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# POTENTIAL WATER SAVING FROM RAINWATER HARVESTING IN SYRIA

## Potentiell vattenbesparing genom insamling av regnvatten i Syrien

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### Abstract

Syria, as well as many other countries in the Middle East, faces serious water shortage problems. Available water per capita (AWPC) will dramatically decrease due to climate change, population increase, and water needed for economic growth. Rainwater harvesting can play an important role in increasing available water in Syria. However, the absence of rainwater sewer systems in many rural areas in Syria necessitates giving a priority to construct collecting systems for future policies and plans. The objective of this paper is to estimate the potential increase in available water from collecting roof rainwater in small reservoirs and using other rainwater harvesting techniques. The potential increase in water availability due to rainwater harvesting could be as much as 35 million m$^3$ of water by roof rainwater harvesting in rural areas. This could be combined with other rainwater harvesting techniques in both urban and rural areas. Rainwater harvesting can be used to irrigate fruit trees that are less sensitive to changes in water quality and that can be especially adapted for passive irrigation techniques.

*Key words* – Middle East, Syria, rainwater harvesting, climate change, reservoirs, water shortage

### Sammanfattning

Liksom många andra länder i mellanöstern står Syrien inför allvarliga problem med vattenbrist. Tillgängligt vatten per person kommer att minska dramatiskt i framtiden på grund av klimatförändringar, populationsökning och ekonomisk tillväxt. Insamling av regnvatten kan komma att spela en viktig roll för att klara av det ökande vattenbehovet i Syrien. Detta är något som planerare måste ta hänsyn till och prioritera i framtiden. Syftet med denna artikel är att uppskatta de potentiella vattenvolymerna man kan erhålla från takavrinning och från andra källor. Vi fann att upp till 35 millioner m$^3$ kan erhållas från takavrinning i rurala områden. Man kan kombinera detta med andra system för att samla in regnvatten, både i rurala och urbana miljöer. Det erhållna vattnet kan exempelvis användas till bevattning av fruktträd, som inte är lika känsliga för vattenföroreningar som andra grödor.

## 1 Introduction

For a better sustainable water management in the Middle East, water scarce countries should optimize use of all available water resources and decrease losses. Available Water Per Capita (AWPC) has witnessed a dramatic decrease in the region due to population increase and economic development. Another future change is expected due to climate change (e.g., Arnell, 1999). Climate change will reduce water resources in Syria by some 1300 MCM (million m$^3$) by 2050 (Mourad and Berndtsson, 2011). Research during the last decades has emphasized the importance of nonconventional water resources in the country's future water budget. For example, greywater reuse in toilet flushing can save up to 35 % of drinking water (Mourad et al., 2011).

Rainwater harvesting, which is a technique to collect, store, and use rainwater for domestic or agriculture purposes, is considered one of the most important non-conventional water resources in the world. Rainwater harvesting is a widely accepted solution to alleviate problems of water shortage (e.g., Cheng and Liao, 2009). In Australia, due to the water shortage, rainwater tanks are considered a vital water resource in most of the rural areas. Eroksuz and Rahman (2010) found that large rainwater tanks, up to 70 $m^3$, in multi-unit residential buildings in Australia can provide up to 50 % of the needed water for toilet flushing, laundry, hot water, and outdoor irrigation. Basinger et al. (2011) found that a significant percentage of the non-potable water needs of multifamily residential buildings in New York City can be supplied with roof harvested runoff. In Jordan, Abdulla and Shareef (2009) reported that a maximum of 15.5 MCM water can be collected from roofs of residential buildings. Other studies in Sweden, Brazil, and UK showed that using rainwater harvesting can give high percentage of potable water saving (e.g., Villarreal and Dixon, 2005; Ghisi et al., 2007; Fewkes, 1999).

Harvested rainwater is considered a clean renewable water resource, its quality in rural areas where air pollution is negligible, depends on the receiving roofs and the collecting tanks. Rainwater harvesting can also be performed in the field by directing surface runoff toward a rainwater reservoir or to agricultural areas. Some rainwater harvesting techniques can also help in reducing soil erosion. Alkouri (2011) found that using large semi-circular bunds reduced erosion of agricultural soil in the Badia rangeland, which is located in the eastern part of Syria with an annual rainfall less than 100 mm, by 16 to 53 %. Rainwater harvesting ponds (reservoirs) can be designed using topographical maps and GIS (e.g., Al-Adamat et al., 2010).

Syria has a vast variability in rainfall depending on season and location. Rainfall can reach more than 1000 mm/year in coastal regions. The lowest rainfall, about 60 mm/year, is found in the east and southeast. Depending on humidity and rainfall, Syria can be divided into five climatic zones: wet (>600 mm), semi-wet (300–600 mm), semiarid (200–300 mm), arid (100–200 mm), and dry (< 100 mm), (Abdul, 2011), see Figure 1.

According to the Ministry of Irrigation in Syria (MoI), the annual renewable available water is about 17000 MCM. The total population is 20.4 million, which means that the available water per capita and year (AWPC) is about 833 $m^3$. Due to the long dry season, from May to November, evaporation has a great impact in reducing available water. The annual evaporated amount from water bodies may reach 1854 MCM (Mourad and Berndtsson, 2011). Urban development, climate change, and a high population growth rate will have a vital impact on reducing AWPC. It has been reported that AWPC will decrease to about 620 $m^3$ in 2025 (FAO, 2008).

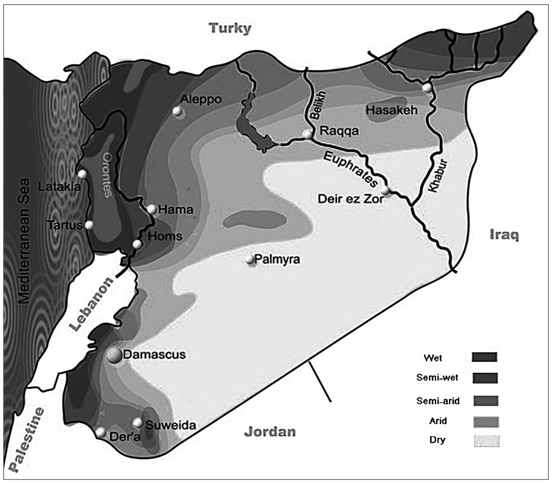


Figure 1. *Climatic zones in Syria (after Abdul, 2011).*

Water harvesting systems in Syria, such as surface water collection in to reservoirs and transport by waterwheels, have traditionally been used since 3000 BC. According to the Syrian topography, 60 % of the Syrian land may be appropriate for water harvesting systems. The Ministry of Agriculture and Agricultural Reform (MAAR) and the General Commission for Scientific Agricultural Research (GCSAR) have conducted a lot of research in this field, see e.g., Abdul (2011). They found the choice of the best water harvesting technique depends on soil, slope, rainfall and runoff amount, socioeconomic situation, and cultivation patterns in the studied area.

Terraces, which are mechanical structures comprising a channel and a bank made of soil or stones, can be considered a good water harvesting technique. They are systematically constructed perpendicular to the slope. Thus terraces intercept runoff, and encourage it to infiltrate,

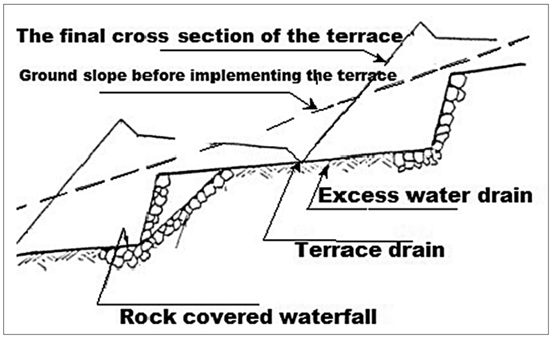


Figure 2. *Terraces (Bakir and Liang, 2004).*

Table 1. *Average precipitation and population in the Syrian Governorates.*

| Governorate | Area ($km^2$) | Rainfall (mm/year) | Total population (million) | Rural population |
|---|---|---|---|---|
| Damascus | 18140 | 255 | 1.702 | 0 |
| Damascus Rural | | 328 | 2.613 | 0.915 |
| Aleppo | 18500 | 378 | 4.566 | 1.715 |
| Homs | 42220 | 749 | 1.705 | 0.78 |
| Hama | 8880 | 842 | 1.541 | 0.973 |
| Lattakia | 2300 | 141 | 0.967 | 0.47 |
| Tartous | 1890 | 516 | 0.768 | 0.549 |
| Idleb | 6100 | 382 | 1.41 | 1.007 |
| Deir Ezzor | 33060 | 218 | 1.146 | 0.635 |
| Dra'a | 3730 | 332 | 0.957 | 0.528 |
| Al Sweida | 5550 | 308 | 0.355 | 0.244 |
| Al-Hasakeh | 23330 | 897 | 1.425 | 0.913 |
| Al-Rakka | 19620 | 619 | 0.887 | 0.544 |
| Quneitra | 1860 | 255 | 0.083 | 0.083 |
| *Total* | *185180* | | *20.125* | *9.356* |

After CBS-SY (2010).

evaporate or to be diverted towards a predetermined and protected safe outlet at a controlled velocity to avoid channel erosion (Bakir and Liang, 2004).

Contour farming can also be used for rainwater harvesting and it controls the erosion. In this method, crops are planted along topography perpendicularly to the slope gradient. Contour farming is, e.g., practiced in Al-Badia in Syria (Bakir and Liang, 2004), see Figure 2.

The objective of the present study was to estimate the potential of rainwater harvesting in Syria from mainly urban areas. By rainwater harvesting other types of high-quality water can be saved for purposes such as drinking water. The needs for this are urgent in Syria.

## 2 Methods and study area

To accomplish the objective of the study, rainfall data, climatic areas, potable water supply, population, and housing type in each governorate were obtained from CSB, MoI, MAAR, and GCSAR. For roof water harvesting, the total roof area in each governorate was calculated based on the average area and number of typical houses. The potential rainwater harvesting volume was estimated based on the total roof area, the average annual rainfall between 1978 and 2007, and the runoff coefficient. Then, the potential saving percentage was calculated by dividing the potential volume of harvested rainfall by the annual domestic demand.

According to CBS, 60 % of the Syrian lands receive less than 250 mm/year and 46 % of the population lives in rural areas (Table 1). Most dwellings in the Syrian rural areas have one floor. However, after 2005 due to the economic crisis, the number of two and three floor dwellings increased especially near village centers. The total roof area in each governorate was estimated with the help of CBS. Table 2 presents the residential building roof area in each rural area of each governorate.

The potentially harvested water (HW) for each governorate was estimated by the following equation:

$$HW = R*A*K \quad (1)$$

where R is the average rainfall in the target governorate, A is the total roof area (assuming that all buildings have two floors), and K is the a run-off coefficient of 80 %, which indicates a loss of 20 % of the rainwater that is discarded for roof cleaning and evaporation (Abdulla and Al-Shareef, 2009).

At the field level, rainwater can be directed to trees by teracess or contour farming (Bakir and Liang, 2004). The result can be improved if trees can be planted in lines depending on slopes and crop water requirement CWR. Further details are described in the results.

Table 2. *Floor area in the Syrian rural areas.*

| Governorate | Floor Area $10^3$ $m^2$ | Governorate | Floor Area $10^3$ $m^2$ |
|---|---|---|---|
| Damascus Rural | 20668 | Al-hasakeh | 11335 |
| Aleppo | 24844 | Al-Rakka | 7731 |
| Homs | 17046 | Al Sweida | 6574 |
| Hama | 15990 | Dra'a | 9873 |
| Lattakia | 13578 | Tartous | 26522 |
| Deir Ezzor | 7847 | Quneitra | 1374 |
| Idleb | 15280 | Al-hasakeh | 11335 |

After CBS-SY (2010).

Table 3. *Roof runoff in the Syrian rural area.*

| Governorate | Roof area $10^3$* $m^2$ | Rainfall (mm/year) | Harvested water MCM |
|---|---|---|---|
| Damascus Rural | 20668 | 255 | 2.11 |
| Aleppo | 24844 | 328 | 3.26 |
| Homs | 17046 | 378 | 2.58 |
| Hama | 15990 | 749 | 4.79 |
| Lattakia | 13578 | 842 | 4.57 |
| Deir Ezzor | 7847 | 141 | 0.44 |
| Idleb | 15280 | 516 | 3.15 |
| Al-Hasakeh | 11335 | 382 | 1.73 |
| Al-Rakka | 7731 | 218 | 0.67 |
| Al Sweida | 6574 | 332 | 0.87 |
| Dra'a | 9873 | 308 | 1.22 |
| Tartous | 26522 | 897 | 9.52 |
| Quneitra | 1374 | 619 | 0.34 |
| *Total* | *169011* | | *35.26* |

## 3 Results and discussion

### 3.1 Roof rainwater harvesting

The harvested rainwater for each rural area in each governorate was estimated by eq. (1). According to Table 3, it is seen that the total potential of harvested water from roofs in the Syrian rural areas could reach 35 MCM. Knowing that the Syrian population in the rural areas is about 9.4 millions (Table 1), the harvested water corresponds to 3.7 $m^3$ per capita and year. This amount can be stored and reused for garden irrigation, groundwater recharge, or for toilet flushing after mixing with greywater systems;

- Garden irrigation: this can be done in individual tanks or in block tanks. In both cases harvested water will be used for garden and/or street irrigation.
- Groundwater recharge: when it is applicable the harvested water can be directed into a recharge well, which help in maintaining the groundwater balance. This option needs a governmental body to be implemented and financed. The Ministry of irrigation, drinking water companies, and the municipality are the main stakeholders in such a project.
- Mixed with greywater: harvested rainwater can be mixed with a greywater system, when it is applicable, the saved water can cover all garden and toilet flushing needs.

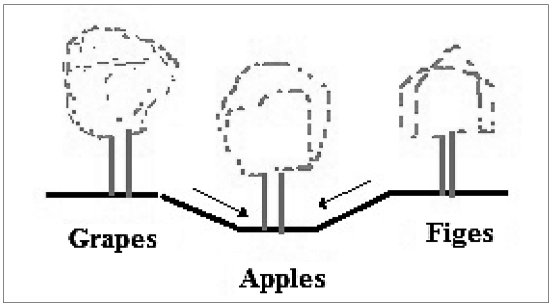


Figure. 3. *Rainwater harvesting at field level.*

### 3.2 Rainwater harvesting at field level

Depending on crop water requirement (CWR; Table 4), areas with fruit trees can be divided into different zones. For example, in the Al-Swaida area people cultivate apples, figs, and grapes. Thus, the land can be divided into three zones depending on CWR. Figure 3 shows how the land can be developed regarding different CWR and collection of rainwater. Crops with higher CWR should be located at lower levels to receive more water. This method can improve the yield without introducing irrigation in the field. However, a pilot project is needed for its verification.

## 4 Conclusions

Rainwater harvesting plays a vital role for water saving in arid and semiarid regions. It is important that these techniques are further developed to alleviate water stress from climate change and population increase. Syria can save up to 35 MCM of water by roof rainwater harvesting in urban areas. Further, rainwater harvesting at field level is also a good technique by which fruit trees can be cultivated depending on topography for different CWR. Contour farming controls erosion and increase pasture areas. Small, medium and large surface water reservoirs, which are constructed in most of the Syrian rural areas, help in providing a good resource for irrigation.

### Acknowledgments

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Table 4. Crop water requirement (CWR).

| Crops | Grapes | Citrus | Apple | Almond | Olive | Dates | Figs |
|---|---|---|---|---|---|---|---|
| CWRs ($m^3$/ha) | 4500 | 9808 | 12192 | 10989 | 4000 | 13950 | 3500 |

Source: Own elaboration based on MAAR-SY (2010) and Shatanawi et al. (1998).

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