Calibration of the Infiltration Rate Curve from the LN Trend Line at Eight Sites of Interest, Based on Infiltration Tests Carried out

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Abstract
The purpose of this research is to demonstrate that a calibration curve can be obtained that can be used for any infiltration test, with the double ring method, as well as an equation that helps speed up data processing. The experimentation was carried out in eight points in Nicaragua, of which five were distributed in Managua and three in Rivas-Nandaime. These results can be used for purposes of other studies of interest. As a result, a calibration curve is obtained, and an expression equal to \( y = -87.2 \ln (x) + 495.64 \) is deduced, which will be the equation to determine the average infiltration of a field test occupying the double ring, for a total of 7 hours. And it is from the result that the texture of the soil can be determined by means of the indicator table. The basic methodology allowed analyzing the data since they are obtained, processed and analyzed, resulting in the calibration curve for infiltration tests. Finally, an equation was determined from the averages of the processed data, resulting in a correlation of 0.9976, above 0.5, which means it is very high and reliable.

Keywords
Double Ring, Infiltration, Calibration, Logarithmic Curve, Data Adjustment

1. Introduction
For [1], the infiltration rate curve is obtained from in situ tests of infiltration tests; the recorded data is used for modeling the curve with the LN trend since a curve approaches the following expression: \( y = \pm a \ln (x) \pm b \), where the values “\( a \)” and “\( b \)” are obtained from statistical analysis.
In theoretical terms, according to [2] infiltration is the process by which the water that reaches the soil surface passes into it. This process is very sensitive to changes in soil management [3]; because, during a test, the instantaneous infiltration rate decreases over time to a constant value called basic infiltration, controlled by the saturated hydraulic conductivity or Ks; understood as a measure of the flow that crosses a section of the porous system of the saturated soil [4].

Infiltration tests allow knowing the variation of the infiltration capacity as a function of time. The simplest and most widespread tests are those that are developed with concentric rings, in which the data obtained from the field practice are recorded in a spreadsheet measuring the different heights of water and the corresponding times. The time intervals depend on the ground where the measurement is made, and with the height and time data the deltas of both are obtained.

The motivation to carry out this research arises from the need to have basic methodological material for specialists and future professionals, which, adapted to the real conditions of our country, and adapted to the methodologies for hydrogeological infiltration test trials, serve as a theoretical-practical reference in the area, its content implies the review of an extensive bibliography that, in addition to being expensive, is scarce in our country.

2. Objectives

Calibrate the infiltration rate curve using the LN trend line, in order to minimize the steps to obtain an own characteristic curve based on the infiltration tests carried out.

- Define the infiltration rate curve by means of the double ring test.
- To implement a calibration methodology for the infiltration rate curve from eight tests.
- Propose a calibration equation that measures infiltration levels in the soil.

3. Methodological Design

Geographic location of the investigation

In the development of the investigation, to carry out the tests, eight points of interest were obtained, five points in Managua and three points in Nandaim-Rivas, the coordinates of the points are the following: see Table 1 and Figure 1.

Kind of investigation

The present work is designed under the methodological approach of the quantitative approach, since this is the one that best adapts to the characteristics and needs of the investigation.

The quantitative approach uses data collection and analysis to answer research questions and test previously stated hypotheses, and relies on numerical measurement, frequent counting, and the use of statistics to accurately establish patterns of behavior in a series of data [5].
From the quantitative approach, the observation technique will be taken to describe the behavior of the infiltration rate curve by means of the LN trend line, in order to minimize the steps to obtain an own characteristic curve based on the infiltration tests carried out [6].

**Execution time**

The development of the research to meet the proposed objectives, was carried out in one week, maintaining one trial per day for eight days, the analysis of the data in one week, and one week to present results in the month of October 2021.

**Data Collection Techniques and Methods**

**Primary Sources**

On-site observation from infiltration tests carried out at eight different points. Archives of the National Water Authority, (ANA), Nicaragua.
In general, they will be the points determined for the infiltration test in any part of the aquifers of Nicaragua.

Sample
They will be the eight infiltration tests carried out in the aquifers of La Sierras Managua, and Nandaime-Rivas.

Inclusion Criteria
- Only the selected points in the La Sierras Managua and Nandaime-Rivas aquifers.

Exclusion criteria
- All those selected points in other aquifers that are not of interest.

Method
The method consists of saturating a portion of soil limited by two concentric rings, then measuring the variation of the water level in the inner cylinder. This information will help us decide what type of soil is determined [7].

Although it is possible that at the beginning of the experiment, the soil is dry or partially wet and therefore in non-saturated conditions, the initially very high values will drop very quickly as a result of the pressure exerted by the water column, greater it will be the bigger it is [8].

The time that elapses until the final conditions of saturation are reached will depend on the previous humidity, the texture and structure of the soil, the thickness of the horizon through which the water flows, and the height of the water in the inner ring.

The rate or speed of infiltration is the speed with which water penetrates the soil through its surface. We normally express it in mm/h and its maximum value coincides with the hydraulic conductivity of saturated soil [8], see Figure 2.

The original method, according to [8], starts from the idea that once the two rings are placed and the saturation situation is obtained (see Figure 3), the difference in water level (H) in the inner and outer rings causes a flow of water that will be input to the inner ring (see Figure 4) if the height is higher in the outer tube, or output if it is lower (see Figure 5).

In any case, in addition to the component of the water flow QH due to the difference in level H between the two rings, the water leaves both cylinders through the surface of the ground in which they are installed as a consequence of its porosity. Therefore, the net flow that leaves (or penetrates in its case) the inner ring is actually the result of two components: the component due to the difference in water level in the rings, the “leakage”; and the component due to the absorption capacity of the soil, infiltration. The problem lies precisely in being able to isolate for each condition of H the component of the “leakage” flow.
Figure 2. Infiltration rate according to the state of the soil. Source [8].

Figure 3. Double ring infiltrometer Source [9]

Figure 4. Inlet water flow. Source [9].

Figure 5. Outlet water flow. Source [9].
from the component of infiltration from the value of the net flow of the inner
tube (value object of the measurement). For this, the hypothesis is adopted that
the component due to absorption is constant during the performance of the
experiment and is not affected by changes in the water level in the inner
cylinder, see Figure 6.

The hypothesis is indeed valid if the measurements are made in a short space
of time and if $H$ remains relatively small. On the other hand, if $H = 0$ then the
flow in the inner tube is due solely to soil absorption, this being precisely the
purpose of the technique proposed in this section. The outer ring also has the
function of preventing the horizontal infiltration of water below the inner
cylinder so that the measurements correspond with certainty to the vertical
flow.

**Materiales y Equipos**
- A double ring infiltrometer
- 3 kg mallet
- Strong wood of length that exceeds the outer ring
- A 1 meter tape measure
- 3 buckets or drum
- 1 stopwatch
- 1 GPS
- Table format for gathering field information
- 1 table for support
- 1 graphite pencil

**Calculation of Hydraulic Conductivity**

To calculate the hydraulic conductivity of the soil in saturated conditions
from the measurements obtained during the experience, a table of results will be
prepared. It must include as many series as the number of times the inner ring
has had to be filled until verifying that the infiltration rate has stabilized. Table 2
shows an example of a field trial.

[9], reports that the equation that allows determining the accumulated
infiltration ($I_{acum}$) is given by Kotiakov (1932) and improved by Philips (1957)
can be indicated by the following expression:

![Figure 6. Flow of water in the ground generated by the double ring. Source [9].](image)
Table 2. Field trial example.

| Ring n°: Caracteristique of soils | 1 | Acumulate time | Date: Initial time: Partial foil | Acumulate foil |
|---------------------------------|---|----------------|---------------------------------|---------------|
| ID n°                           |   | Partial time   | Lecture Cup                    |               |
| Horas minutes                   | cm | cm | mm | mm |               |
| 16:00                           | 0  | 0  | 15 | 0  | 0             |
| 16:05                           | 5  | 5  | 13.5| 15 | 15            |
| 16:10                           | 5  | 10 | 12.8| 7  | 22            |
| 16:15                           | 5  | 15 | 12.2| 15 | 6  | 28            |
| 16:20                           | 5  | 20 | 14.6| 4  | 32            |
| 16:25                           | 5  | 25 | 14.2| 4  | 36            |
| 16:30                           | 5  | 30 | 13.7| 5  | 41            |
| 16:40                           | 10 | 40 | 12.7| 15 | 10 | 51            |
| 16:50                           | 10 | 50 | 14.4| 6  | 57            |
| 17:00                           | 10 | 60 | 13.6| 8  | 65            |
| 17:30                           | 30 | 90 | 11.2| 15 | 24 | 89            |

Source: [8] and [9].

\[
d = K * t^m
\]  \hspace{1cm} (1)

where:
- \(d\) = accumulated infiltration at time \(t\) (mm);
- \(K\) = constant that depends on the initial structure of the soil (dry). It is the layer that infiltrates in the first instant greater than zero (mm);
- \(m\) = constant that depends on the stability of the soil structure against water, \(0 > m < 1\);
- \(K\) in sandy or loamy soils with cracks show values between 10 to 30, soils with stable structures against water show values of \(m\) greater than 0.6.

To obtain the values of \(K\) and \(m\), the following is done:
\[
\log d = \log K + m \log t
\]  \hspace{1cm} (2);

equation that responds to the straight line
\[
y = b + a \times x,
\]

where:
- \(\log d = y\); dependent variable;
- \(\log K = b\); ordinate at the origin (ground constant);
- \(m = a\); slope of the line (ground constant);
- \(\log t = x\); independent variable.

Solving by least squares, we have:
Then Equation (1) is as follows  \( d = K \cdot t^m \).

To determine the average infiltration rate, we start from the following expression:

\[
I = \frac{d}{t} \left( \frac{\text{mm}}{\text{h}} \right)
\]

Substituting 1 into 4 we get:

\[
I = \frac{d}{t} = \frac{K \cdot t^m}{t} = K \cdot t^{m-1}
\]

where:
- \( I \) = infiltration at a time \( t \) (mm/h);
- \( k = K \cdot m \cdot 60; \)
- \(-n = m - 1.\)

Remaining the following expression

\[
I = k \cdot t^{-n}
\]

The result of the average infiltration is compared with the table related to the soil texture, Table 3, the average infiltration is closely related to the soil texture.

### 4. Results

A summary table of processed data is presented for each point in Graph 1. See Table 4.

The trend line is presented as a log of the data for each point. See Graphs 2-5.

Data adjusted to the logarithmic trend line are presented below, see Table 5 and Graph 6.

From the original data, the average is obtained, it is plotted to obtain a curve that can be adjusted and then define the calibration curve, see Table 6 and Graph 7.

**Table 3.** Average soil infiltration values (mm/h).

| Soil Texture  | Basic infiltration. Variation range (mm/h) | Ib average (mm/h) |
|---------------|---------------------------------|------------------|
| Sand          | 25 - 50                         | 50               |
| Sandy Loam    | 13 - 75                         | 25               |
| Frank         | 7.5 - 20                        | 12.5             |
| Loamy-loamy   | 2 - 15                          | 7.5              |
| clay-loam     | 0.2 - 5                         | 2.6              |
| Clay          | 0.1 - 1                         | 0.5              |

Source [9].
Table 4. Data obtained from the tests and processed to obtain I (mm/h).

| Accumulated Time (min) | Infiltration mm/h | Infiltration mm/h | Infiltration mm/h | Infiltration mm/h | Infiltration mm/h | Infiltration mm/h | Infiltration mm/h | Infiltration mm/h |
|------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
|                        | Point 01          | Point 02          | Point 03          | Point 04          | Point 05          | Point 06          | Point 07          | Point 08          |
| 1                      | 384.119           | 631.384           | 332.93           | 314.71            | 332.93            | 338.98            | 351.78            | 332.93            |
| 2                      | 228.475           | 625.165           | 388.71           | 348.52            | 393.78            | 383.68            | 415.50            | 393.78            |
| 3                      | 216.041           | 625.685           | 403.91           | 389.35            | 486.69            | 444.25            | 512.89            | 486.69            |
| 4                      | 124.662           | 668.885           | 437.94           | 478.04            | 594.45            | 531.81            | 332.93            | 594.45            |
| 5                      | 180.540           | 308.105           | 473.76           | 546.64            | 321.45            | 316.00            | 393.78            | 235.42            |
| 6                      | 133.541           | 545.552           | 514.85           | 323.04            | 352.06            | 333.62            | 506.73            | 321.45            |
| 7                      | 137.625           | 463.025           | 336.21           | 362.11            | 388.70            | 353.59            | 327.09            | 355.00            |
| 8                      | 170.907           | 516.190           | 351.89           | 456.53            | 401.94            | 376.45            | 387.10            | 374.94            |
| 9                      | 177.655           | 640.131           | 365.93           | 496.67            | 434.52            | 402.92            | 495.02            | 401.94            |
| 10                     | 122.457           | 420.305           | 411.74           | 543.03            | 468.35            | 457.44            | 516.10            | 434.52            |
| 12                     | 144.177           | 364.702           | 208.69           | 179.89            | 257.63            | 262.08            | 164.70            | 234.18            |
| 14                     | 189.768           | 447.221           | 214.49           | 221.17            | 286.43            | 142.54            | 191.58            | 257.63            |
| 16                     | 148.815           | 469.909           | 232.53           | 233.80            | 160.17            | 178.37            | 228.47            | 122.76            |
| 18                     | 93.981            | 594.679           | 238.84           | 259.08            | 172.52            | 196.59            | 272.82            | 160.17            |
| 20                     | 120.467           | 320.700           | 132.24           | 285.95            | 186.89            | 219.62            | 162.41            | 172.52            |
| 22                     | 115.410           | 396.859           | 162.19           | 175.76            | 216.25            | 249.79            | 184.47            | 192.73            |
| 24                     | 121.651           | 412.509           | 170.21           | 187.74            | 222.15            | 291.38            | 199.43            | 204.24            |
| 26                     | 128.606           | 404.742           | 173.45           | 209.71            | 245.05            | 175.89            | 240.52            | 222.15            |
| 28                     | 136.405           | 285.411           | 179.61           | 220.46            | 274.11            | 207.75            | 286.61            | 245.05            |
| 30                     | 130.261           | 337.637           | 184.35           | 260.66            | 323.68            | 256.45            | 159.08            | 274.11            |
| 35                     | 141.721           | 309.394           | 75.58            | 113.22            | 52.51             | 66.59             | 71.84             | 48.01             |
| 40                     | 95.281            | 385.931           | 77.54            | 71.12             | 69.89             | 78.76             | 78.64             | 64.74             |
| 45                     | 122.138           | 290.996           | 97.56            | 80.30             | 76.06             | 82.04             | 95.17             | 69.89             |
| 50                     | 123.173           | 372.206           | 76.73            | 92.66             | 83.61             | 88.52             | 104.04            | 76.06             |
| 55                     | 121.894           | 237.121           | 82.09            | 110.37            | 93.08             | 96.29             | 67.80             | 83.61             |
| 60                     | 64.160            | 234.837           | 83.92            | 61.47             | 105.40            | 61.13             | 80.15             | 93.08             |
| 70                     | 112.775           | 226.703           | 42.51            | 43.90             | 37.29             | 31.35             | 51.91             | 52.36             |
| 80                     | 120.062           | 198.106           | 42.71            | 60.16             | 45.61             | 33.36             | 37.29             | 25.71             |
| 90                     | 78.361            | 197.215           | 43.26            | 38.45             | 58.71             | 35.36             | 56.06             | 37.39             |
| 100                    | 91.935            | 202.028           | 43.53            | 54.43             | 46.53             | 37.65             | 36.56             | 45.48             |
| 110                    | 80.814            | 186.539           | 44.11            | 37.07             | 58.68             | 38.50             | 53.62             | 59.03             |
Continued

| Accumulated Time (min) | Infiltration Point 01 mm/h | Infiltration Point 02 mm/h | Infiltration Point 03 mm/h | Infiltration Point 04 mm/h | Infiltration Point 05 mm/h | Infiltration Point 06 mm/h | Infiltration Point 07 mm/h | Infiltration Point 08 mm/h |
|------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| 1                      | 241.57                      | 691.70                      | 496.94                      | 523.73                      | 527.22                      | 500.02                      | 521.87                      | 495.59                      |
| 2                      | 218.29                      | 622.68                      | 431.53                      | 456.08                      | 458.83                      | 434.60                      | 453.60                      | 430.54                      |
| 3                      | 204.68                      | 582.31                      | 393.26                      | 416.51                      | 418.82                      | 396.33                      | 413.67                      | 392.49                      |
| 4                      | 195.02                      | 553.67                      | 366.12                      | 388.43                      | 390.43                      | 369.18                      | 385.33                      | 365.49                      |
| 5                      | 187.53                      | 531.45                      | 345.06                      | 366.65                      | 368.42                      | 348.12                      | 363.36                      | 344.54                      |
| 6                      | 181.40                      | 513.29                      | 327.85                      | 348.85                      | 350.43                      | 330.91                      | 345.40                      | 327.43                      |
| 7                      | 176.23                      | 497.95                      | 313.30                      | 333.81                      | 335.22                      | 316.37                      | 330.22                      | 312.97                      |
| 8                      | 171.74                      | 484.65                      | 300.70                      | 320.78                      | 322.04                      | 303.76                      | 317.07                      | 300.43                      |
| 9                      | 167.79                      | 472.92                      | 289.59                      | 309.28                      | 310.42                      | 292.65                      | 305.47                      | 289.38                      |
| 10                     | 164.25                      | 462.43                      | 279.65                      | 299.00                      | 300.02                      | 282.70                      | 295.09                      | 279.49                      |
| 12                     | 158.13                      | 444.28                      | 262.44                      | 281.20                      | 282.03                      | 265.49                      | 277.13                      | 262.38                      |
| 14                     | 152.95                      | 428.93                      | 247.89                      | 266.16                      | 266.82                      | 250.95                      | 261.95                      | 247.91                      |
| 16                     | 148.47                      | 415.63                      | 235.29                      | 253.13                      | 253.65                      | 238.34                      | 248.80                      | 235.38                      |
| 18                     | 144.51                      | 403.91                      | 224.18                      | 241.63                      | 242.03                      | 227.23                      | 237.20                      | 224.33                      |
| 20                     | 140.97                      | 393.41                      | 214.23                      | 231.35                      | 231.63                      | 217.28                      | 226.82                      | 214.44                      |
| 22                     | 137.77                      | 383.92                      | 205.24                      | 222.04                      | 222.23                      | 208.29                      | 217.43                      | 205.50                      |
| 24                     | 134.85                      | 375.26                      | 197.03                      | 213.55                      | 213.64                      | 200.08                      | 208.86                      | 197.33                      |
| 26                     | 132.16                      | 367.29                      | 189.47                      | 205.74                      | 205.74                      | 192.52                      | 200.98                      | 189.82                      |
| 28                     | 129.67                      | 359.91                      | 182.48                      | 198.51                      | 198.43                      | 185.53                      | 193.68                      | 182.86                      |

Source: Self-made (2021).

Table 5. Data fitted to the logarithmic trend line for each point.
Table 6. The calculation of the average with which one works to determine the calibration of the curve is shown.

| Point 01 | Point 02 | Point 03 | Point 04 | Point 05 | Point 06 | Point 07 | Point 08 | Average |
|----------|----------|----------|----------|----------|----------|----------|----------|---------|
| Accumulated Time (min) | Infiltration mm/h | Infiltration mm/h | Infiltration mm/h | Infiltration mm/h | Infiltration mm/h | Infiltration mm/h | Infiltration mm/h | Infiltration mm/h |
|----------|----------|----------|----------|----------|----------|----------|----------|---------|
| 1        | 384.119  | 631.384  | 332.93   | 314.71   | 332.93   | 338.98   | 351.78   | 332.93   | 377.471 |
| 2        | 228.475  | 625.165  | 388.71   | 348.52   | 393.78   | 383.68   | 415.50   | 393.78   | 397.202 |
| 3        | 216.041  | 625.685  | 403.91   | 389.35   | 486.69   | 444.25   | 512.89   | 486.69   | 445.688 |
| 4        | 124.662  | 668.885  | 437.94   | 478.04   | 594.45   | 531.81   | 332.93   | 594.45   | 470.395 |
| 5        | 180.540  | 308.105  | 473.76   | 546.64   | 321.45   | 316.00   | 393.78   | 235.42   | 346.963 |
| 6        | 133.541  | 545.552  | 514.85   | 323.04   | 352.06   | 333.62   | 306.73   | 321.45   | 378.856 |
| 7        | 137.625  | 463.025  | 336.21   | 362.11   | 388.70   | 353.59   | 327.09   | 355.00   | 340.420 |
|   |    |    |    |    |    |    |    |    |    |
|---|---|---|---|---|---|---|---|---|---|
| 8 | 170.907 | 516.190 | 351.89 | 456.53 | 401.94 | 376.45 | 387.10 | 374.94 | 379.493 |
| 9 | 177.655 | 640.131 | 365.93 | 496.67 | 434.52 | 402.92 | 495.02 | 401.94 | 426.847 |
| 10 | 122.457 | 420.305 | 411.74 | 543.03 | 468.35 | 457.44 | 516.10 | 434.52 | 421.743 |
| 12 | 144.177 | 364.702 | 208.69 | 179.89 | 257.63 | 262.08 | 164.70 | 234.18 | 227.007 |
| 14 | 189.768 | 447.221 | 214.49 | 221.17 | 286.43 | 142.54 | 191.58 | 257.63 | 243.854 |
| 16 | 148.815 | 469.909 | 232.53 | 233.80 | 170.21 | 196.59 | 272.82 | 248.586 | 221.853 |
| 18 | 93.981 | 594.679 | 238.84 | 259.08 | 172.52 | 199.43 | 291.38 | 204.24 | 226.163 |
| 20 | 120.467 | 320.700 | 132.24 | 285.95 | 186.89 | 219.62 | 172.52 | 200.098 | 226.163 |
| 22 | 115.410 | 396.859 | 162.19 | 214.49 | 221.17 | 286.43 | 142.54 | 191.58 | 257.63 |
| 24 | 121.651 | 412.509 | 170.21 | 187.74 | 222.15 | 199.43 | 257.63 | 243.854 | 221.853 |
| 26 | 128.606 | 404.742 | 173.45 | 170.21 | 187.74 | 222.15 | 199.43 | 257.63 | 229.425 |
| 28 | 136.405 | 285.411 | 179.61 | 220.46 | 274.11 | 207.75 | 286.61 | 245.05 | 225.014 |
| 30 | 130.261 | 337.637 | 184.35 | 260.66 | 323.68 | 256.45 | 159.08 | 274.11 | 240.777 |
| 35 | 141.721 | 309.394 | 75.58 | 113.22 | 52.51 | 66.59 | 71.84 | 48.01 | 109.855 |
| 40 | 95.281 | 385.931 | 77.54 | 71.12 | 69.89 | 78.76 | 78.64 | 64.74 | 115.236 |
| 45 | 122.138 | 290.996 | 97.56 | 80.30 | 76.06 | 82.04 | 95.17 | 69.89 | 114.269 |
| 50 | 123.173 | 372.206 | 76.73 | 92.66 | 83.61 | 88.52 | 104.04 | 76.06 | 127.125 |
| 55 | 121.894 | 237.121 | 82.09 | 110.37 | 93.08 | 96.29 | 78.76 | 64.74 | 111.531 |
| 60 | 64.160 | 234.837 | 83.92 | 61.47 | 105.40 | 61.13 | 80.15 | 93.08 | 98.018 |
| 70 | 112.775 | 226.703 | 42.51 | 43.90 | 37.29 | 31.35 | 51.91 | 52.36 | 74.849 |
| 80 | 120.062 | 198.106 | 42.71 | 60.16 | 45.61 | 33.36 | 37.29 | 25.71 | 70.375 |
| 90 | 78.361 | 197.215 | 43.26 | 38.45 | 58.71 | 35.36 | 56.06 | 37.39 | 68.101 |
| 100 | 91.935 | 202.028 | 43.53 | 54.43 | 46.53 | 37.65 | 36.56 | 45.48 | 69.767 |
| 110 | 80.814 | 186.539 | 44.11 | 37.07 | 58.68 | 38.50 | 53.62 | 59.03 | 69.795 |
| 120 | 89.483 | 184.087 | 47.10 | 38.59 | 38.55 | 35.45 | 24.95 | 62.254 |
| 140 | 87.197 | 292.339 | 16.26 | 20.70 | 24.86 | 21.70 | 29.72 | 23.38 | 63.394 |
| 160 | 77.770 | 168.578 | 25.59 | 22.35 | 18.96 | 23.55 | 17.66 | 28.97 | 47.928 |
| 180 | 71.393 | 141.940 | 23.04 | 22.65 | 23.00 | 24.24 | 27.04 | 12.97 | 43.284 |
| 210 | 75.705 | 137.197 | 17.75 | 15.58 | 17.38 | 10.53 | 10.90 | 12.85 | 37.237 |
| 240 | 70.776 | 138.702 | 15.45 | 15.62 | 12.59 | 10.03 | 11.44 | 16.57 | 36.398 |
| 270 | 70.364 | 133.243 | 7.76 | 7.88 | 7.04 | 5.23 | 6.62 | 4.44 | 30.322 |
| 300 | 70.776 | 151.154 | 7.79 | 7.98 | 7.96 | 5.37 | 7.72 | 6.32 | 33.132 |
| 360 | 139.516 | 7.82 | 8.10 | 9.08 | 5.51 | 9.34 | 7.67 | 26.719 |
| 420 | 144.903 | | | | | | | | |

Source: Self-made (2021).
Graph 1. The behavior of the infiltration is shown for each of the points. Source: Self-made (2021).

Graph 2. Trend line with data from point 1 and 2. Source: Self-made (2021).

Next, the calibration of the curve is presented to determine the infiltration in a period of 7 hours, see Table 7 and Table 8, Graph 8.
Graph 3. Trend line with data from point 3 and 4. Source: Self-made (2021).

Graph 4. Trend line with data from point 5 and 6. Source: Self-made (2021).
Graph 5. Trend line with data from point 7 and 8. Source: Self-made (2021).

Table 7. Dates for the graphic.

| Accumulated Time (min) | Infiltration mm/h | Accumulated Time (min) | Infiltration mm/h | Accumulated Time (min) | Infiltration mm/h |
|------------------------|-------------------|------------------------|-------------------|------------------------|-------------------|
| 1                      | 500.53            | 20                     | 233.67            | 90                     | 99.69             |
| 2                      | 438.78            | 22                     | 225.18            | 100                    | 90.30             |
| 3                      | 402.67            | 24                     | 217.43            | 110                    | 81.81             |
| 4                      | 377.04            | 26                     | 210.30            | 120                    | 74.06             |
| 5                      | 357.16            | 28                     | 203.70            | 140                    | 60.33             |
| 6                      | 340.92            | 30                     | 197.55            | 160                    | 48.43             |
| 7                      | 327.19            | 35                     | 183.82            | 180                    | 37.94             |
| 8                      | 315.29            | 40                     | 171.92            | 210                    | 24.21             |
| 9                      | 304.80            | 45                     | 161.43            | 240                    | 12.31             |
| 10                     | 295.42            | 50                     | 152.05            | 270                    | 1.82              |
| 12                     | 279.17            | 55                     | 143.56            | 300                    | 0.90              |
| 14                     | 265.44            | 60                     | 135.81            | 360                    | 0.60              |
| 16                     | 253.55            | 70                     | 122.07            | 420                    | 0.50              |
| 18                     | 243.06            | 80                     | 110.18            |                        |                   |

Source: Self-made (2021).
Graph 6. Curves fitted to the logarithmic trend line for each point are shown. Source: Self-made (2021).

Graph 7. The curve with the average of the data is shown. Source: Self-made (2021).

Graph 8. The curve calibrated to the data with a correlation of 0.9976 is shown. Source: Self-made (2021).
Table 8. Basic infiltration variation range.

| Soil Texture   | Basic infiltration variation range (mm/h) | Ib average (mm/h) |
|---------------|------------------------------------------|-------------------|
| Sand          | 25 - 50                                  | 50                |
| Sandy Loam    | 13 - 75                                  | 25                |
| Frank         | 7.5 - 20                                 | 12.5              |
| Loamy-loamy   | 2 - 15                                   | 7.5               |
| Clay-loam     | 0.2 - 5                                  | 2.6               |
| Clay          | 0.1 - 1                                  | 0.5               |

Source [9].

5. Analysis of the Results

From the calibration curve, an expression equal to

\[ y = -87.2 \ln(x) + 495.64 \]

which will be the equation to determine the average infiltration of a field test occupying the double ring, for a total of 7 hours. And it is from the result that the texture of the soil can be determined by means of the indicator table.

6. Conclusions

The infiltration rate curve was successfully defined by applying the double ring theory, following a basic methodology.

The basic methodology allowed analyzing the data since they are obtained, processed and analyzed, resulting in the calibration curve for infiltration tests.

Finally, an equation was determined from the averages of the processed data, resulting in a correlation of 0.9976, above 0.5, which means it is very high and reliable.

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Conflicts of Interest
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