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Article

A New Methodology for Evaluating Potential for Potable Water Savings (PPWS) by Using Rainwater Harvesting at the Urban Level: The Case of the Municipality of Colombes (Paris Region)

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Abstract: The practice of rainwater harvesting (RWH) is spreading rapidly in urban areas. This article studies the impact of a possible generalization of this practice for municipalities by proposing a new method to quantify the potential for potable water savings (PPWS) by using rainwater harvesting at the urban level. The proposed method is based on the adaptation of an already validated model assessing the PPWS for single buildings and the use of urban databases. Two concepts are introduced: (1) the "building type" that allows gathering all the buildings sharing common features; and (2) the "equivalent building," which is used to assess the PPWS of a set of buildings (of a same building type) as if it were a single building. In the case of the municipality of Colombes (located in the suburbs of Paris), the method shows that the PPWS by using rainwater harvesting represents about 10% of the total potable water consumption: the residential buildings account for 64% of this potential. This method can be applied to other

municipalities with a level of acceptable reliability with regard to the means to be implemented in terms of collecting information.

Keywords: rainwater harvesting; water savings; urban scale; uses scenario

1. Introduction

The practice of rainwater harvesting (RWH) is spreading rapidly in urban areas all over the world. All continents are involved in its development. In Australia, the scarcity of water has, for many years, led to the use of rainwater; today, 3.2 million Australians use RWH as their sole source of drinking water [1]. In Africa, RWH systems are used to overcome the lack of public networks in countries such as Kenya, Mali and Malawi [2]. In Asia, RWH development has also been important in recent years. In Japan, for example, the number of buildings with a RWH system has risen from 3 in 1970 to 1000 buildings in 2003 [3]. In the Americas, the increasing development of this practice has led to the production of specific guides or standards [4,5]. In Europe, the development of RWH varies from one country to another: Germany is leading with many experimental programs conducted during the 1990s [6], while in countries such as Portugal, there is very little diffusion [7]. In French urban areas, according to a recent survey conducted in 2009, 15% of French people have a rainwater harvesting system [8]. This rapid spread is due to a combination of three factors: new legislation (French Government Order of 21 August 2008 relating to rainwater harvesting); incentive mechanisms developed by public bodies to foster the practice; and the increasing "green" sensitivities of the different stakeholders (citizens, enterprises, associations) [9–11].

RWH systems are mainly implemented at the building's scale. The scientific literature shows that this scale is often considered as the relevant one for studying the RWH practice and is privileged by stakeholders. However, the analysis of the impact of the RWH practice on water and sanitation systems is one of the issues that emerged in recent years [12–15].

The answer to this issue challenges the building as a relevant scale, because the impact of RWH on drinking water and wastewater systems is clearly observed at broader scales: municipality, agglomeration, and catchment [16].

In this paper, we propose an innovative method to move from the impact of RWH at the building level to larger and more complex scales.

2. Context and Objective

There are different methods for calculating water drinking savings at the building scale by setting up a system of RWH. These methods take into account the three basic functions of the RWH system: collecting, storing and using rainwater [17–24]. By contrast, the few works evaluating such savings at the urban scale [25,26] only take into account the function of collecting, through a single indicator, what is known as rainwater capture and harvesting potential (RCHP), expressed by Equation (1):

$$RCHP = TRA \times RC \times R/1000 \quad (1)$$

where:

- RCHP (rainwater capture and harvesting potential): volume of rainwater that could be harvested at the considered urban scale (m^3/year);
- TRA (total roof area): total roof area at the same urban scale (m^2);
- RC (runoff coefficient): runoff coefficient indicates a loss of the rainwater that is discarded for roof cleaning and evaporation (non-dimensional);
- R (rainfall): the annual rainfall at the same urban scale (mm/year).

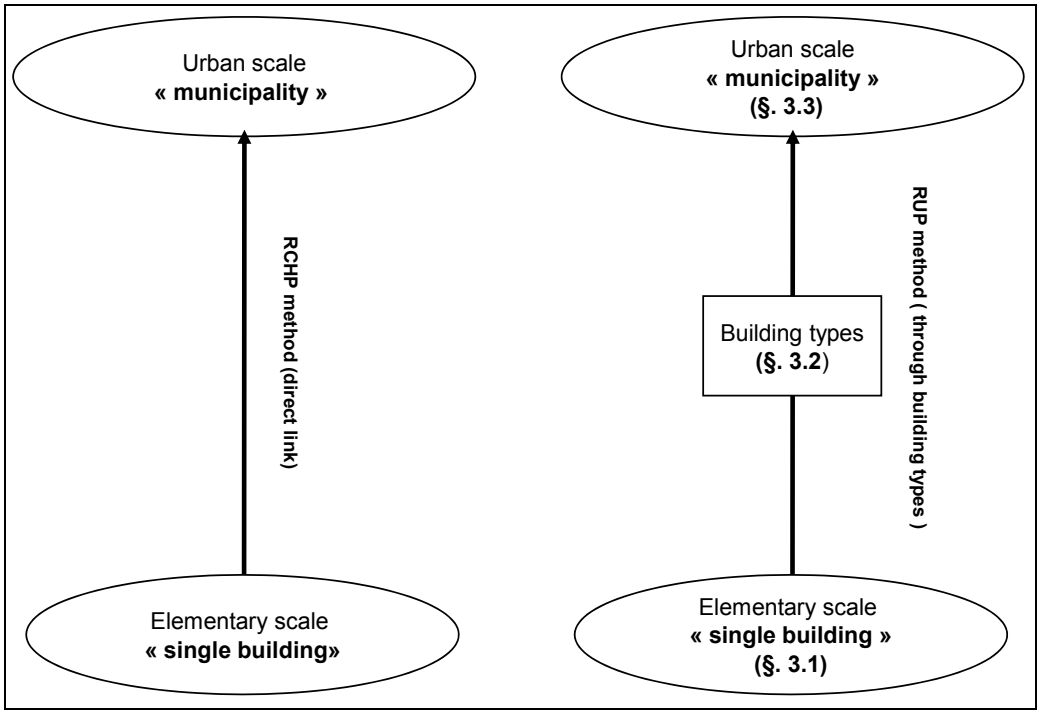
The RCHP calculation tends to overestimate the PPWS because it only considers the harvesting component and neglects the other two key components of a rainwater harvesting system, namely "storage" and "uses". Actually, because of these components, the PPWS represents only a fraction of RCHP. A more comprehensive approach needs to factor in the specific features of buildings which cannot be simply generalized at urban level.

The aim of this paper is to put forward a method that integrates this difficulty by factoring in the constraints involved in storing and using the harvested rainwater in order to estimate more precisely the water savings that can effectively be achieved at urban scale. A new method is developed, based on a new indicator: **rainwater utilization potential (RUP).**

3. Methodology

In order to switch from the building's scale to the municipal scale while integrating the constraints of storing and using the harvested rainwater, the objective is to adapt methods used on the building's scale so that they become usable at the municipal scale. Figure 1 synthesizes this methodology.

Figure 1. Methodology to link building scale to urban scale.



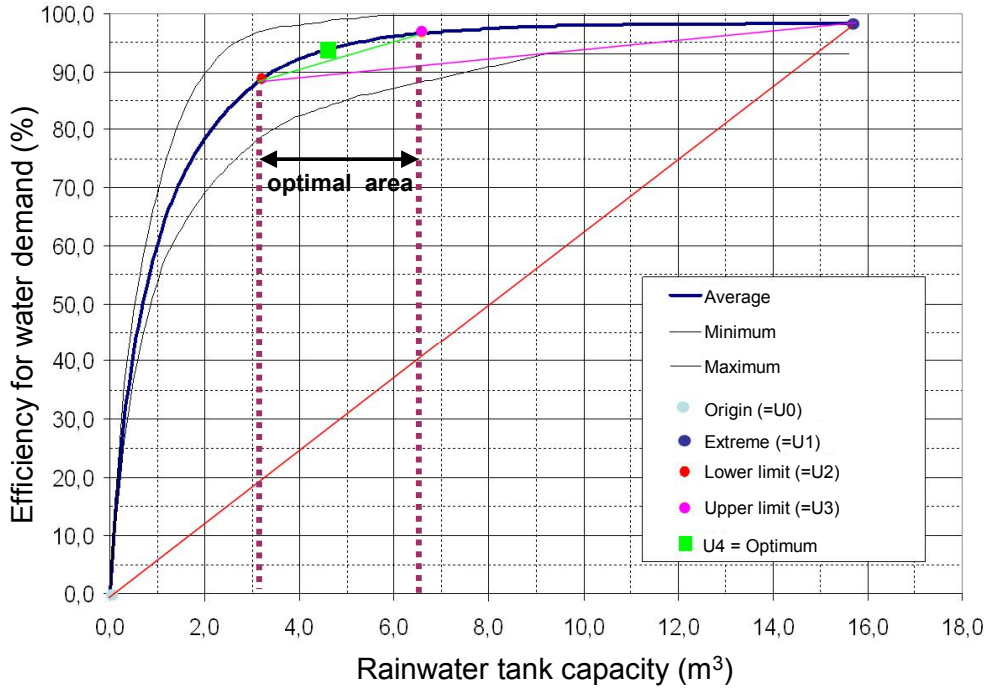
As shown in Figure 1, for switching from the elementary scale (building) to the municipal one, a new concept named "building type" is required. The next section details the methodology allowing the

calculation of the RUP at the municipal scale by describing the specific role of the building's scale, the building types, and the municipal scale.

3.1. Elementary Scale "Single Building"

The behavior of a RWH system for a single building has been modeled by Fewkes [18]. For a specific water demand D (m^3/year)—corresponding to a set of "targeted" uses for which potable quality is not required (such as: toilet flushing, watering, car washing and/or washing machine)—this model allows the drawing of the curve expressing the water-saving efficiency E (%) as a function of the storage volume V (m^3). In fact, E represents the proportion of rainwater used in the demand corresponding to these targeted uses. Such a curve is used by technicians as a decision-making tool for choosing the storage volume and to know the related average expected water savings in their projects. The decision maker has to select a point on the curve. In order to determine this point, design offices sometimes draw onto this curve an "optimal area" (see Figure 2), considered as a good compromise between the volume of the tank capacity and the water-saving efficiency. The decision maker then decides upon a point inside this "optimal" area.

Figure 2. Automatic method of extraction of optimal area. Source [27] (Example for an individual house).



A method of automatic extraction of this "optimal area" based on the creation of a sequence of points (Un) of the curve has been elaborated [27]. The sequence is defined as follows:

U0 = (0, 0), *i.e.*, the origin point;

U1 = (Max (E), Min (V)), *i.e.*, the first point of the curve E (V) from whom the value of E does not increase.

U(n + 2) is the point where the tangent in the curve is parallel to the right segment [Un, U(n + 1)]. The authors [27] showed that, considering the characteristic shape of this type of curve, point U2 and

point U3 provide good approximations of the lower and superior borders of the "optimal area". The point U4 supplies a proposal of optimal point.

By adopting the point of view of maximizing the quantity of usable rainwater, the point U3 is chosen to define the RUP value, as stated in Equation (2).

$$\text{RUP} = E_{U3} \times D \quad (2)$$

where:

- RUP: rainwater utilization potential (m^3/year);
- E_{U3}: efficiency for water demand (%);
- D: water demand (m^3/year).

It is worth noting that at this scale (building) the RUP is identical to the PPWS.

3.2. "Building Types"

A municipality generally contains a significant number of buildings. The calculation of the RUP of each of these buildings in order to aggregate the results at the municipal scale is a time-consuming and very difficult task due to the required variables to be completed for every building. It is thus necessary to find another method.

The approach proposed consists in grouping the buildings of the municipality in several "building types", each type comprising a set of buildings homogeneous with respect to the rainwater "uses scenario". The calculation of RUP for a building type is then calculated through an "equivalent building".

3.2.1. Description of "Uses Scenarios"

The criterion adopted for grouping together buildings is similar to "uses scenarios". Two buildings have the same rainwater "uses scenario" if they have the same uses (e.g., toilet flushing and watering) with the same *ratio* (e.g., 3 L/m^2 for watering a lawn) and the same *frequency*.

It is worth noting that the same use can have a different value for ratio or frequency depending on the kind of building considered or of the people considered. For instance, in a commercial building, the toilet-flushing ratio is different for employees and for visitors, because visitors do not spend all the day in the building. Table 1 summarizes the main uses and their related ratio and frequency which are factored into this study. The aforementioned values have been established by a variety of references and synthesized by Belmeziti [16].

Table 1. Parameters of the "uses scenarios".

Use	Ratio	Frequency
Toilet flushing–housing (1)	30 (L/capita)	every day (340 days/year)
Toilet flushing–employee (2)	18 (L/capita)	every working day (220 days/year)
Toilet flushing–visitor (3)	1.8 (L/capita)	every working day (220 days/year)
Toilet flushing–student (4)	4 (L/capita)	every working day (175 days/year)
Toilet flushing–overnight stay (5)	27 (L/capita)	every day
Watering (6)	3 (L/m^2)	every day between April and October (except on rainy days)
Floor washing (7)	0.15 (L/m^2)	4 times a week
Washing machine (8)	80 (L/capita)	once a week
Car washing–service station (9)	150 (L/car)	every month by car

3.2.2. Creation of "Building Types" and "Situation Types"

The creation of the building types requires, on the one hand, finding a building database covering the area of our study, and, on the other hand, adapting the categories of this database by similar uses scenarios as previously defined.

The land use database from IAU-IF (*Institut d'Aménagement et d'Urbanisme d'Ile-de-France,* the urban planning and development institute for the Greater Paris region) which covers all the Greater Paris Area has been chosen. The great advantage of this database is its exhaustiveness (it provides a breakdown of all buildings in the region). However, the buildings are grouped together by land use (according to MOS-IAU (*Modes d'Occupation des Sols de l'IAU*), the IAU-IDF's land use categories), whereas we wish to focus on grouping them together by rainwater "uses scenarios." It is thus necessary to reorganize the way the buildings are grouped to make it more relevant to our study. For grouping land use categories into building types, a procedure has been developed in three stages.

Stage 1: from "MOS-IAU land use categories" to "building categories". This stage consists in eliminating all of the MOS-IAU land use categories that cannot harvest and store rainwater, mainly unbuilt urban land (such as roads, woods and lakes) and a number of MOS-IAU categories for specific land/building forms with only negligible rainwater use (such as cemeteries). At this stage, we only retain the MOS-IAU categories relating to buildings that are able to harvest and use rainwater: 54 out of the 83 MOS-IAU categories of the IAU-IDF database have been selected and renamed "building categories".

Stage 2: from "building categories" to "building types". This stage consists in grouping the building categories according to the criterion with similar rainwater "uses scenarios". For example, here, secondary schools and higher schools can be grouped together, but primary schools stay apart (because, according to the French rainwater use regulation framework, the use of rainwater for toilet flushing is not allowed in this school category). We call these groups building types. This stage generated 13 building types from the 54 buildings categories obtained from stage 1.

Stage 3: from "building types" to "situation types". This stage aims to rework each building type according to its urban and functional reality by uniform sub-category in terms of uses scenario. We call these sub-categories "situation types". This stage generated 29 rainwater utilization situation types based on the 13 preceding building types. Table 2 describes all these situation types.

3.2.3. Building type RUP Calculation through "Equivalent Building"

The "equivalent building" is a virtual entity used to calculate the corresponding RUP of a set of buildings *within a same situation type* as if it were a single building, in order to avoid calculating the RUP of each building of the set. Technical characteristics of the equivalent building (roof area, number of occupants per category of use, surface to be cleaned, surface to be watered) are obtained by aggregating those of all the buildings included in the set. RUP of the equivalent building is obtained by applying the method used for the elementary scale (described in Section 3.1). In this method, 30 years of daily rainfall data in Paris (1977–2006) were used.

Table 2. Uses scenarios per situation-types.

Building type	Situation types of buildings	Toilet flushing	Watering	Floor washing	Washing machine	Car washing
Individual housing	Individual housing with a garden	(1)	(6)	(7)	(8)	
	Individual housing with no garden	(1)		(7)	(8)	
Collective housing	Collective housing with a garden	(1)	(6)	(7)	(8)	
	Collective housing with no garden	(1)		(7)	(8)	
Other housing	Temporary housing with a garden	(5)	(6)			
	Temporary housing with no garden	(5)				
Secondary activities	Secondary premises with a garden	(2)	(6)	(7)		
	Secondary premises building with no garden	(2)		(7)		
Commercial premises	Large commercial premises with a car wash device	(2)	(6)	(7)		(9)
	Large commercial premises with no car wash device	(2)	(6)	(7)		
	Small commercial premises	(2)	(6)			
Offices	Office premises accessible to the public with a garden	(2) (3)	(6)			
	Office premises not accessible to the public with a garden	(2)	(6)			
	Office premises accessible to the public with no garden	(2) (3)				
	Office prem. not accessible to the public with no garden	(2)				
Sport (structured)	Sports facilities with a green space	(3)	(6)			
	Sports facilities with no green space	(3)				
Teaching facilities	Education facilities with a green space	(4)	(6)			
	Education facilities with no green space	(4)				
	Higher education facilities with a green space	(2)	(6)			
	Higher education facilities with no green space	(2)				
Other facilities	Administration facilities with a green space	(2)	(6)			
	Administration facilities with no green space	(2)				
	Building service rooms			(7)		
Large infrastruct.	Large infrastructure	(2)	(6)	(7)		
Transport facilities	Transport facilities			(7)		(9)
Primary schools	Primary schools with a garden		(6)	(7)		
Healthcare facilities	Healthcare facilities with a garden		(6)			

Significant possible use (corresponding to the uses scenario. For numbers: § table 1)

Insignificant possible use (not corresponding to the uses scenario)

Use forbidden

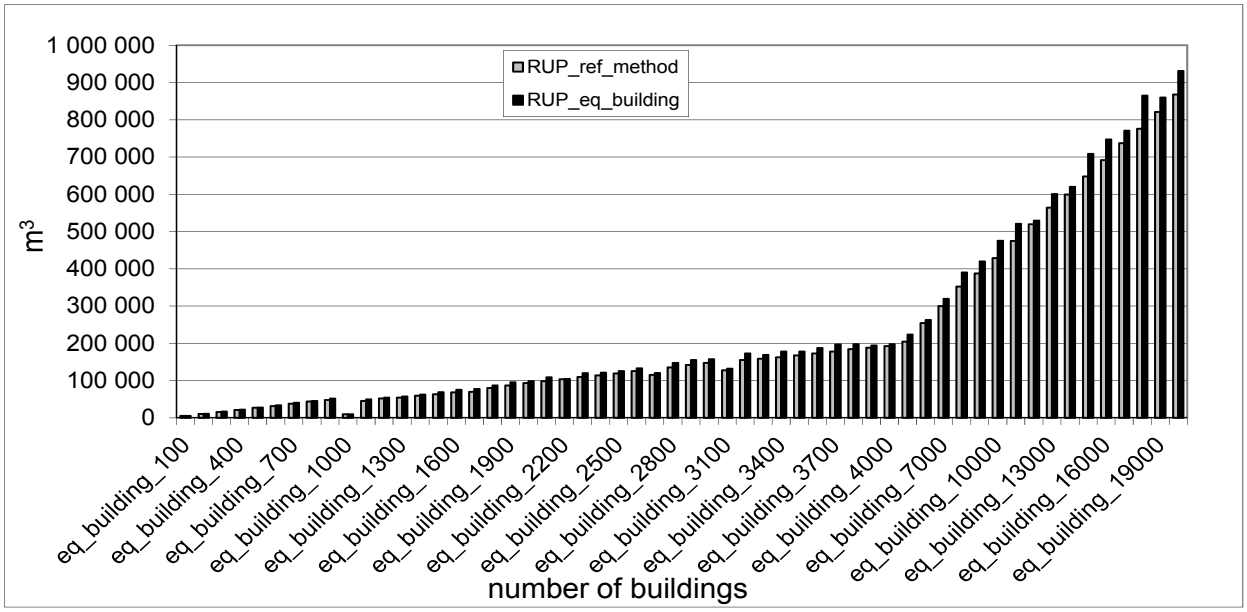
At this stage, the question that naturally arises is: within a same situation type, can the RUP of an equivalent building really represent the sum of all the *RUPs* of a set of buildings calculated one by one (which we name here "reference method")? To answer this question, we developed the following testing protocol:

A database of 4000 realistic "individual houses with no garden" with roof surface and number of occupants is randomly created by crossing census data and cadastral data from the region Ile-de-France. It is worth noting that "individual housing with garden" is chosen, because it is the most significant situation type observed in all the municipalities of the region (see Section 4.1.1, the example of Colombes).

- More than 50 equivalent buildings are then created by randomly selecting a set of houses from the database. For example: the first equivalent building consists of 100 buildings randomly selected from the 4000 building database and the last equivalent building consists of 20,000 buildings where each building of the database may be selected multiple times.
- The calculation of RUP of each buildings set is evaluated based on the following methods: "reference method" (it means adding the RUP values of each building of the set) and "equivalent building" (it means calculating the RUP for the equivalent building corresponding to the set of buildings selected)

The comparison between the results of the two methods is reported in Figure 3.

Figure 3. Comparison of the RUP for the situation type "individual housing with garden" calculated by "reference method" (RUP_ref_method) and "equivalent building" (RUP_eq_building).



The comparison shows that the RUP value calculated using the "equivalent building" is slightly greater than the RUP value calculated using the reference method, the difference between both results being always lower than 10%. This testing protocol allows us to consider the "equivalent building" method for calculating RUP of a situation type. In comparison to the "reference method", the equivalent building method means considerable costs incurred by computing time and resources needed.

3.3. Urban Scale (Municipality)

Using the land use database from IAU-IDF, any municipality of the Ile-de-France region can be divided into several building types and their related situation types (13 building types and 25 situation types, as explained in Section 3.2). However, assessing the contribution of each building type to the total PPWS at the urban scale remains a complicated task, mainly because of the lack of data for some buildings. A set of rules has been defined in order to overcome this difficulty.

Rule 1. Classification of building types into significant *and* marginal *ones*

For a given municipality, the *marginal building types* are all the building types for which the cumulated RCHP value does not exceed 10% of the global RCHP of the municipality by beginning with the lowest types in RCHP. All the other building types are considered as *significant building types*.

Rule 2. Selection of the indicator to evaluate the PPWS related to the kind of building types

For any significant building type, the related PPWS is assessed by the RUP indicator. For any marginal building types, the related PPWS is directly assessed by the RCHP indicator.

Rule 3. Evaluation of RUP for significant building types

For each significant building type, the RUP of all the related situation types (see Table 2) is calculated. The characteristics of the equivalent building of each situation type are defined using several sources of information: land use database from IAU-IDF, census data from INSEE (*Institut National de la Statistique et des Etudes Economiques*), and topographic information database from IGN (*Institut Géographique National*). When required information does not exist in these sources, a specific survey has been conducted in order to produce it [16].

The RUP value of the building type is then defined as the highest value of the RUP of its related situation types.

Rule 4. Evaluation of the PPWS of the municipality

Finally, the PPWS of a given municipality is assessed by adding the RUP of all the significant building types and the RCHP of all the marginal ones.

4. Application Example: The Case of the Municipality of Colombes

In this second section, based on the example of the *municipality* of Colombes, we will set out the methodology for moving to urban scale as described previously.

4.1. Modeling

4.1.1. Breaking out Significant and Marginal Building Types

A given municipality comprises between 10 and 13 building types. Some of these types are of marginal importance in the municipality in question and are not significant in terms of rainwater use at the municipality level. We will use the *RCHP* to assess the importance of a particular building type. We consider that if the *RCHP* for a building type is very low in relation to the *RCHP* for the municipality as a whole, then its *RUP* (if this has been calculated) will be marginal in relation to the *RUP* for the municipality as a whole.

In practical terms, we will define marginal building types in a given municipality as the building types of which the sum of their *RCHPs* does not exceed 10% of the municipality's total RCHP, starting with the type with the lowest *RCHP*. The other types are considered to be significant.

Table 3 gives the RCHP and the category of each building type for the municipality of Colombes.

The RCHP of each building type has been evaluated using the Equation (1) (see Section 2): the surface of the roofs of buildings (TRA) is obtained by aggregating the corresponding MOS-IAU data,

the recovery coefficient (RC) is considered as a constant for all buildings (0.85) and annual rainfall (R) is calculated on the base of 25 years of precipitation in the Paris region.

Table 3. Table of significant and marginal building types (Colombes).

Building type	RCHP (m^3/year)	% in relation to total RCHP for the municipality	Sum of RCHPs (from lowest RCHP)	Marginal or Significant?
Large infrastructure	8.04×10^2	0.09%	0.09%	Marginal
Other housing	1.29×10^3	0.14%	0.23%	Marginal
Commercial premises	1.60×10^3	0.17%	0.40%	Marginal
Sport (structured)	4.73×10^3	0.50%	0.90%	Marginal
Administration facilities	1.24×10^4	1.33%	2.23%	Marginal
Healthcare facilities	1.57×10^4	1.67%	3.90%	Marginal
Other teaching facilities	2.39×10^4	2.55%	6.45%	Marginal
Offices	3.02×10^4	3.21%	9.66%	Marginal
Primary schools	4.27×10^4	4.54%	14.20%	Significant
Secondary activities	6.02×10^4	6.41%	20.61%	Significant
Collective housing	3.22×10^5	34.30%	54.92%	Significant
Individual housing	4.24×10^5	45.08%	100.00%	Significant
Municipality of Colombes	**9.40×10^5**	**100.00%**	–	–

This table highlights four building types considered as significant because of their great potential for collecting of rainwater "RCHP". For these four building types, the RUP will be calculated using the detailed method, as explained in Section 3. Moreover, it is worth noting that it is easier to complete the variables needed to calculate the RUP, especially for the last two classes (individual housing and collective housing), which are the most significant. The eight remaining building types are considered marginal types, because their cumulated RCHP is already low and therefore can be used directly as an acceptable proxy of their contribution to the PPWS of the municipality of Colombes.

It should be noted that the number and the nature of the significant building types and the marginal ones may vary from a municipality to another. For example, for Drancy (another municipality in the Paris region), two significant building types (individual housing and collective housing) and ten marginal building types were identified [28].

4.1.2. Sources of Information for Calculating Variables

Two methods were used to calculate the required variables.

Direct method (data available in the sources mentioned in Section 3.3, rule 3): for Colombes, data for "built area" and "number of inhabitants" is available for each building type using IAU-IDF and INSEE databases.

Indirect method (no data available): data for "area of lawn to be watered" is not available. It is thus calculated by analyzing the components of plots that comprise a given building type. Equation (3) describes these components:

$$Spl = Sp - (Sb + Sa) \quad (3)$$

where:

- Spl: area of lawn to be watered (*i.e.*, the target data);
- Sp: area of the plot (*i.e.*, available data);
- Sb: built area (*i.e.*, available data);
- Sa: other area reserved for traffic and parking within the plot (*i.e.*, unavailable data).

To obtain the area of lawn to be watered, we analyzed a certain number of plots for each building type in order to estimate the "other area" in relation to total plot area. We performed the analysis from the Google Earth database by extracting the necessary data based on a randomly selection of plots.

Table 4 shows the results of analysis using 60 buildings belonging to the four significant building types. For each building, we calculated the area of the plot (other area) that fulfills diverse functions (such as circulation or playground). The area of lawn to be watered is then deduced by Equation (3). In Table 4, we summarize the calculation of the other area in % of the area of the plot of each building type.

Table 4. Method of extracting of "area of lawn to be watered".

Building type	Number of buildings studied	Average range of "other area" (% of plot)
Individual housing	30	20%
Collective housing	10	33%
Secondary activities	10	18%
Primary schools	10	12%

To facilitate calculations, we took the average as a reference when deducting the area of lawn to be watered. Table 5 presents the variables needed to calculate RUP for the three significant building types.

Table 5. Values of the variables needed to calculate "RUP".

Building type	Built area (m^2)	Number of capita	Lawn area (m^2)	Other area (m^2)
Individual housing	7.74×10^5	2.38×10^4	1.62×10^6	1.79×10^3
Collective housing	5.98×10^5	5.65×10^4	2.75×10^5	2.75×10^3
Secondary activities	1.10×10^5	7.77×10^3	Not significant	5.19×10^3
Primary schools	7.80×10^4	Not known	3.49×10^4	8.13×10^2

The lawn area for the building type "secondary activities" is considered as not significant, because the buildings of this class are dedicated to industrial activities, where green spaces are scarce and small. For the building type "primary schools", it is not necessary to know the number of inhabitants, because the use of rainwater is prohibited within this building type in France.

4.1.3. Calculating RUP at Situation Type level

For each significant building type, we calculated the RUP for the corresponding situation types by taking the aforementioned rainwater "uses scenarios" (see Table 6).

For the four significant building types of the municipality of Colombes the situation type depends on the presence or absence of a garden (lawn watering). For this purpose, several usage scenarios of rainwater that take into account the presence or absence of a garden were tested.

The simulation tool developed by de Gouvello [27] is used. The results of simulation of each situation type are reported in Table 7.

Table 6. Situation types and uses scenarios studied for Colombes.

Building type	Situation type	Corresponding uses scenario
Individual housing	Individual housing with garden	Toilet flushing "housing" + watering + floor washing + washing machine
	Individual housing without garden	Toilet flushing "housing" + floor washing + washing machine
Collective housing	Collective housing with garden	Toilet flushing "housing" + watering+ floor washing + washing machine
	Collective housing without garden	Toilet flushing "housing" + floor washing + washing machine
Secondary activities	Secondary activities with garden	No uses scenarios
	Secondary activities without garden	Toilet flushing "employee" + floor washing
Primary schools	Primary schools	Toilet flushing "student" + floor washing

Note: Gardens are not significant in this building type.

Table 7. "RUP" calculations by situation type for Colombes.

Building type	Situation type	RUP (m^3/year)
Individual housing	Individual housing with a garden	2.78×10^5
	Individual housing with no garden	2.30×10^5
Collective housing	Collective housing with a garden	2.10×10^5
	Collective housing with no garden	2.11×10^5
Secondary activities	Secondary activities with a garden	0
	Secondary activities with no a garden	3.04×10^4
Primary schools	Primary schools	1.26×10^4

We observed that, in the case of collective housing, the situation type "with no garden" promotes more use of rainwater compared to the situation type "with a garden". This comes from the shape of the curve of the tank volume based on the recovery rate (see Figure 2), which becomes more linear in shape in the case of a situation type with garden. Therefore, the projection of point U3 gives a rate of efficiency "E" less than that given in the case of a situation type "with no garden".

4.1.4. Choice of Situation Type and Evaluation of the PPWS

For each building type, the situation type with the major RUP is selected (rule 3 in Section 3.3). The situation type selected for the significant building types and the PPWS for the municipality of Colombes are presented in Table 8.

Table 8. RUP of the municipality of Colombes.

Building type	Situation type selected	RUP (m^3/year)
Individual housing	Individual housing with a garden	2.78×10^5
Collective housing	Collective housing with no garden	2.11×10^5
Secondary activities	Secondary activities with no a garden	3.04×10^4
Primary schools	Primary schools	1.26×10^4
Marginal types (RUP = RCHP)	–	9.09×10^4
PPWS for the Municipality of Colombes	–	$\mathbf{6.24 \times 10^5}$

4.2. Analysis and Interpretation of Results

The application of our method shows that the municipality of Colombes is able to save 6.24×10^5 m^3 of drinking water per year using rainwater for some uses (toilet flushing, watering, floor washing and washing machine). Such savings represent 10% of the total drinking water consumption of the municipality.

The results also show that the PPWS of the municipality of Colombes registers a reduction by 35% compared to the method identified in the literature using only RCHP [26] and our own method using RUP for the significant building types. The individual housing represents the dominant class (45%), followed by collective housing (34%). The secondary activities class represents 5% and the primary schools class represents 2%, while the remaining classes (eight classes) share a 15% participation. As the residential sector (which includes both individual and collective housing) is important (79% of the municipal PPWS), this sector has to be taken into account in priority strategies for the development and dissemination of rainwater harvesting in the municipality of Colombes.

5. Conclusions

This study proposed a method for evaluating the potential for potable water savings (PPWS) achievable by applying rainwater harvesting practices to an entire municipal area.

The method consists of, first, a methodology for changing scale (based on *building types* in relation to rainwater *scenarios uses*) and, second, calculating water savings (based on rainwater harvesting and utilization potential, RUP). For the specific municipality of Colombes (in the Paris area), the PPWS calculated by this method represents about 10% of the total drinking water consumption of the municipality and is 35% less than the PPWS calculated considering that all the water from the roof is available.

It is worth noting that the proposed method is based on a maximalist development of RWH across the municipality (all the buildings of the town recover and use rainwater). To have a more realistic assessment of the PPWS, it will be necessary to define other development scenarios based on the behavior of stakeholders (property owners and policy makers, environmental associations, *etc*.). It is also important to point out that such a method gives an average value of PPWS based on past rainfall series. Therefore, this method does not take into account current inter-annual fluctuations nor future fluctuations related to the climate change, which may affect noticeably the efficiency of the RWH as it has been shown in the case of Australia [29].

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