Sustainable water management methods in Hungary.

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SUSTAINABLE WATER MANAGEMENT METHODS IN HUNGARY

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Abstract:
According to many facts, the broader utilization of rainwater is desirable. It raises the question how this goal can be achieved and who would potentially fund such projects. The answer is rather complex, and closely associated with surface and groundwater management and protection. Sustainable water quality is a common interest for everyone. As a result of environmental damage, new technical achievements are introduced into water extraction protocols; more sophisticated water treatment methods, drilling deeper wells result in additional costs that ultimately burden common people in a form of higher bills or taxes. From this viewpoint, protection of our water supplies is a financial concern to everyone. In our paper we analyzed a case study supported with our calculations and the available climatic and social statistical data and we set up a useful sustainable water management model based on the rainwater harvesting practices.

INTRODUCTION

Surface and subsurface water contamination has been in the centre of public awareness for the past few decades. Either directly or indirectly, humans are the major agents of such water contamination. Beyond the widespread ecological effects of contaminants, the utilization of such waters is limited for both communal and industrial purposes. For obvious reasons, water quality is especially important in drinking water management.

Due to the global hydrologic cycle, water treatment is essential in most cases when surface or groundwater is used for drinking purposes. Thus, as a result of higher average water contamination levels, treatment costs have also increased. Simultaneously, water consumption has also shown an increasing tendency. At the same time, in many cases, water management is wasteful and impractical. Commonly, besides everyday communal consumption, drinking water is used for irrigation, car-washing, or in technological processes of small industries.

Communal drinking water in Hungary is not only obtained from surface waters but, primarily, from wells. In the latter cases water is pumped to the surface from confined aquifers, which are less contamination-prone than shallow unconfined aquifers. However, undesired contamination of confined aquifers has also been observed lately.

As a consequence of increasing water costs, many households have drilled their own well or, in some cases, temporarily non-used wells were reopened and reutilized. These private wells have their own benefits and drawbacks. The use of such water decreases the use of expensive pipe-line supplied running water, and, for instance, is used for irrigation or car-washing.

However, at the same time, it does not decrease the volume of water extracted from subsurface, only distributes the water more evenly and over a larger area. In several cases, due to the high dissolved electrolyte concentration of these aquifers, such waters are non-usable for irrigation or industrial purposes. Even though it considerably varies spatially, usually a large one-time investment is associated with the establishment of communal wells (BUGYA 2004, WILHELM 2008).

ADVANTAGES AND DRAWBACKS OF RAINWATER USE

The most practical way to meet our everyday water needs is rainwater harvesting. Practically, this water is free of charge and almost pure water, and can be treated easily and economically, at least compared to well waters. Still, its collection is only sparse and negligible in volume. Beyond its obvious availability, it has several direct and indirect advantages.

- Clean and almost pure, however, locally acidic or alkaline (yet, acid rains are more frequent). Most importantly, it does not include any microbial contaminations. Additionally, as it does not contain any dissolved mineral[1], it has a low hardness, i.e. CO_3^{2-} content. It is optimal for irrigation and general communal use.
- It does not decrease groundwater level and moderates general groundwater extraction rate.
- Its use and storage is cheap and economical
- Mitigates the cost of pipeline and drainage establishment and maintenance
- Reduces soil erosion on areas of strong relief. Due to the so-called umbrella effect, drained water, is concentrated in gutter outlets, thus causing significant erosion when directly contacts with soil. Gully erosions can cause considerable damage in places (WILHELM 1996, 1997). Also, on highly sealed built-up surfaces, infiltration is limited. In such places water erodes the surrounding areas more intensively[2]. By the roof-harvesting of precipitation, erosion rates would considerably dwindle.

The primary drawback of rainwater harvesting is the high prime costs of cistern or storage facility establishments. Secondly, water needs to be pumped to the site of utilization, which increases the electricity consumption of the household[3]. Thus, a significant single-time investment is associated with cistern building, which likely involves significant soil removal and transportation in advance.

According to the above mentioned facts, the broader utilization of rainwater is desirable. It raises the question how this goal can be achieved and who would potentially fund such projects. The answer is rather complex, and closely associated with surface and groundwater management and protection. Sustainable water quality is a common interest for everyone. As a result of environmental damage, new technical achievements are introduced into water extraction protocols; more sophisticated water treatment methods, drilling deeper wells

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1 More precisely, rainwater contains some dissolved minerals or suspended particles, for instance in the form of salt crystals or condensation nuclei. Still, their concentration in rainwater is negligible compared to that of surface waters.

2 The area of sealed surfaces have considerably increased over the past decade or two. Consequently, soil erosion is significant in certain parts of the city.

3 Solar panels can be purchased at lower price for such purposes, thus the increase of energy costs is negligible.

result in additional costs that ultimately burden common people in a form of higher bills or taxes. From this viewpoint, protection of our water supplies is a financial concern to everyone.

Today in Hungary, the majority of environmental investments are analogous to infrastructural development (KOVÁCS 2003). A question arises again: would that be practical to include the rainwater-harvesting techniques in such financial funding and investments? Such programs could finance the establishment costs of cisterns, as well as subsidizing the construction and modernization of water treatment and sewage systems. With very little investments remarkable results could be achieved not only at the level of the individual but for the entire society. Considering that mean annual precipitation in Hungary is 600 mm, from a 100-m^2 roof-area 60 m^3 water can be harvested annually. This volume would cover the water use of an average Hungarian family for the time period of 9 to 10 months. However, to start such environmental-conscious projects, demands and potentials need to be estimated and surveyed in advance.

For instance, constructing cisterns of concrete shells can be problematic on formerly built-in areas. In the case of higher customer demand, prefabricated cisterns of either plastic or metal walls can be produced, in a size range of 5 to 10 m^3. The use of this latter tank types would be more cost-efficient and less labor-intensive than the concrete cisterns, and additionally, can be fabricated much more rapidly, which also saves production costs. With appropriate planning, the most suitable cistern type and size can be chosen, thus increasing efficiency and reliable water supply.

For obvious reasons, despite the cistern systems, demand for running water would not eliminate in any household. However, consumption of running water is expected to decrease when a cistern system is introduced. This suggests a decreasing tendency of water extractions from the local aquifers and surface waters, and, simultaneously water suppliers could provide services of higher quality for the consumers.

This paper presents a case study with the appropriate conclusions. The case study is based on the data of the meteorological station of the national network located at Tiszadob, Eastern Hungary. We analyzed a 49-year rainfall dataset of this meteorological station, and provided estimations for the most efficient rainwater use protocol. Our conclusions are based on a 10-square-metre rainwater harvesting area.

OVERVIEW OF THE WATER-HARVESTING SYSTEM

- Harvesting area. The most appropriate surfaces are house or garage roofs. Obviously, the larger the surface area, the more water can be collected. Roof material can also play an important role in water quality. Various clay and concrete roofs, solid plastic covers, panes, and metal connecting pieces are the most desirable as their components are practically insoluble. However, care needs to be taken to keep the roofs as clean as possible. The recently popular tar-roofs are undesirable from this viewpoint. Due to the direct sunlight in the summer tar can melt[4]. During direct contact with rainwater, molten tar contaminates the effluent, thus limiting the general use of the harvested water, requiring an additional decontamination procedure.

- Effluent draining system or gutters. Care also needs to be taken to keep the system clean, congestion-free and unplugged.

- Water container or cistern. Rainfall is temporally unevenly distributed. The cistern stores the collected rainwater until water is used for the selected purpose. From a sanitary viewpoint it is important that water quality is maintained in the cistern on the long run. Usually, cistern walls are made of concrete, with cement-mortar insulation to achieve water impermeability. However, prefabricated plastic and metal (usually steal) shelled cisterns also exist. Brick-walled cisterns can also be found; in such cases cement mortar plasters make the wall impermeable. The choice of the building material is primarily determined by the costs of the material. Practically, large containers are built underground, which decrease the hazard of freezing. Underground tanks obviously require earth removal and digging. As prefabricated tanks of appropriate size and shell-material rarely available, brick and concrete walls are the primary materials of choice. However, such materials are rather cost-intensive, due to their large weight and volume that results in high transportation and storage costs. Framework and plaster are also expensive, further increasing the construction costs. The above mentioned prefabricated tanks could be desired alternatives of the brick and cement cisterns.

- The size of the cistern is also an important concern during its construction. When surface tanks are built, it should be created in accordance with its surroundings. Such problems can be neglected when underground tanks are created. The larger the cistern, the larger the construction costs are, and more issues are associated with its establishment (e.g. more soil removal, issue of soil deposition, etc.). However, specific costs (per unit volume of water) decrease with increasing cistern sizes. A smaller cistern is cheaper, but, perhaps is

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4 Construction manuals also refer to this. Special attention needs to be paid, as can result in the shifting of the cover element, or can cause its damage.

unable to store sufficient volume of water and can only partially operate. If the cistern is oversized, stagnant water can trigger undesirable microbial and chemical processes and aquatic fauna appears in the water. Furthermore, construction costs are unnecessarily high and cleaning and maintenance costs are extreme. Thus, we need to find the most suitable cistern size for our needs. We are discussing this problem in the latter part of this study.

- Household water supplier and pumps. Pump conveys the water to the site of use from the cistern. According to their flow rate (Q) or discharge capacities, there is a considerable price different between the various pump types. A small pump can be purchased for 8 to 10 thousand HUF, while a more complicated, more powerful pump (so-called household water-supplier) typically costs HUF 25,000 to 50,000.

- Other supplementary parts. Filtering and purifying systems. Filter types and costs vary to a great extent according to quality demands and the type and source of water used. Physical straining is highly recommended before the water flow reaches the cistern, for instance in a form of gravel bed. Incorporation of active carbon and microfiltering systems are also suggested.

SIZE OF THE CISTERN

The size of the cistern is determined by the following factors:
- The size of the available area
- Available financing
- Annual precipitation
- Temporal distribution of rainfall
- Surface area of rainwater-harvesting surfaces
- Planned and expected changes of the rainwater-harvesting surfaces
- Length of snow pack accumulation
- Sublimation of snow during accumulation
- Volume of utilized water
- Temporal distribution of water usage intensity
- Other (e.g. static) factors

Consequently, climatic and especially precipitation characteristics of the studied area have to be examined on a statistical basis. Similarly, communal water use can be estimated. In a general case per capita water consumption can also be reliably determined. Maximum water use can vary greatly according to the households; however, an average minimum value can be calculated with a relative precision and will be discussed later in this article.

The most important climatic properties of Tiszadob are the followings:
- Mean annual precipitation: 557 mm
- Annual sum of precipitation when daily precipitation exceeds 1 mm per day: 521 mm
- Characteristic annual minimum and maximum precipitation: 400 mm and 700 mm
- Recorded lowest annual precipitation: 350 mm
- Recorded highest annual precipitation: 900 mm
- Longest expectable drought: 90 days
- Time period of longest expectable drought: any time throughout the year
- Wettest week during a calendar year: May and June
- Total precipitation of the wettest week of the year: 10 to 15% of the annual total precipitation
- Average number of winter days annually (mean daily air temperature is equal or less than 0°C): 30−35.
- Total precipitation of the winter season: 200 mm
- Total evapotranspiration in the winter season: 100 mm
- Proportion of the total precipitation of the 10% wettest days: 37−42% of the annual precipitation

VOLUME OF POTENTIALLY HARVESTABLE PRECIPITATION ANNUALLY

In this case study, theoretically, from a roof area of 10 m^2, 5.57 m^3 of water can be collected. Considering a normal temporal distribution of the total annual precipitations, the probability of the lowest and highest annual rainfall is 7% and less than 1%, consecutively. The probability of characteristic annual rainfalls exceeds 10%, thus, practically, unlike the observed extremes, they should be considered in our calculations below.

Thus, on a statistical basis, we can state that annually 5.57±1.50 m^3 precipitation can be collected. However, this theoretical maximum value is reduced by the following factors:

- loss due to evaporation
- loss due to infiltration
- amount of "rinsing" water

Loss due to evaporation is negligible as water rapidly flows from the roof to the cistern. Hot roofs are also rapidly cooled by the rainwater, further reducing evaporation loss. Losses are more significant over the winter season when snow accumulates on roofs for weeks or even for months. In this case, snow slowly melts, then evaporates, or sublimates directly forming water vapour. As a general observation, during a pronounced warm up period, 10 cm of snow can be lost due to sublimation. This physical process is even more pronounced when relative humidity is low in the air mass above. Unfortunately, relative humidity data is not available at the meteorological station, thus we are unable to consider this physical property. When snow melts, evaporation is still a factor of water loss; however its volume is much smaller then in the case of sublimation.

In Tiszadob, the majority of the annual precipitation is rainfall. In many cases snow does not accumulate as in many cases it melts or sublimates within hours or days. It is important to note that even in the winter season, precipitation is predominantly rain, thus decreasing the potential length of snow accumulation. Thus evaporation and sublimation losses of snowpacks should only be considered when snowpack reaches a considerable depth. According to the long term dataset, snowpack depth very rarely exceeds 50 cm in the studied area. In such cases about 50 to 70 mm of water stored in the snowpack. By assuming a 50% evaporation loss (remember total evaporation loss in the winter season is 100 mm) we can conclude that evaporation loss form snowpack does not exceed 30 to 40 mm annually. By subtracting this value from the theoretical maximum, 520 $\pm$ 150 mm of precipitation can be collected annually. Including additional losses, such as evaporation from the gravelbed, adsorption of water by the roof material an annual 500 ± 150 rainwater can be potentially harvested during a year. However this value is further decreased by the water obtained from rainfalls providing less than 1 mm precipitation. This amount is unsuitable for the appropriate dilution of contaminants accumulated on roofs and is only able to rinse them off. Thus, such effluent is highly contaminated and partially adsorbed to the roof by adhesive forces. Thus we can consider this rinsing water as a loss. Since the amount of precipitation accumulated from these < 1mm/day rainfalls totals 36 mm, the annual harvestable water reduces to 470 mm$\pm$150 mm considering a roof area of 10 m^2. This amount equals to a water volume of 4,7$\pm$1,5 m^3, that is about 84% of the total annual volume of water from rainfall.

TEMPORAL VARIATION OF RAINFALL WATER HARVESTING–ISSUE OF WATER USE AND RECHARGE

Due to annual fluctuation of both the rainfall and water use distribution cisterns have to be built with some excess volume. If rainwater distribution is even throughout the year, then we only need to consider the uneven use. If we look at the other extreme, i.e. the annual amount of precipitation reaches the surface over a single occasion then obviously the volume of the cistern need to equal with this amount. However, reality lies in between these two extreme cases.

Annual rainfall is unevenly distributed in Tiszadob. For instance, from August 1st, 1961 to November 1st, 1961 only 23.79 mm of rainfall was measured, and no rainfall was detected between August 1st , 2000 and August 30th, 2000. Monthly precipitation in June, 2003 totaled only 8.6 mm.

A good example of the wet extremes is June, 1958, when the monthly precipitation reached 196 mm. On June, 17th, 1977 79 mm of rainfall was measured in a few hours, in October, 1974, 195 mm and in March, 2001 78 mm precipitation was registered. In other words, droughts last as long as 3 months continuously, or precipitation that generally falls over a month and half can reach the surface in a single day. However these are extremes that cannot set the framework of cistern constructions.

These extremes imply that cistern-owners have to prepare for a 30-day period with no rainfall at all while in other cases 0.05 to 0.07 m^3 m^{-2} of rainwater can be harvested over a week. Water demands over droughts can be amended by pipe water or water from wells, as sufficient amount of water requires unrealistically large cisterns in such cases.

Also, recharge rates can be low and insufficient following droughts when precipitation is low throughout the year; such observation was made in the year 2003. From the viewpoint of extraordinarily wet periods, construction of extremely large cisterns is cost-inefficient and impractical. Extremely high rainfall rate is typical in wet years; during such periods water demands are less, and cisterns suffer from lack of water. At Tiszadob, an optimal cistern need store 4.7m^3 $\pm$1.5m^3 of water annually. At he same time, the cistern need be capable to store 0.7 m3 short term water input. If water supply can be solved solely from local sources (wells, streams, rainfall) then the cistern can be recharged from such water sources. If running water is available, such problems can be neglected. When cisterns are empty, general maintenance can be conducted.

WATER USE

Water demand is even more unevenly distributed throughout the year than water recharge. Although its value can be somewhat closely estimated, still, it can only be used with high uncertainty in our calculations. The degree of consumption is determined by the following factors:

· Use of water (drinking water, general household use, irrigation, etc.)
· Temporal distribution of water use (diurnally, weekly, weekends only, during droughts, etc.)
· Number of consumers/users (if used as drinking water or for general household purposes)

According to the objectives of our studies, we only discuss the use of water for drinking and general household purposes below. Water demand depends on the following factors:

· social factors and traditions
· level of conveniences and infrastructure
· number of users

Our calculations are based on average Hungarian living standards and level of conveniences. Besides the everyday cooking and drinking water consumption, it includes laundry, flush toilet, weekly cleaning of apartments and houses, showering, etc.

Our calculations are based on one, - two, and four-member families. According to the Hungarian Statistical Office (KSH), average monthly water use in Hungary is about 3.5 to 4.0 m^3. Thus the average monthly water use of a single-member household is 3.5 m^3. The average monthly water use of a two-member family is 6 m^3, while that of four-member family is 10 m^3, obviously on a considerable range[5]. As it is evident from the data, there is a nonlinear relationship between the number of family members and water consumption, its causes, however, are not discussed in the paper.

In the case of one-member family, annual water use is 42 m^3. In Tiszadob, this amount can be harvested from a collection area of 84 m^2. During a wet year, however, a harvesting roof area of 65 m^2 is sufficient, while in a dry year 120 m^2 is required. This roof area is identical with a ground area[6] of about 60 m^2, as the roof covers a larger area than the building's groundplan area. If we intend to rely on this water source during droughts, we need a building area of about 100 m^2. In a case of a two-member family, water demand is 72 m^3 annually, requiring a roof area of 150 m^2 annually in a year of average precipitation. In a dry year however, a roof area of 225 m^2 is required, while in a wet year 112 m^2 is sufficient. Converting these roof areas to groundplan areas, 160, 240, and 100 m^2 areas are needed, resp. The annual water demand of a four-member family is 120 m^3. In an average year this volume of water can be harvested from a roof area of 250 m^3, in a dry year from 375 m^2, while in a wet year from 194 m^2.

However, we need to emphasize, that these roof and groundplan areas are estimations based on average statistical values. The given value can vary greatly according to the type of settlements, traditions, and income levels. From the above discussion, two conclusions can be drawn:

· Considering the average house groundplan areas, roof areas are insufficient to cover annual water demands by roof-harvesting rainfall. Thus water demands has to be supplemented with running water or water drawn from wells.
· modern households use water wastefully, thus mitigation of unnecessary water use would be desirable[7].

No national average groundplan area values are statistically available for houses which are potentially capable harvesting rainwater (e.g. detached family or farm houses). Thus groundplan areas have to be estimated based on personal studies.

Statistical data indicate that recently built houses include at least three bedrooms. As a consequence, average groundplan areas of houses have increased lately. However at same time, houses with smaller-than-average plan area are also typical among families of low income. Based on these estimation and data analysis, average house plan areas in Hungary ranges between 60 to 80 m^2, however, certain values deviate considerably. Consequently, in our calculations, we can use an average plan area of 70 m^2 with an equivalent roof area of 80 m^2. However, in many cases additional utility buildings (garages, storage rooms, etc.) are also found in the same property. With the harvesting area of 80 m^2, the following results can be calculated:

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5 It depends on the age distribution of the family. Water use of old-fashioned and modern washing machines can differ greatly.

6 The surface area of the roof is projected to an equivalent horizontal surface. Consequently it differs from the roof area, as roof areas can be much larger.

7 The per capita water use for drinking, eating and cooking purposes is 3 to 4 liters per day. It adds up to 100 to 120 liters monthly. To flush toilets, 3 to 4 times more water is used (http://www.foek.hu/korkep/vizgazd/3-2-8-0-.html).

Table 1. *Theoretical percentage of volume of harvested rainwater compared to the total water demand of an average household in a dry, an average, and wet year, assuming 80 m² water harvesting area (discussed in details in the text)*

No. of household members	Dry year (25,6 m³/80m²)	Average year (37,6 m³/80 m²)	Wet year (49,6 m³/80m²)
1 member (42 m³)	60%	89%	118%
2 members (72 m³)	35,5%	52%	69%
4 members (120 m³)	21%	31%	41%

(Source: BUGYA, T.–WILHELM, Z. 2006)

Assuming average water consumption rate and water harvesting roof areas, annual water demands cannot be solely covered from harvested rainwater. However, especially in a wet year, a considerable proportion of water demand can be met form this source. On average, one third of the annual water demand of a 4-member family can be covered from rainwater, and one-fifth during a dry year. Fulfilling water demands (e.g. irrigation water) this way would be especially beneficial in rural areas. Consequently three cases should be studied:

1. Household water demands are completely covered with rainwater;
2. Rainwater is only used for flushing toilets, laundry and smaller household cleaning processes;
3. Rainwater is solely used for irrigation;

As a result of the above discussed problems, it is non-feasible to base a household solely on harvested rainwater. In the second case, as the water use of household is constant, the proportion of harvested rainwater use can be substantial. Laundry and flushing toilets use one-third of the water of an average family. Thus we can modify the contents of Table 1 the following results can be obtained (Table 1).

Table 2. *Percentage of water used for laundry and flushing toilets that can be theoretically covered from harvested rainwater, assuming 80 m² water harvesting area (value are based on 30% of the values shown in Table 1, discussed in details in the text)*

No. of household members	Dry year (25,6 m³/80m²)	Average year (37,6 m³/80 m²)	Wet year (49,6 m³/80m²)
1 member (42 m³)	182%	268%	354%
2 members (72 m³)	106%	156%	206%
4 members (120 m³)	64%	94%	124%

(Source: BUGYA, T.–WILHELM, Z. 2006)

Table 2 clearly illustrates that water demands for laundry and flushing toilets can be most likely covered from harvested rainwater even in a 4-member household. However, in dry years water requirements may be supplemented with running water. However, in wet years, excess water can even be used for car washing and wetting paved surfaces, etc.

In most communal buildings the majority of water is used for cleaning, irrigation, flushing toilets. As the roof of such buildings often extends over several hundreds of square meters, water harvesting would be extremely beneficial in such cases.

In the third case water is solely used for irrigation purposes. In such cases low cost waters are used. In this case, water use is seasonal (from April to September, with a maximum use in July and August), and water quality is of low importance. Assuming a 500-m² yard and 10 mm of irrigation rate monthly, 15 m³ is used over three months. This volume (or even twice as much) can be supplied even during droughts by harvested rainwater. However, use of high-salt irrigation waters should be avoided, to prevent intense salinization of soils.

THE CONNECTION BETWEEN WATER USE AND WATER HARVESTING: THE SIZE OF THE CISTERN

Based on the above-discussed issues, the problem of determining the appropriate cistern size can be solved. Let us consider the following scenarios:

1. The total water demand is fulfilled entirely form harvested rainwater
2. Harvested rainwater is used only for laundry, flushing toilets and for smaller cleaning purposes
3. Harvested rainwater is solely used as irrigation water
4. Harvested rainwater is used for cleaning purposes (cleaning toilets, floors, irrigation) in communal buildings

As we stated above he first case is unfeasible i.e. cannot be accomplished solely from harvested rainwater. Thus, water demands need to be supported from waters of different sources (e.g. running water or waters pumped from

wells). In this case cisterns are rarely completely filled up with water, as extraction predominantly and consistently exceed water recharge rates (in a case of a harvesting surface area of 80 m^2). Obviously, in this case, the construction of cisterns that capable to store rainwater of an entire month is useless. It can be easily understood from the following example. Assuming a 4-member family that has a cistern of 10 m^3, i.e. the monthly water demand can be stored here. After the first week of the month, only 8 m^3 of water is left in the cistern, while the expected recharge volume is only 1.4 m^3. On average, by the end of the month, only 3 m^3 of water is left in the cistern. This volume is used up in 9 days, while recharge volume is only 0.3 m^3 that is sufficient only for a single day. Consequently, a cistern of 10 m^3 is able to supply water for only a month and a half. Afterwards, on average, we need to wait 3 months to completely fill up the cistern.

As a result, partial water demand fulfillment from harvested rainwater is the feasible solution for this problem. However, most likely, such water demands should also be supplemented with running water. The most economic solution in such case is the construction of two independent water-supplying systems. One connects to the running water system (sinks, shower cabin, bathroom), while the other conducts water from the cistern to the washing machine and the toilet. If water level is low in the cistern, it can be replenished from the running water system. However, it should not be completely filled up, as in a case of a potential rainfall event water in the cistern can overflow. In Tiszadob, June is the wettest month with a long-term average of 80 mm. Considering the standard deviation of 55 mm, the high frequency of above-100 mm June precipitation values, we use 100 mm in our calculations. With a collection efficiency of 84%, from a harvesting area of 10 m^2 840 liters of water can be collected in a wet June. From a roof area this amount totals 6.7 m^3. Consequently cistern of larges volume is unnecessary.

When rainwater is exclusively used as irrigation water, we need to determine the periods, when demands for irrigation water are the highest. Obviously the maximum volume of available irrigation water equals to the total collected cistern water over the period of irrigation. Irrigation period lasts from beginning of April until the end of August in the studied area. However, the length of the irrigation period strongly depends on the type of crop, i.e. longer in the case of lawns and flower, while shorter when fruits and vegetables are grown.

Crops are not irrigated between October and April in Tiszadob, thus water can be collected throughout this period. The objective in this period is to collect the possible maximum amount of water, thus we need to consider the total precipitation over the winter season. If water inputs are low in the winter season, water quality deteriorates, however, due to the type of utilization; it does not present considerable utilization drawbacks. The average precipitation in Tiszadob totals 215 mm in the between October and April. The highest ever registered value in this period has been 348 mm. The probability of above-300 mm precipitation in the winter season has a high probability (16 %). Thus assuming a potential 350 mm of precipitation for this period, and a collection efficiency of 84 %, theoretically 294 mm reaches the surface over this period. This rainfall equals to 2.94 m^3 of collected water from a roof area of 10 m^2 and 23.5 m^3 from a roof area of 80 m^2. Thus, this amount is potentially available in an ideal case at the beginning of the irrigation period. As droughts are expected in wet years as well, cistern volumes exceeding 23.5 m^3 can be practical. Waters irrigated in April and the first part of May can be complemented with the precipitation maximum of the second part of May and June. The total average precipitation measured in May and June totals 129 mm, of which 108 mm can be collected. However deviations are large; the lowest ever measured value reached only 33 m (of which 27 mm is harvestable), while the highest totaled 259 mm (217 mm harvestable). Obviously, care has to be taken during the spring period, as, despite the high frequency of 100 mm per two month precipitation rate, water sources can be limited. It can be easily calculated, that a 100 mm precipitation equals to 8 m^3 of water in a case of 80 m^2 harvesting area. As a consequence, construction of cisterns with 27-plus m^3 water-holding capacity is impractical.

Water use characteristics of communal buildings differ from that of households. In the case of the former, the majority of water is used for flushing toilets and general cleaning, as well as for gardening, irrigation and other general purposes. Due to the diverse function, size and water use rate of such buildings, it is very difficult to estimate their annual water consumption rate and the reasonable storage capacity if cisterns are constructed. However, as we mentioned above, it is realistic to assume a roof area of 200 m^2 even in a case of a small rural school. Annually, 94 m^3 of water can be collected from this surface. An additional, but on the long run very important benefit of rainwater harvesting is the establishment and development of students', and the broader young generation's environmental-conscious attitude.

GENERAL COMMENTS

The above discussed examples are generally based on estimations. Thus, we can only approximate the magnitude of water use supported by rainwater harvesting. However, in this study, we clarified the overall benefits of rainwater harvesting on nationwide socio-economical scale as well as on household levels. We also made suggestion on the size of a feasible and cost-efficient cisterns and water storage facilities.

CONCLUSION

As surface and underground water are increasingly overburdened with contamination of various sources, human needs to concern the utilization of rainwater. However, it requires the integration of such systems into the local infrastructure and general water supplying structure. Firstly, the volume of economically collectable water has to be determined. Secondly, we have to estimate what proportion of the total water demand can be covered from harvested rainwater. Based on our calculations, we were able to estimate these parameters. Our calculations only partially refer to the magnitude of investment needed for the most appropriate rainwater harvesting surface areas and cistern volumes. However, general conclusions and the basic principles of such environmental friendly water-supplying solutions are provided.

With increased use of rainwater-harvested water use of waters from other sources could be reduced. From ecological viewpoints, financial support and funding of the construction costs of rainwater-harvesting systems is appropriate and desirable. As it is the interest of the whole nation, or broadly the whole global ecosystem, besides financial funding, establishment of such systems should be administratively supported. This administrative supports should include reduced property and construction taxes and dues. Similarly, issue and delivery of construction permits should be eased.

Management of water reservoirs is a nationwide socio-economic concern, central governmental support is expected. This type of support should include the modification of communal buildings, to enable schools to harvest and store rainwater. The large-scale conversion of our water supplying systems could include large-scale and low-cost production and installation of cisterns, manufactured from, for instance, various plastic materials. We are convinced that the broader use of rainwater harvesting system would equal to the application of alternative energy resources (e.g. solar energy) and the use of e.g. biofuels. Unfortunately, in the case of such innovations Hungary considerably lags behind the Western European societies.

In our paper we analyzed a case study supported with our calculations and the available climatic and social statistical data. The mean of the annual precipitation in Hungary is 620 mm. The harvestable precipitation equals to 84 per cent of this value. Assuming an average harvesting area of 80 m^2 and a total of 4 million households in Hungary, if just one household out of ten would support its water demand this way, 16,640,000 m^3 of water could be supplied by harvesting precipitation. At the present water cost rates (250 HUF per m^3) it means a save of 4,160,000,000 HUF, i.e. about 4 per cent of the communal water costs annually. To illustrate the volume of water supported by rainwater harvesting, it is twice as much as the volume of running water used annually by the 150,000 residents of Pécs, Southern Hungary (RONCZYK–LÓCZY 2006). This amount approximately equals to the annual running water use (which totaled 15.5 million m^3 in 1996) of the residents of Baranya County, the southernmost county of Hungary.

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