Economic and Financial Analysis of Rainwater Harvesting Pond: A Case Study at Morehead State University

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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. 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, and operation of rainwater 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 catchment points
- **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 chemically treated
- A backup source for water emergencies
- Ideal for cities with water use restrictions
- Reduces the demand for existing water supply (ground water or municipal water)

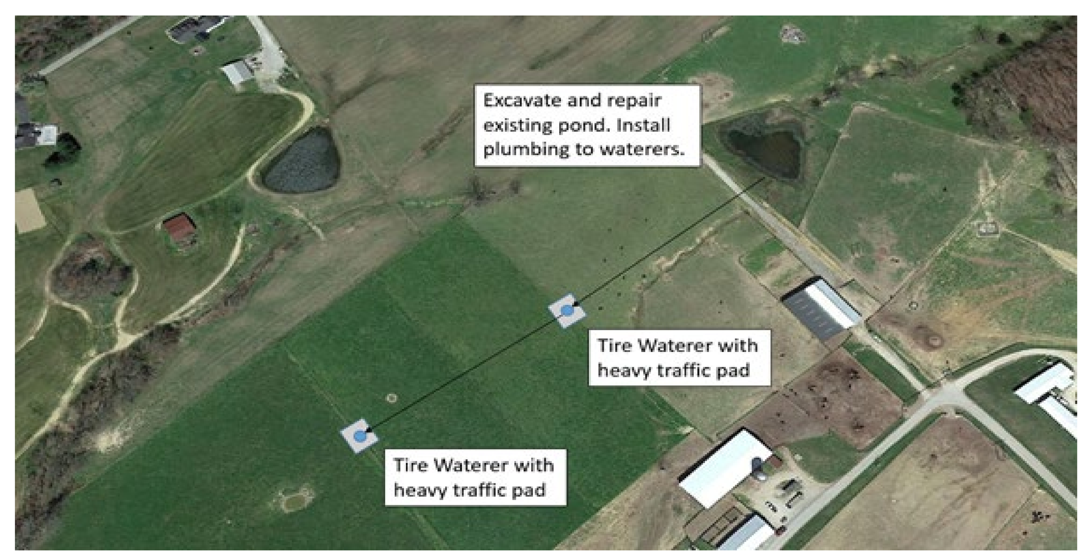
Map of Morehead State University Rainwater Harvesting Projects

Morehead State University Water Harvesting Projects

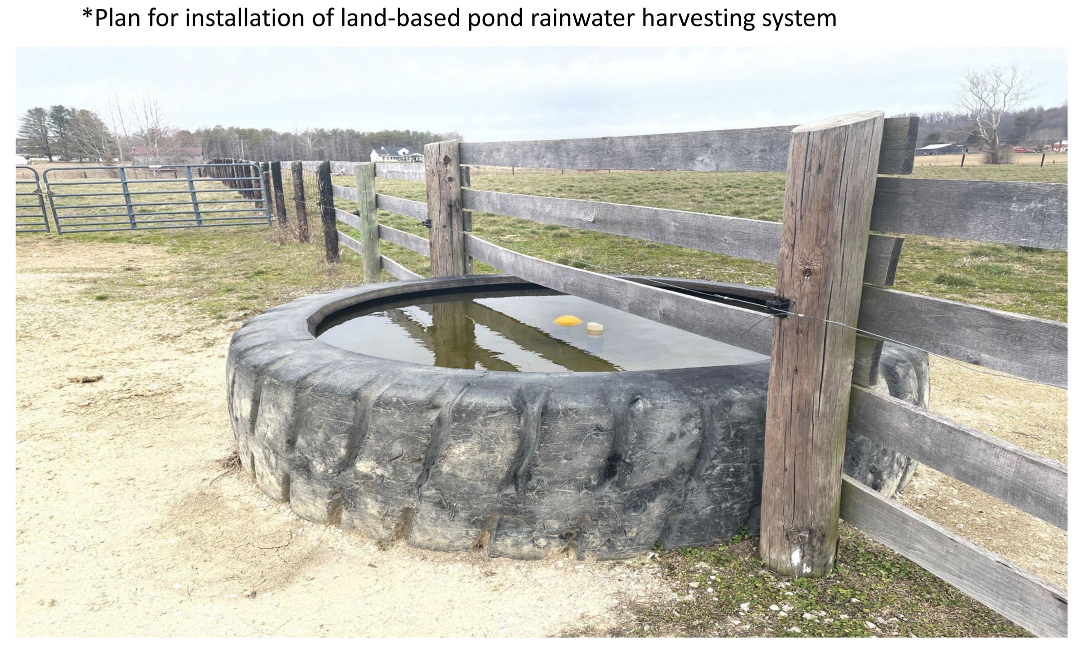
Morehead State University (MSU) has designed and installed four storm water-harvesting systems on MSU's Derrickson Agricultural Complex as a demonstration site for best management practices.

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

Land Based Pond and Distribution System



*Plan for installation of land-based pond rainwater harvesting system



*Tire waterer for water distribution to cattle

Table 1: Cost of Land Based Pond Rainwater System Installation

Description	Amount
Pond cleanout: remove mud, replace dam, install cattle waterers	$19,600
Dense graded aggregate base for pond & tire waterers	$1353
Equipment supplies needed for water harvesting project: tire waterers	$104
Concrete for tire waterer	$721
Tire waterer parts	$11
Tire waterer valves	$152
Dense graded aggregate base	$423
Pipe	$22
Total	$22,386

Table 2: Average Precipitation, Amount of Rainwater Collected, Evaporation Loss, and Value of Collected Water from Land-Based Pond

Month	Average Rain (inches)	Average Rainwater Collected (gallons)	Evaporation Loss (gallons)	Available Water (gallons)	Value of Water ($0.0095/gallon)
January	3.15	26649	2307	24342	$231.25
February	3.88	32825	1615	31210	$296.50
March	4.14	35024	10382	24642	$234.10
April	5.63	47630	16150	31480	$299.06
May	6.28	53129	27685	25444	$241.72
June	5.16	43654	36914	6740	$64.03
July	6.77	57274	36914	20360	$193.42
August	3.33	28172	36914	0	$0.00
September	4.07	34432	25378	9054	$86.01
October	3.49	29525	11536	17989	$170.90
November	3	25380	5768	19612	$186.31
December	4.27	36124	1154	34970	$332.22
Total	53.17	449818	212717	245843	$2,336

- Rainfall: 10- year average
- Catchment area: 18,800 sq. ft.
- Average Morehead City Water Price: $0.00955 per gallon
- Gallons evaporated calculated based on data from Climate Prediction Center – United States Evaporation Monitoring
- Total gallons per month was calculated using the following formula:

$$\text{Gallons Collected} = \text{Area} * \text{0.6 gallons per sq.ft.} * \text{rainfall in inches} * 0.75$$

Investment Analysis

Water harvesting equipment (investment) cost: $22,386

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*

$$A = \frac{22{,}386}{14.0909} \Rightarrow \$1589 \text{ per year.}$$

The investment analysis show that the required annual benefits of the rainwater harvesting system is $1,589 per year.

Scenario 1:

Value of harvested water is $2,236 per year (assumed 100% utilization, average price is $0.00955 per gallon)

Total monetary benefits using 3% discount rate:

$$V_0 = A\ (USPV_{i,N})$$
$$V_0 = 2{,}236 * 17.4131$$
$$= \$38{,}936$$

Scenario 1 shows that the current value of future incomes from this investment is $38,936 which provides a gain of $16,550 with 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 $1,476 per year (9 months of utilization)

$$V_0 = A\ (USPV_{i,N})$$
$$V_0 = 1{,}476 * 17.4131$$
$$= \$25{,}702$$

Scenario 2 shows the economic benefit of this investment is $3,316

Scenario 3:

Value of harvested water is $1,476 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*

$$V_0 = \frac{1{,}476\ (1+0.04)\left[1 - \left(\frac{1+0.04}{1+0.05}\right)^{25}\right]}{(0.05-0.04)}$$

$$V_0 = \$32{,}661$$

Scenario 3 shows that the rainwater harvesting system is beneficial if the city water price increases by 4% per year, assumed 9 months of 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.
- A 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
- https://www.cpc.ncep.noaa.gov/products/Soilmst_Monitoring/US/US_Evaporation-Monthly.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

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