's vegetable and/ or medicinal herb garden

Pre-existing Conditions

Water access and availability	Water collection prior to intervention	Water application prior to intervention
Communal land. Sloped land (approximately 30%) upwards from the water connection.	Use of 9 tanks to store irrigation water, which arrives through pipes to the lower part of the land once a week for 2 hours.	They applied the water using gallons of water, making 7 trips.



Irrigation method before the intervention

Miriam Soria is a medicinal plant producer from the 1ero de Mayo Central Market and belongs to the Tola Chica de Tumbaco Commune located on the slopes of Ilalo. This area is under a lot of urban pressure, and it has been affected by deforestation. In this community, water is a limited resource, so each family receives communal irrigation water through rationing: one day per week for two hours. This amount of water is less than what their crops demand. This is why, with this experiment, we are not seeking to reduce water consumption but rather to optimize it.

Before the intervention, during the summer season, the family manually applied all their reservoirs (1130 liters per week) to the crops, and since the quantity was insufficient, they lost approximately 30% of the crop. Miriam says that the plants with the highest water demand were dying, namely: dill, insulin, dandelion, Peruvian marigold, sainfoin, thyme, and spearmint. This represented a significant economic loss, not only because they did not have the product for commercialization, but also because they were forced to reinvest in new seedlings to replace the dead ones.

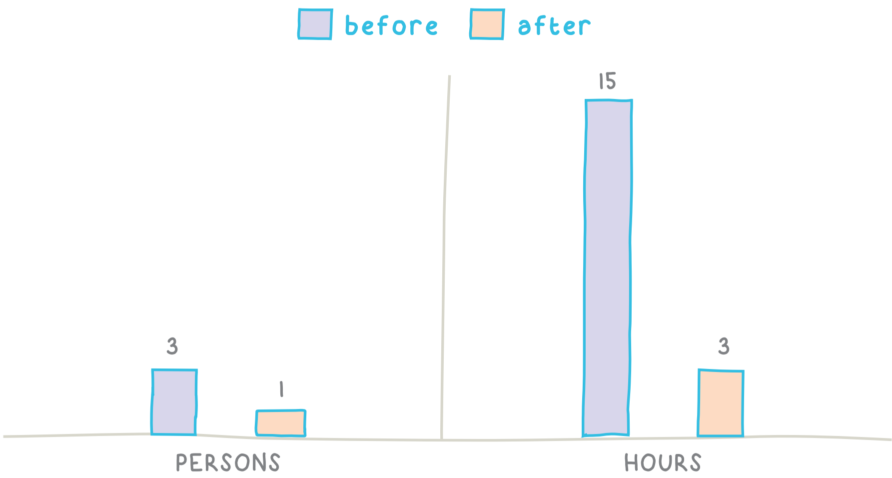
Tumbaco Results

Reduction in physical effort and time

In the case of this extremely sloped land, manual irrigation was excessively exhausting due to the number of trips each person had to make to carry the water from the tanks to the crops. Four irrigators connected to hoses and a 1hp power pump were installed. The mechanical component of the intervention managed to reduce the effort, as expected, although we must consider that it does not fully automate the work.

Figure 3

Reduction in physical effort per week

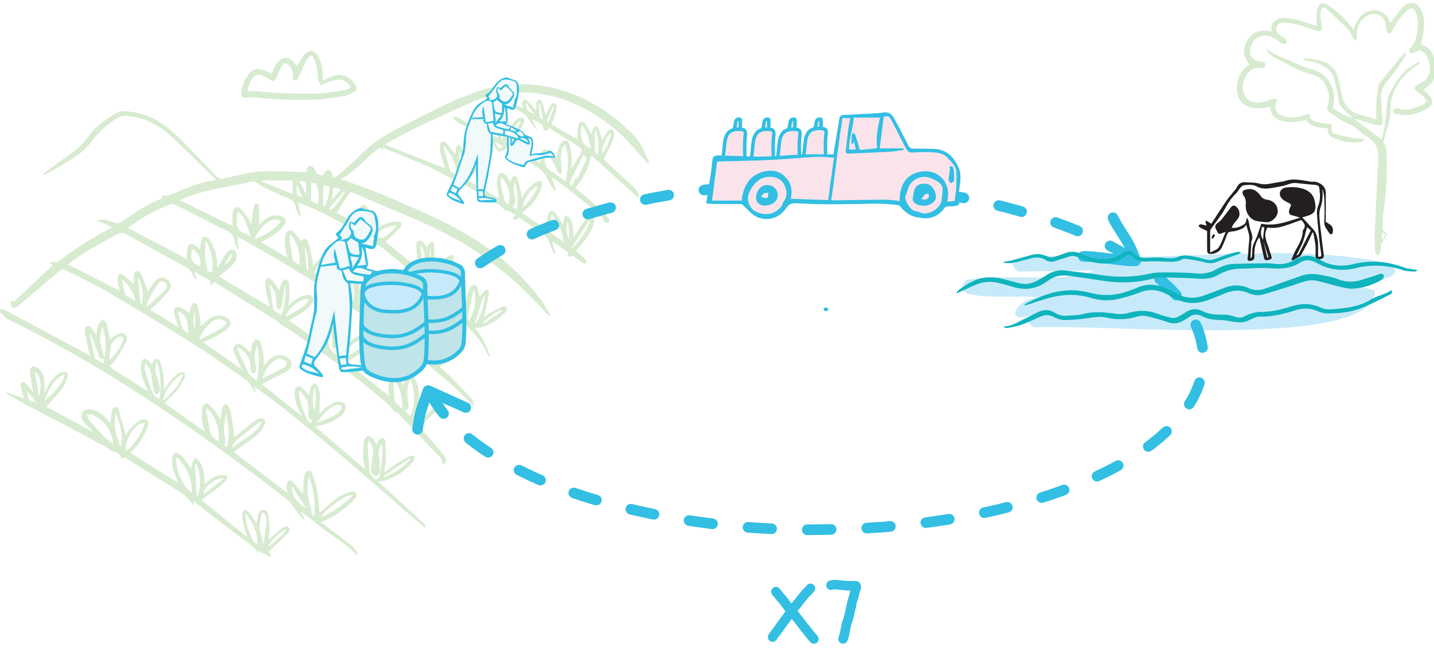


This reduction is significant, so with the intervention, hypothesis H1 was confirmed.

Water use efficiency

Before the intervention, Miriam Soria and her family used to collect water from the irrigation ditch. They would use 9 water jugs with a capacity of 6 liters each and made a total of 7 trips each (3 people) from the water source to the 2 storage tanks, and then, from the tank, they carried the water to the crops in watering cans or gallons.

Deposit:	Qty	Liters	Number of trips or replenishment	TOTAL LITERS	TOTAL IN ONE MONTH
trash cans	2	140	1	280	
buckets	9	6	7	378	
LITERS COLLECTED AND APPLIED EACH TIME				658	
TWICE A WEEK (WEEKLY DATA)				1316	5264



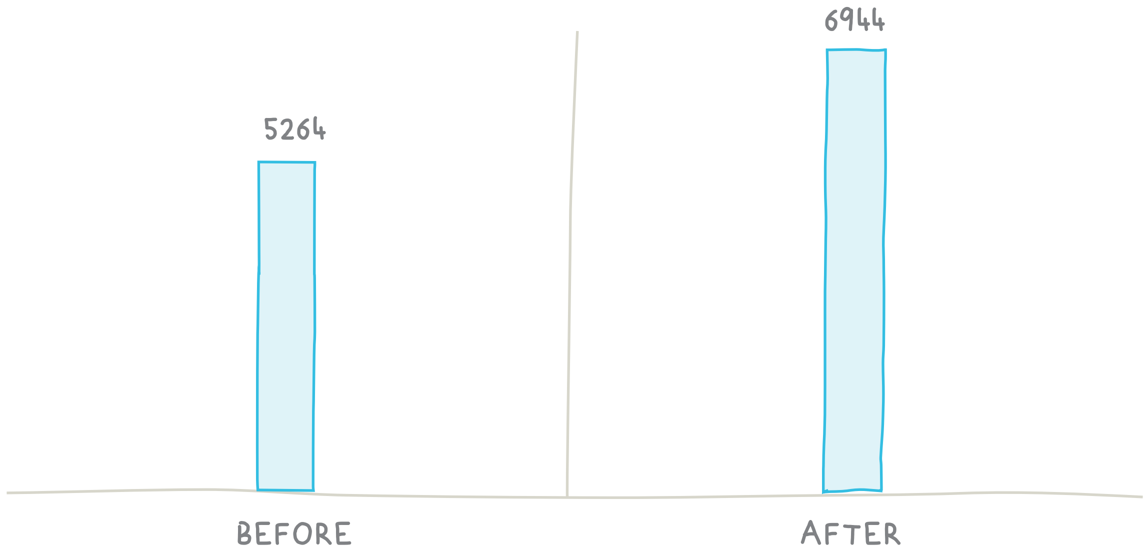
This tank filling operation was supposed to be carried out twice a week during a dry period, however, the water was insufficient to meet the demand, as 30% of the crop was lost.

With the donation of a 55-gallon tank, we increased the storage capacity, making it possible to irrigate during the summer. However, let us remember that the primary limiting factor lies in water availability and not in reservoirs.

Qty	Reservoir	liters	total liters	TOTAL IN ONE MONTH
1	TANK	210	210	
2	BLUE TANKS	140	280	
7	BUCKETS	6	378	
LITERS COLLECTED AND APPLIED EACH TIME			868	
TWICE A WEEK (WEEKLY DATA)			**1736**	6944

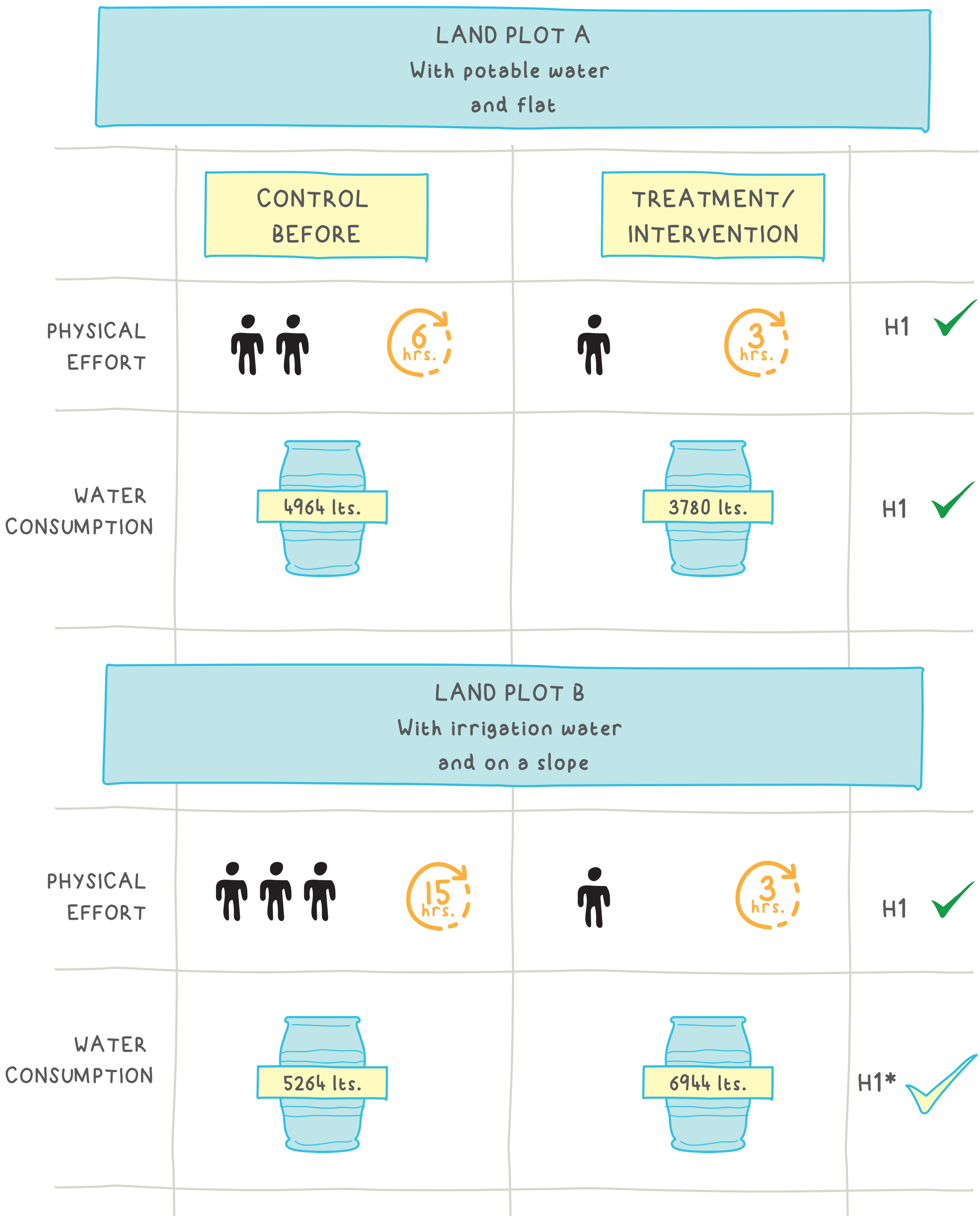
Figure 4

Monthly liters Tumbaco



It is important to note that the collected water is still below demand. However, the main result is that thanks to the intervention, crops are no longer lost. On the one hand, increasing a reservoir contributes to this objective, but also, the sprinkler irrigation method contributes to water-saving. While the manual distribution of water led to losses and spills, now the water reaches the vegetable and/or medicinal herb garden more efficiently. Finally, the liters collected depend on the flow rate of the community irrigation water they receive, which is a scarce resource for the entire commune.

Conclusions



*The increased water application was desired because there was a loss of 30% of crops.

Mechanical component (reduction in physical effort):

- The mechanical irrigation component (using a pump and sprinklers) significantly reduces human effort in cases where manual irrigation was performed without the use of hoses.
- Even though they have access to the drinking water network, some producers prefer to store water and let it sit to dissipate the chlorine, so this solution could facilitate the work for producers in urban and rural contexts.
- This solution is focused on irrigation application and not on water harvesting, and time reduction was centered on this activity. However, we recommend incorporating rainwater collection systems.

Technological component with hygrometer (reduction in water consumption):

- Water consumption was reduced on flat land by applying the optimal irrigation time according to the hygrometer signals.
- In the case of water consumption on slopes, there was no reduction but more efficiency in its application. The increase in storage improved crop conditions.
- Irrigation effectiveness was achieved by avoiding losses due to spills, waterlogging, percolation, or water runoff.
- In land plot B, 30% of the crops were lost before the intervention, and now the plants remain alive, though they have low production because they require more water than what is available.
- A small increase in electric power consumption for the 0.5hp and 1hp pump is 69 cents per month with a usage of 2 hours twice a week. This consumption compensates for the reduction in physical effort and the efficiency of water use.
- The possible resistance to incorporating technological components into daily practices would be reduced by parameterizing the required irrigation time by the hygrometer once during the dry period. Once this data is known, users can use the manual mode or with a timer.
- The signal emitted by the sensor located furthest from the sprinkler should be taken as the optimal irrigation time. Therefore, percolation is partially reduced since the crops closest to the sprinkler would be receiving 2 additional minutes of irrigation.
- For a systematic moisture measurement, we share the instructions provided by the Guatemala UNDP Acceleration Lab using the same type of hygrometer.
- This same intervention can be used for drip irrigation designs; however, it would require a greater investment in materials. It was not the case for this intervention because crops are not in line or terraced.
- This solution is suitable for family and community lands with an area of up to 1,000 square meters.

Recommendations

- Incorporate rainwater collection systems for a more comprehensive intervention, as these systems are mainly focused on reducing physical effort and improving water use efficiency.
- Apply reforestation policies, as well as conservation in these areas, especially on the Ilaló mountain, the water scarcity faced by farmers is the result of deforestation in recent decades due to urban sprawl.
- Promote greywater treatment and reuse systems in urban vegetable and/or medicinal herb gardens and sports facilities through incentives such as property tax reductions once these systems are implemented.
- Capacity building for Water Associations leaders for a better administration, management, and efficient maintenance of community water systems.
- Share information about this solution with entities that include Agrupar of CONQUITO Corporation for Economic Promotion or the Ministry of Agriculture, to benefit a larger number of producers.

Resources

- Manual to replicate the irrigation system
- User instruction manual

UNDP

accelerator labs