Economic Feasibility of Rainwater Harvesting: A Case Study at Morehead State University

Riley Q. Williams, rqwilliams@moreheadstate.edu, Mentor: Vijay Subramaniam

Introduction

Rainwater harvesting (RWH) was primarily considered as a source for fresh water supply or a conservation practice for overcoming water shortages in drought prone areas. By retaining storm-water run-off for on site use, harvesting systems reduce the runoff volumes and pollutant masses entering waterways. Consequently, using roof-top RWH as a best management practice has been encouraged by many state and local governments. Some of the most interesting aspects of RWH are the methods of capture, storage, and the use of this natural resource at the place it occurs.

Main objectives of this study are to:

1. Illustrate the benefits, design, operation of rain-water harvesting practices
2. Conduct an economic and financial analysis to assess if the rainwater harvesting strategies are economically warranted management practices.

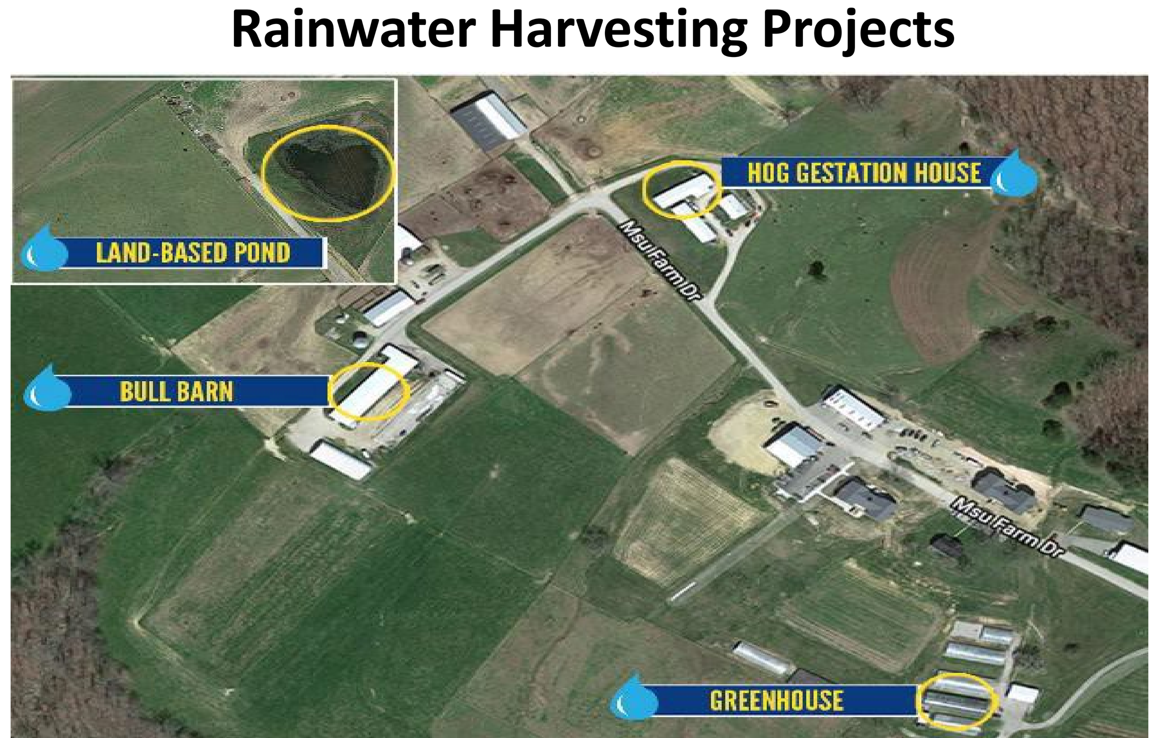
Rainwater Harvesting Systems – What is it?

- **Collection**: Storm water is collected from the catchment
- **Pre-Storage Treatment**: Trash, gross solids, and particulate matter are removed
- **Water Storage**: The storage reservoir for harvested storm water
- **Post-Storage Treatment:** Biological or chemical treatment of harvested storm water.
- **Distribution System:** Pipes and pumps needed to distribute harvested storm water for indoor/ outdoor use

Major Benefits of Rainwater Harvesting System

- Reduces runoff of nutrients, pathogens, and soil
- Reduces flood and solves drainage problems
- Better water source for landscape plants/ garden – not chlorinated
- A backup source for water emergencies
- Ideal for cities with water restrictions
- Reduces the demand for existing water supply (ground water or municipal water)

Map of Morehead State University Rainwater Harvesting Projects



Morehead State University Water Harvesting Projects

Morehead State University (MSU) has designed and installed four storm water-harvesting systems on MSU's Derrickson Agricultural Complex as a demonstration site for best management practices.

1. Hog gestation house evaporative cooling water harvesting system
2. Greenhouse evaporative cooling water harvesting system
3. Land based (pond) water harvesting and distribution system for livestock
4. Water harvesting systems for livestock consumption at bull barn

Bull Barn
Use of Rainwater for Livestock Consumption

Economic Analysis
Use of Rainwater for Agricultural Use
Bull Barn

Previous System:

Used city water

Needed water for 9 months (March to November) Average price of city water: $0.0095 per gallon

New system:

Installed three 2000-gallon cisterns (below ground) to collect rainwater, and two water tanks (above ground) 3000-gallons each, which will substitute the city water.

Table 1: Cost of Rainwater System Installation

Description	Amount
3 Concrete cisterns for the Bull Barn (2000 gal. each)	$5,080.00
2 Above ground water tanks for the bull barn (3000 gal. each)	$3,737.82
Bull barn cistern tank	$156.28
Excavate for water tanks & cisterns at the Bull Barn	$2,500.00
Equipment rental: Core drill for cistern holes	$154.00
Bull barn cistern plumbing	$749.00
Bull barn cistern plumbing	$86.34
Bull barn cistern plumbing	$46.52
Water Tank plumbing at the Bull Barn (above ground tanks)	$275.69
DGA: Dense Aggregate Base for the Bull barn cisterns and above ground tanks	$431.37
PVC pipe for Bull Barn	$799.62
Gutters for Bull Barn	$1,108.25
Total	$15,124.89

Table 2: Average Precipitation, Amount of Rainwater Collected, and Value of Collected Water from Bull Barn

Month	Average Rain (inches)	Average Rainwater Collected (gallons)	Value of Water ($0.0095/gallon)	Water used for livestock consumption
January	3.15	6804	$64.64	
February	3.88	8381	$79.62	
March	4.14	8942	$84.95	$84.95
April	5.63	12161	$115.53	$115.53
May	6.28	13565	$128.87	$128.87
June	5.16	11146	$105.89	$105.89
July	6.77	14623	$138.92	$138.92
August	3.33	7193	$68.33	$68.33
September	4.07	8791	$83.51	$83.51
October	3.49	7538	$71.61	$71.61
November	3.00	6480	$61.56	$61.56
December	4.27	9223	$87.62	
Total	53.17	14847	$1091.05	$859.17

- Rainfall: 10- year average
- Roof area: (Length 120 ft and width 40 ft) = 4,800 sq.ft.
- Average water price: $0.00955 per gallon
- Total gallons per month was calculated using the following formula:

$$\textit{Gallons Collected} = \textit{Roof area} * \textit{0.6 gallons per sq.ft.} * \textit{rainfall in inches} * 0.75$$

Investment Analysis

Water harvesting equipment (investment) cost: $15,125

Assumptions:

Lifetime of the system is 25 years

Opportunity cost of capital is 5%

Formula for present value of a uniform series of payments provides:

$$V_0 = A\ (USPV_{i,N})$$

where V_0= present value of investment, A= required annual benefits, N = life-time of the system and i = opportunity cost of capital

$$A = \frac{15{,}125}{14.0909} \Rightarrow \$1073 \text{ per year.}$$

The investment analysis show that the required annual benefits of the rainwater harvesting system is $1073 per year.

Scenario 1:

Value of harvested water is $1091.05 per year (assumed 100% utilization, average price is $0.00955 per gallon)

Total monetary benefits using 3% discount rate:

$$V_0 = A\ (USPV_{i,N})$$

$$V_0 = 1091.05 * 17.4131$$

$$=\$18{,}999$$

It shows that the current value of future incomes from this investment is $18,999 which provides a gain of $3,874 with a 100% utilization of harvested water. We cannot expect 100% utilization during the winter months so this is an unlikely situation.

Scenario 2:

Value of harvested rainwater is $859.17 per year

$$V_0 = A\ (USPV_{i,N})$$

$$V_0 = 859.17 * 17.4131$$

$$=\$14{,}961$$

Economic loss of this investment is $164.

Scenario 3:

Value of harvested water is $859.17 per year (assumed city water price is $0.00955 per gallon and it will increase by 4% per year, and 9 months of water harvesting)

$$V_0 = \frac{A\ (1+g)\left[1-\left(\frac{1+g}{1+i}\right)^N\right]}{(i-g)}$$

where V_0= present value of future incomes, A = annual benefits, g = growth rate of water cost, N = life-time of the system and i = discount rate

$$V_0 = \frac{859.17(1+0.04)\left[1-\left(\frac{1+0.04}{1+0.05}\right)^{25}\right]}{(0.05-0.04)}$$

$$V_0 = \$19{,}012$$

Scenario 3 shows that the rainwater harvesting system is beneficial if the city water price increases by 4% per year, assumed 9 months of 100 percent harvested rainwater utilization.

Conclusion

- Economic benefits of RWH system depend a number of factors such as the size of catchment area, annual rainfall and its distribution, usefulness of rainwater, cost of installation and cost of alternative water sources.
- The building used in this study is relatively large (4,800 sq. ft. catchment area). Larger catchment area will provide better economic benefits compared to our experience with smaller catchment areas.
- Environmental benefits are not included in this analysis. However, both short- and long-term benefits seem to be significantly higher than the economic losses showed in this analysis.
- More research needs to be conducted to assess if there is a justification for governmental support for RWH.

References

- Barry, J. P. and P.N. Ellinger (2012). Financial Management in Agriculture 7th Edition. Pearson. Prentice Hall.
- https://www.grownyc.org/images/ospace/infra/rainwater_collection_calculation.pdf
- http://www.kymesonet.org/historical_data.php
- Durham, M., C. Clark and V. Subramaniam. (2019).Economic Analysis of Water Harvesting at Derrickson Agriculture Complex, Morehead State University, Poster presented at the 2019 Celebration of Student Scholarship, Morehead, KY

Acknowledgements

- This research was partially supported by the Kentucky Division of Water. We thank Dr. Higgins and Moser from the University of Kentucky who provided insight and expertise that greatly assisted our research.