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Study on Rainwater Viability for Non-Drinking use in an Agricultural Research unit in Brazil

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***Abstract*— *The reduction in the availability of drinking water to populations has stimulated the search for alternative forms of technologies that enable the use and reuse of rainwater for non-drinking purposes, which are associated with practices that contribute to the reduction of waste. Thus, the aim of the present work was to propose a model for capturing rainwater and to identify the demands for the use of non-potable water for an agricultural research unit, in order to replace the current model with a more sustainable one. The work was carried out in a research station of IDR-Paraná-Institute of Rural Development of Paraná – Iapar-Emater, in the municipality of Ponta Grossa, Paraná. Three factors were evaluated: precipitation, collection area and demand quantity in each activity. The system is feasible to be implemented. The maximum demand for a month of higher consumption was estimated at 56.700 liters. It was possible to estimate the intake for the month with the lowest precipitation at the site, with this volume exceeding 46.000 liters of water, a value sufficient to meet the unit's demand for washing vehicles and for use in agricultural spraying, contributing to the reduction of use of drinking water at the station. Water use technologies are sustainable solutions and contribute to the rational use of water, providing the conservation of water resources for future generations.*

***Keywords*— Efficiency in the use of water, sustainability, use.**

I. INTRODUCTION

We are currently experiencing aggravations regarding the availability of drinking water in several regions. This lack of water reflects a set of situations that range from prolonged periods of drought to high levels of pollution in rivers and lakes, associated with not using alternative sources such as the capture and use of rainwater [29]; [22]; [7]; [32]; [27]; [4].

Concern about the lack of drinking water is growing worldwide. Brazil, despite being one of the richest in relation to this element, has presented serious problems that are not restricted to the northeastern semiarid. These facts contribute to the discussion that we are all responsible and that we can all contribute to the reduction of waste [9].

The lack of water is a reality in several regions of our country [33]. According to Almeida et al [5]., Brazil has huge reserves and great potential for water production, but this does not occur in the regions with the highest population density, a factor that would require the adoption of practices to maximize the management of this valuable resource, a fact that are not occurring, at least not on the scale that would be necessary.

Good practices such as reducing bath time, turning off the tap while brushing teeth and not washing the car with a hose are advertised and disseminated among the population as ways of reducing waste and helping the preservation movement, however despite these efforts, and in Depending on the number of our current population, new forms and methods need to be implemented to overcome this problem [24]; [4].

Water losses in Brazil are gigantic, either due to misuse or through leaks in the supply system, this is unacceptable above all when it comes to drinking water for human consumption [8]. According to the Brazilian Association of Engineering and Sanitary and Environmental - ABES [1], the national supply system loses 40% of all water, when compared to countries like Germany and Japan, which presents 11% losses, we realize that a better management of that system.

In addition to reducing losses in the supply system, other alternative ways can be implemented, the use of rainwater and the reuse of water are two practices that have great potential for expansion and are currently being used in new projects for houses and buildings [13]; [9].

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The reuse of rainwater has been shown to be a viable alternative. This capture and reuse of water is an ancient technique used for agricultural and domestic purposes. The technique, over time, became less common as piped water systems expanded [22]. Currently, due to the increased need, water reuse has been rescued and practiced more frequently [26]; [4].

Assunção et al., [6] found a reduction in spending on the water bill, in addition to the indirect environmental gain through the use of non-potable water for less noble purposes such as flushing the toilet, washing the floors and using gardens through adoption rainwater collection and storage system.

For Salla et al. [28], it is necessary to present and encourage the use of rainwater collection and conservation systems. In view of the fact that water is a limited natural resource and essential to life, questions about the conservation and preservation of water resources have been the focus of studies by conservation organizations that seek alternatives for a better use of natural resources. Water use technologies are sustainable solutions and contribute to the rational use of water, providing the conservation of water resources for future generations [11], [21].

The lack of sustainability of agricultural projects, associated with increased water demands, whether for direct consumption or food production, has been growing worldwide [32], [25], [23], [15], [4]. This work aimed to identify components that allow the replacement of the current model of water supply in an agricultural research unit by the use of water collected from the rains. We sought to analyze demanding activities, volume used and quantity needed to be stored in order to replace the current model with a more sustainable one.

II. MATERIAL AND METHODS

The work was carried out at the research station of IDR-Paraná-Institute of Rural Development of Paraná-Iapar-Emater, in the municipality of Ponta Grossa, Paraná, in 2015. The total area of the unit is 438 hectares (ha), of which of these 170 ha are used for agricultural research purposes and the rest of the area comprises: permanent reserves, legal reserves and construction areas. The agricultural areas of the farm where the research experiments are carried out are managed with the use of agrochemicals during the year, this practice demands water as a means of transport for the other sprayed products.

Vehicle washing is carried out at the unit itself, which has a fleet of 05 wagon vehicles for travel, 05 popular vehicles, 05 utility vehicles 06 field vehicles, 14 tractors, 02 harvesters, 03 trucks and 01 buses.

Among the various buildings found on the property, a 13.6 m wide and 50 m long shed with a total area of 680 m2, with a fiber cement roof, was identified as potential for use in rainwater harvesting. and that has a gutter system installed, those with dimensions of 0.2 m wide and 0.1 m high, in addition to conductors of PVC pipes that direct rainwater to the drainage system of the station.

We sought to identify the demands for water use in the unit. For the design of the rainwater collection and storage system, the methodology proposed by the ABNT - NBR 10,844.1989 [2] standard was used. In order to calculate the ratio of intensity, duration and frequency - IDF, equation 1, below, was used:

Equation (1) $I = ((K.(Trm))/((t + t0)n)$,

Where: I = intensity (mm / h); Tr = return time; t = time of concentration (minutes); K, m, t0, n = parameters determined on the spot, we used the values obtained by Frendrich apud Festi [14] we consider: K = 1902.39; m = 0.152; t0 = 21; n = 0.893. According to ABNT - NBR 10844 [2] the concentration time is 5 minutes (t) and the return time for roofs and roofs Tr = 5 years.

To calculate the collection area (roof), equation 2 was used:

Equation (2) $A = (a + h/2).b$,

Where: A corresponds to the contribution area (m²); a corresponds to the roof width (m); h represents the height of the scissors (m); b is the length (m), to calculate the total passive volume of water to be captured in that coverage [2].

Precipitation values were obtained from the website of the Instituto de Águas do Paraná [16], Table 01, which presents the monthly average for the municipality of Ponta Grossa in the last 40 years, in addition to the number of rainy days during the months in that period. [17].

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Table 01 - Average rainfall in (mm) and number of rainy days in the last 40 years.

Month	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Octo.	Nov.	Dez.
Average (mm)	171	162,7	142	100	123	111,4	115	82,5	147,4	156,5	142,8	164,3
Rainy days	14,4	13,5	11,6	7,9	7,8	7,7	7,2	6,4	9,9	10,9	10,7	12,6

Source: Adapted from: Instituto de Águas do Paraná Station installed on 10/01/1975. Tibagi basin. Lat: 25 12 ’00” Lon 50 09 ’00”.

Dornelles et al. [12], consider months of little or no rain to show rainfall below 100 mm, with rainfall data representing the amount of rain for a given region, with 1 mm of water being equivalent to 1 liter of rainwater that falls. in a square meter.

Next, the project flow rate was calculated which corresponds to the total volume that can be collected in the area, using equation 3

Equation (3) $Q = ((I .A)/60)$

Where: A = contribution area (m²); I = rainfall intensity (mm / h); Q = design flow (L / min) [2].

The use of rainwater for non-potable use in Brazil is standardized by ABNT NBR 15.527 [3], in which rules are established for the collection system through gutters and conductors, observing the need to install devices for the minimum disposal of the first two milliliters (mm).

As it is necessary to consider that not all collected water is used, since it is recommended that the first water be discarded, since it cleans the collection area, thus ABNT - NBR 15.527 [3], suggests the disposal of first 2L / m², to calculate the disposal volume, equation 4 was used:

Equation (4) $V = Ac .2$,

Where V is volume (L), Ac is the collection area (L) and 2 mm is the value considered necessary for the initial cleaning of the roof, the volume (precipitation) necessary for cleaning the roof was calculated, with the equation 5:

Equation (5) $V= P. A. C. \eta$

Where, V = the precipitation volume in (L), P = precipitation in (mm), A = contribution area and C. ŋ = runoff coefficient, whose adopted value was 0.8 to calculate the usable rainfall volume.

In sizing the reservoir, the Azevedo Neto methodology was used, as recommended by ABNT - NBR 15,527 [3], to calculate the volume of rainwater, equation 6,

Equation (6) $V = 0,042 \times P \times A \times T$

Where: P - average annual precipitation, (mm); T - number of months of little rain or drought; A - collection area, (m²); V - volume of water in the reservoir, (L). We emphasize that ABNT - NBR 15,527 [3], establishes the need for maintenance in the entire system for the use of rainwater.

III. RESULTS AND DISCUSSION

The rainwater harvesting system for non-potable consumption is an unconventional measure in southern Brazil. Currently, the use of rainwater is practiced in countries such as the United States, Germany, Japan, among others [19], [31], [20].In Brazil, the system is used in some cities in the Northeast as a source of water supply. The feasibility of using rainwater is characterized by a decrease in the demand for water supplied by the sanitation companies, with the consequence of lowering the costs with drinking water and reducing the risk of flooding in the event of heavy rains [10].

In the present work, a technical analysis of the site was carried out in order to map demand systems for the water used in the unit. The station uses water in flushing boxes, showers, toilets, washing environments, washing vehicles and spraying agrochemicals, in addition to human consumption.

With this information, two demand systems were established that can be replaced by the use of non-potable water, rain collection, with relative ease of installation and low investment, the vehicle washing system and the use in agrochemical applications.

Through a survey with those responsible for the sector, it was possible to ascertain that vehicle washes are carried out throughout the month, in addition, tractors, buses, seeders and harvester are washed, but in a much lower frequency, thus an average of 25 washes during each month.

The washing system installed has an average flow rate of 24 L / minutes, which is measured with a gallon with graduation through the volume of water collected in one minute. Due to the great variation of types of vehicles that pass through the washing system and the situation that reaches it, from dusty to very muddy, it is difficult to establish an exact amount of water used in the system, thus the average quantity was measured of water used when washing vehicles, with an average of 196 liters of water being washed. Silva et al., [30] observed 90 to 110 liters of water spent per vehicle in a car wash.

In order to work with a safety margin, we will set the value recorded in the local wash as the reference value. Therefore, as the monthly consumption is 196 L / vehicle, multiplied by 25 (number of vehicles washed during the month), it totals 4.900 liters of water.

The station uses several agrochemicals to manage its annual crop areas that are sprayed at a rate of 200 liters of water per hectare (ha), with the total arable area being 170 ha, it is necessary to note that spray rates and species cultivated crops change from one crop to another, so an estimate for the 2014/2015 crop was considered. Table 02 shows the main crops produced in the season, as well as the demand for agrochemical applications in each of them during the 2014/2015 season.

Thus, it is estimated that 242.000 liters of water are used per year for the application of agrochemicals. These applications are carried out during the crop phases (Table 03), with the month of November presenting the highest consumption demand, with an estimated need of 51.800 liters for this purpose during that month, currently the water used comes from an artesian well dug in the property.

Table 02: Water demand for total spraying and for each crop. Ponta Grossa, Paraná. 2015.

Culture	Total area (ha) cultivated in summer	Total cultivated area (ha) Winter	Number of Agrochemical Applications	Volume of water used per crop L / ha	Total water expenditure (Liters)
Soy	70	0	8	1.600	112.000
Corn	70	0	5	1.000	70.000
Bean	10	0	7	1.400	14.000
Wheat	0	10	5	1.000	10.000
Ground cover	20	160	1	200	36.000
Total					242.000

Source: Data obtained from the administration of the experimental station 08 oct. 2015.

Table 03: Water consumption (L) by crop during the 2014/2015 season.

Month	Soy	Corn	Bean	Wheat	Ground cover	Total
Jan.	21.000		1.200			22.200
Feb.	7.000					7.000
Mar.					12.000	12.000
April					12.000	12.000
May				1.200	12.000	13.200
June				800		800
July						
Aug.o		14.000		2.000		16.000
Sep.	7.000	9.000	800	2.800		19.600
Octo.	14.000	23.000	2.800	3.200		43.000
Nov.	28.000	19.000	4.800			51.800
Dez.	35.000	5.000	4.400			44.400

Source: Data obtained from the administration of the experimental station 08 oct. 2015.

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In this condition, the total value of water that can be replaced by non-potable water collected from the rain is 58.800 L for vehicle washing plus 242.000 L for spraying, totaling 300.800 L of water. In relation to the period of greatest demand, we have 4.900 L for vehicle washing plus 51.800 L for spraying, totaling 56.700 L for the month of greatest demand. For the calculation of the intensity, duration and frequency (IDF) ratio, equation 7 below was used:

Equation (7) Imax = (K.(Trm))/(t + t0)n

Imax = (1902,39 . (50,152))/(5 + 21)0,893

Imax = 2429,65/18,35

Imax = 132,41 mm

A maximum intensity of Imax = 132.41 mm was obtained for this station. According to ABNT –NBR 10,844 [2], it establishes for Ponta Grossa a value of Imax = 126 mm.

Through ABNT - NBR 10.844 [2] the surface area for rainwater collection was determined using equation 8

Equation (8) A = ((a + (h/2)) .b

A = ((13,6 + (1,2/2)) .50

A = 14,2 . 50

A =710 m2

Where: A = Contribution area (m²); a = Roof width 13.6 m; h = Scissor height 1.20 m; b = Roof length 50 m, with a contribution area of 710 m2. The collection area is represented by a 710 m2 shed with a gutter system already installed. The month of August represents the period of lowest monthly precipitation for the city of Ponta Grossa according to data from the Instituto do Águas do Paraná [16], in a 40-year historical series the average rainfall recorded was 82.5 mm.

The average rainfall and the number of monthly rainy days, the average annual rainfall for the period 1975 - 2015 was 1601.9 mm according to data from the Instituto de Águas do Paraná [18]. Next, the project flow rate was calculated using Equation 9:

Equation (9) Q = ((I .A)/60)

Q = ((132,41 . 710)/60)

Q = 94011,10/60

Q = 1566,85 L/min

Where: A = contribution area (m²); I = rainfall intensity (mm / h); Q = design flow (L / min), with a flow rate of 1566.85 L per minute, ABNT - NBR 10844, [2].

According to ABNT -NBR-15527 [3] it is recommended the initial disposal of 2 liters of water for each m² of the area collected in this way, the self-cleaning reservoir is calculated by the equation 10 V = Ac .2 where V is the volume (L), Ac is the collection area (L) and 2 mm is the value considered necessary for the initial cleaning and a value of 1.420 L is calculated for cleaning the collection area.

Equation (10) V =Ac . 2

V = 710 . 2

V = 1.420 L

Using equation 5, the usable volume of rain was calculated for the month with the lowest precipitation (V1), August and for the month with the greatest demand (V2), November, with A = 710 m2, C. ŋ = 0.8, and P = 82.5 mm for August and P = 142.8 mm for November.

V1 = P . A . C . ŋ

V1 = 82,5 . 710 . 0,8

V1 = 46.860 L

V2 = 142,8 . 710 .0,8

V2 = 81.110 L

It is noted that the month of August, corresponding to the lowest annual precipitation, it is possible to collect more than 46 thousand liters, and the estimated demand in that month is 20.900 liters. In addition, for the month of November, the month with the highest demand of 56.700 L, it is possible to capture 81.110 L, with the values likely to be raised higher than the demands, providing viability to the system.

Applying equation 11, it was possible to determine the size of the reservoir, which was 47.768 liters, where P = 1601.9 mm; A = 710 m2 and T = 1:

Equation (11) V = 0,042 x P x A x T

V = 0,042 . 1601,9 . 710 . 1

V = 47.768,87 L

For the use of the system it is important to install a filter that performs the retention of solid particles and allows the removal of leaves. It is intended that the collected water is conducted by PVC pipes of 100 mm to a reservoir with 2 boxes of 10.000 L installed next to the shed where the water will be collected, which is used for the car wash system that is 20 m from the reservoir and has a 5 hp pump.

The system will be composed of PVC pipes, swirling reducer and outlet thief which, after complete filling, will lead the water to a second reservoir through PVC pipes 100 mm, via gravity this second 10.000 L reservoir located at 120 m will be used to supply the sprayers.

In this regard, the implementation of the evaluated system is suggested, since most of the material needed for installation is available at the unit and there are employees available to perform the installation, the shed that will serve as the collection area already has PVC gutters and conductors that currently direct rainwater to the station's drainage system. This set of factors provided a great reduction in the initial investment costs, being a stimulating factor for the implementation of the system.

IV. CONCLUSION

The presented system proves to be viable since the shed that will be used has a collection system and conductors are already installed, in addition to the labor available for the installation of the other components, factors that greatly reduced the cost of implementing the collection system rainwater.

The washing of vehicles and the use of water for agricultural spraying can be carried out using the water collected from the rain.

The use of rainwater for non-potable purposes contributes to the decrease in the demand for water supplied by the sanitation company, with the consequence of lowering the costs with potable water. Contributing to the rational use of this resource.

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