Rainwater Harvesting for the GCUOF

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Abstract. A rainwater harvesting system is proposed to meet the irrigation water demands of the Guelph Centre for Urban Organic Farming. The entirely gravity fed system collects rainwater from nearby townhouse roofs and stores it in a buried tank for use during periods of insufficient precipitation. Periods of inadequate water supply for crops are reduced by twenty days per year with use of the system as evaluated using a soil moisture balance approach.

Key words: rainwater harvesting, Guelph Centre for Urban Organic Farming, drip irrigation, University of Guelph, soil moisture balance, organic agriculture

1 Introduction

The Guelph Centre for Urban Organic Farming (GCUOF) is a one hectare sustainable farming demonstration project currently in development on the University of Guelph campus. An irrigation water supply system is required to:

- reduce the risk of crop damage due to drought,
- provide regular irrigation for a greenhouse,
- and have the capacity for vegetable processing and utility services as proposed for future expansion.

Municipal water distribution services and drilled groundwater wells do not meet the sustainability objectives of the GCUOF as these methods increase demand on already strained local water resources. As such, rainwater harvesting has been considered as an environmentally responsible approach. The proposed design aims to significantly reduce the risk of drought damage to crops without using fossil fuels or electricity from the grid while also minimizing capital and operating costs.

The rainwater harvesting system consists of a collection system, a storage tank, and the necessary piping to transport water directly to the farm (figure 1). Townhouse roofs, located uphill from the farm, have been selected as a collection surface. Rainwater is intercepted at existing downspouts with a first flush apparatus. Water passing this quality control measure flows under gravity into the storage tank. The recommended drip irrigation system operates under the water pressure provided by the elevation difference between the farm and the storage tank. The entirely gravity fed system does not require any additional energy inputs thereby minimizing operating costs and serving as an excellent example of environmentally sustainable agricultural practice.

2 Design Specifications

The layout and primary components of the rainwater harvesting system are illustrated in figure 1. Townhouse roofs provide 1435 m^2 collection area and are situated at a higher elevation allowing water to flow freely through collection pipes. These collection pipes are buried below the frost line to a depth of 1.2 m allowing the system to operate during winter months. Pipe diameter increases incrementally from 15 to 20 to 25 cm based on modelled flow volumes thus avoiding collection system back up due to high rainfall intensity of valuable midsummer storms.

A first flush apparatus must be installed at each downspout to prevent contaminants from unnecessarily entering the system. This simple device, constructed from PVC pipe, diverts the first 24 L of rainfall from each downspout. This allows the first 0.5 mm of any precipitation event to effectively wash the collection surface.

The 91 m^3 buried storage tank provides adequate capacitance to avoid prolonged drought periods as described in the discussion.

A 10 cm diameter main pipe is used to convey water to the farm without significant pressure head losses due to friction. Although not within the scope of the rainwater harvesting design, a custom drip irrigation system is recommended to operate within the water supply and pressure constraints of the proposed rainwater harvesting system. The specifications for all major components has been provided.

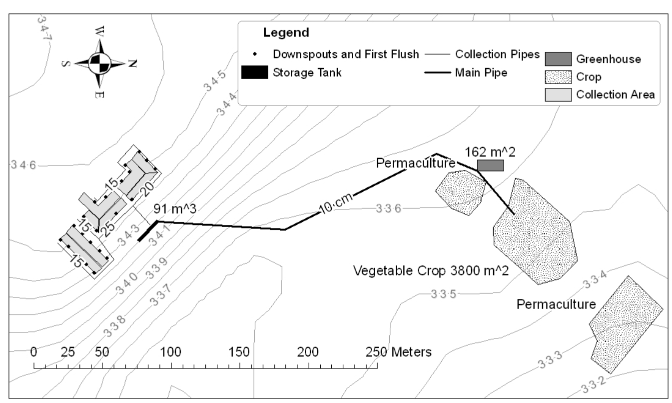

Fig. 1. Rainwater harvest system layout

3 Methodology

A soil moisture balance model based on climatic data was built to estimate water demands and evaluate the effectiveness of the system. Storage tank volume, a significant cost to the design, was determined using this model by weighing costs against irrigation performance. Other components have been sized for system compatibility.

3.1 Soil Moisture Model and System Optimization

The water demands of the GCUOF site have been estimated by analysing the past fifty five years of local precipitation data and modelling evapotranspiration with soil moisture content. Water collection is modelled using the townhouse roof surface area and accounting for first flush volume requirements. Storage tank volume has been incorporated as a parameter to be optimized while tank overflow, regular irrigation demands of the greenhouse, and crop irrigation during periods of low soil moisture content are accounted for.

The performance of the irrigation system is quantified using an average of days per year with soil moisture content above critical levels (figure 3). Soil moisture content does not drop below critical levels at all once storage volume reaches 330 m^3.

However, there is a point when the cost of increasing tank volume becomes proportionally greater than the associated irrigation performance benefits. This point is identified by graphing performance against tank volume on normalized axis where 100% performance indicates soil moisture never drops below critical levels and 100% maximum storage volume represents 330 m^3 (figure 2). Proportional performance is not incurred by increasing storage volume beyond 73 m^3 and as such is considered the largest economically viable storage volume required for irrigation purposes. This volume will reduce field crop damage during dry periods while also providing regular irrigation for the greenhouse.

The closest commercial tank size sourced in Canada has a volume of 91 m^3. The additional volume can be used for vegetable processing and visitor centre utilities as proposed for future expansion. The costs of storage tank volume has been balanced with irrigation performance while also providing for operational needs.

3.2 Drip Irrigation Recommendations and Main Pipe Diameter

Water pressure at the farm is limited by the three meter elevation gain to the storage tank. A pipe diameter of 10 cm is determined to reduce pressure losses associated with friction between the fluid and the pipe walls.

Commercial drip irrigation systems designed to operate under municipal water pressure will not work with this limited pressure availability. As such a customized drip irrigation system constructed from PVC hose with perforated sections kept shorter than 16 m will ensure even irrigation distribution.

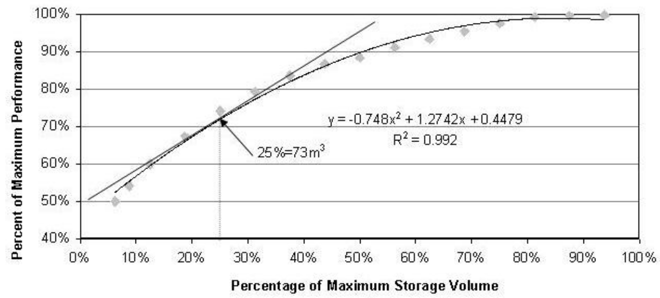

Fig. 2. Balancing performance against storage tank cost

4 Discussion

The average irrigation performance of the system over the course of a year is illustrated in figure 3. Soil moisture is kept above critical levels by an additional 20 days a year on average thus minimizing the risk of crop damage due to drought. The entirely gravity fed system does not need any additional energy requirements thereby minimizing operating costs. Total capital costs of the system is estimated to be \$55 000 including excavation, labour, piping, first flush apparatus, and the \$25 000 purchasing cost of the storage tank. The proposed rainwater harvesting system meets the needs and sustainability objectives of the GCUOF.

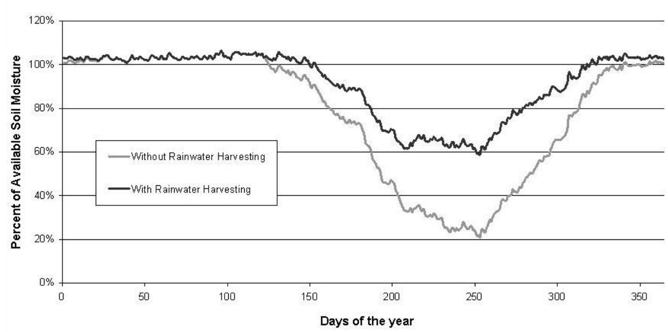

Fig. 3. Irrigation performance of the rainwater harvest system

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