PNNL-25498 Rev 1

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Rainwater Harvesting Potential Maps

June 2019

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U.S. DEPARTMENT OF ENERGY
Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830

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Pacific Northwest National Laboratory
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1.0 Background

Alternative waters are sustainable sources of water, not supplied from fresh surface water or groundwater, that offset the demand for freshwater. Alternative water can serve as a vital water supply to federal agencies in support of water resilience by providing diverse water sources. One type of alternative water, rainwater harvesting, involves capturing, diverting, and storing rainwater from rooftops for later use. Uses for rainwater include landscape irrigation, ornamental pond and fountain filling, cooling tower make-up, and toilet and urinal flushing.

The Federal Energy Management Program has developed a series of alternative water source maps. The first map, developed in 2015 and updated in 2019, is a state-level rainwater harvesting regulations map that visually represents the rainwater harvesting policies across the country and provides general information on state programs, if applicable. This map allows the user to quickly discern where rainwater harvesting is supported and regulated by the state.

As a complement to this first map, Pacific Northwest National Laboratory (PNNL) created two additional rainwater harvesting maps to help federal agencies strategically identify locations in the U.S. that are conducive to rainwater harvesting projects. The first map shows the relative potential for capturing rainwater for any use. The second map specifically identifies areas in the U.S. that have potential for supplying rainwater for irrigation.

2.0 Benefits of Rainwater Harvesting

Along with offsetting the consumption of freshwater, rainwater harvesting can help to manage stormwater by reducing the amount of runoff, which eases flooding and erosion by slowing runoff and allowing it to soak into the ground, turning stormwater problems into water supply assets. Less runoff also means less contamination of surface water from sediment, fertilizers, pesticides, and other pollutants that might be transported in rainfall runoff.

3.0 Map Development Methods

PNNL developed the rainwater harvesting potential maps using zip-code-level monthly weather data across the U.S. [1] The following section describes how these data were used.

3.1 Rainwater Harvesting Potential for All Applications

Using monthly zip code precipitation data, PNNL developed a metric to determine the relative potential for capturing rainwater across the U.S., following these steps:

1. Gathered 30-year historical average monthly data for rainfall by zip code. Only frost-free months were used to avoid issues with water freezing in the rainwater harvesting system.

[1] Precipitation data were provided to PNNL by the Environmental Protection Agency in 2010. Data originated from the International Water Management Institute Climate Atlas, which uses 30 years of historical climate data at the zip code level.

2. Estimated total amount of rainfall available for harvesting by summing the total rainfall by zip code for frost-free months.
3. Mapped total rainfall (Step 2) with the geographical information system (GIS) software ArcGIS using natural breaks[1] to determine a relative ranking of rainwater harvesting potential.
4. Mapped the number of months with monthly rainfall of 1 inch or more.
5. Combined areas in the top two tiers of total monthly rainfall (28.3 to 38.7 and 38.8 to 146 total inches of rainfall) to form a single tier (28.3 to 146 total inches of rainfall). Superimposed map of number of months with rainfall of 1 inch or more (Step 4) over map of total rainfall (Step 3)(Figure 1). Regions in which the annual precipitation was higher than 28.3 inches and which have 9 -12 months with at least 1 inch of rain were ranked as Highest. Regions in which the annual precipitation was between 22.6 and 28.3 inches or, if greater than 28.3 inches but less than 9 months with at least 1 inch of rain were ranked as High. Other areas identified in Step 3 were not affected by the superimposed (Figure 2). Table 1 provides the scale that was used for the map's ranking.

Table 1. Rainwater harvesting potential map ranking

Ranking	Total Rainfall during Frost-Free Months (inches)	Ranking Notes
Lowest	0.4 to 7.7	Areas with little rainwater, making harvesting very limited
Low	7.8 to 13.0	Areas with low rainwater, making harvesting limited
Medium	13.1 to 18.5	Areas with adequate rainfall for harvesting
Medium-High	18.6 to 22.5	Areas with significant rainfall, making harvesting feasible
High	22.6 to 28.3	Areas with significant rainfall, making harvesting very attractive
Highest	28.3 to 146.0	Areas with significant rainfall and year round storage potential, making harvesting optimal

[1] Natural breaks were used in ArcGIS software, produced by ESRI, to classify the data. Using natural breaks is a method to partition a dataset based on the natural distribution inherent in the data. The natural groups are delineated by similar values and the maximum differences between groups.

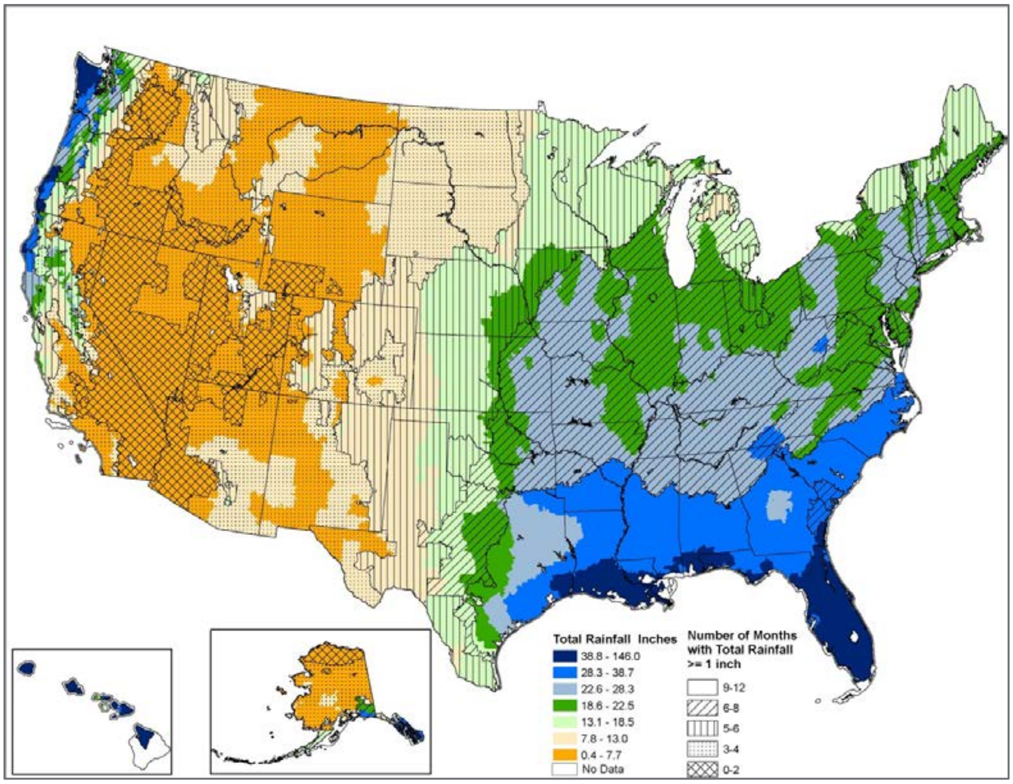

Figure 1. Total rainfall for frost-free months with number of months with 1 inch or more of rainfall superimposed

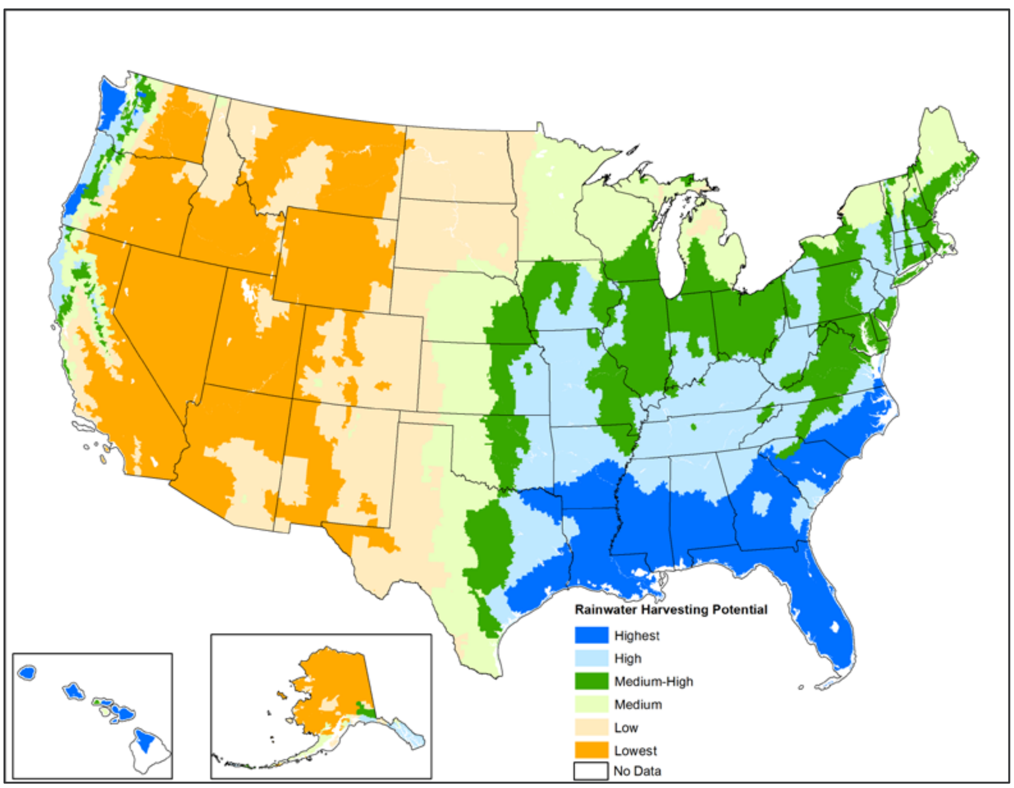

Figure 2. Final map of rainwater harvesting potential for all applications

3.2 Rainwater Harvesting Potential for Irrigation

PNNL developed a second map to determine the areas of the U.S. that are specifically conducive to capturing rain for irrigating landscape. This was accomplished using zip-code-level monthly precipitation and evapotranspiration (ET) data across the U.S. ET represents the amount of water a plant requires to stay healthy, which includes the total amount of water lost to the atmosphere due to evaporation (e.g., water loss from soil) and plant transpiration (water loss from the plant itself). Some factors that can affect ET include solar radiation, air temperature, air humidity, and wind. Reference ET (ETo) is the rate of ET of a hypothetical reference crop that is an actively growing, well-watered plant of uniform height. To determine the amount of water needed for a specific type of plant, ETo is multiplied by a crop coefficient. A crop coefficient is an adjustment factor applied to specific plant species, which represents the amount of water expected to produce optimum growth. For example, cool season turf grass, such as Kentucky bluegrass, has a plant coefficient of 0.8 whereas warm season grass, such as Bermuda, has a plant coefficient of 0.6.

A metric was calculated for each zip code location by subtracting ET from the monthly rainfall received at the specific location during months without freezing temperatures. This value represents the total amount of supplemental irrigation required for the given landscape plant.[1]

The following step-by-step process was followed to determine the metric that was used to map the rainwater harvesting potential for irrigation:

1. Gathered 30-year historical average monthly data for rainfall and ETo by zip code for frost-free months.[2]
2. Determined the ET for cool season turf for each zip code. The ETo reference plant was alfalfa. To determine ETo for cool season turf grass, ETo was multiplied by the plant coefficient of 0.8. The assumption is that cool season grass is the most prevalent landscape around federal facilities.
3. Subtracted monthly ET from monthly rainfall to determine supplemental irrigation required for each frost-free month. (Supplemental irrigation is how much additional water is needed by the grass that is not being met by rainfall.)
4. Summed the supplemental irrigation for all frost-free months, which estimates the total amount of irrigation required for the irrigation season.
5. Determined the number of months where rain exceeds ET.
6. Mapped supplemental irrigation metric (Step 4) with ArcGIS using natural breaks to determine a relative ranking of rainwater harvesting potential (Figure 3).
7. Superimposed the number of months where rainfall exceeds ET (Step 5) on the supplemental irrigation requirements map (Step 6) to reveal the regions in the U.S. that may have additional rainfall available for storage by the rainwater harvesting system (Figure 4).

[1] Negative numbers represent rainfall not meeting the plant's water requirements. Positive numbers represent that rainfall exceeding the plant's water requirements.

[2] Precipitation and ET data were provided to PNNL by the Environmental Protection Agency in 2010. Data originated from the International Water Management Institute Climate Atlas.

8. Ranked the rainwater harvesting potential from lowest to highest, based on the rainwater available for harvesting during frost-free months and the number of months where rainfall exceeds ET. Table 2 provides the scale used for the map's ranking.

Table 2. Rainwater harvesting potential map ranking

Ranking	Monthly rainfall minus ET (inches)	Ranking Notes
Not recommended	-77.6 to -47 .4	Areas with very high ET and very little rainwater, making harvesting unfeasible
Lowest	-47.3 to -25.3	Areas with high ET and little rainwater, making harvesting very limited
Low	-25.2 to -11.4	Areas with high ET and low rainwater, making harvesting somewhat limited
Medium	-11.3 to -1.8	Areas where ET typically exceeds rainfall and 0 to 3 months have positive rainfall; adequate rainfall can be stored for irrigation during drier times
Medium-high	-11.3 to -1.8	Areas where ET typically exceeds rainfall and 3 to 6 months have positive rainfall; a significant amount of rainfall can be stored for irrigation during drier times
High	-1.7 to 13.9	Areas where ET closely matches rainfall and 1 to 4 months have positive rainfall, where collection and storage of rainwater for irrigation during drier times is very feasible
Highest	-1.7 to 13.9	Areas where ET closely matches rainfall and more than 4 to 9 months have positive rainfall, where collection and storage of rainwater for irrigation during drier times is optimal
Rainfall exceeds ETo	14.0 to 102	Areas where ample rainfall exceeds ET and rainwater harvesting for irrigation may not be necessary

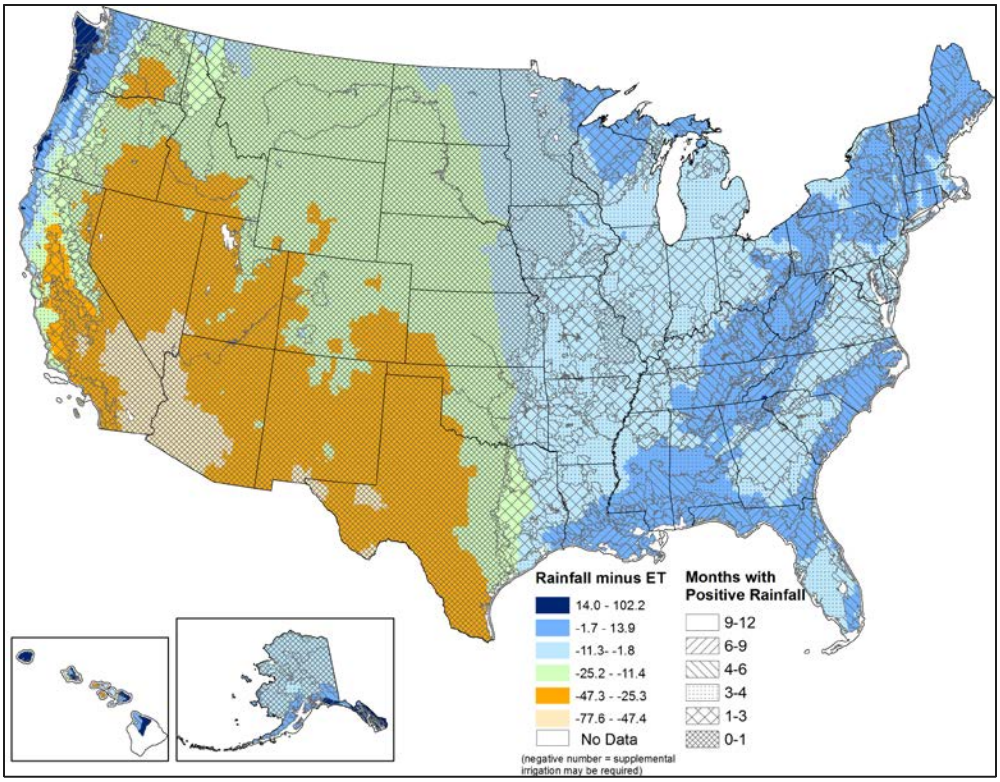

Figure 3. Rainfall minus ET for frost-free months with total number of positive months of rainfall overlaid

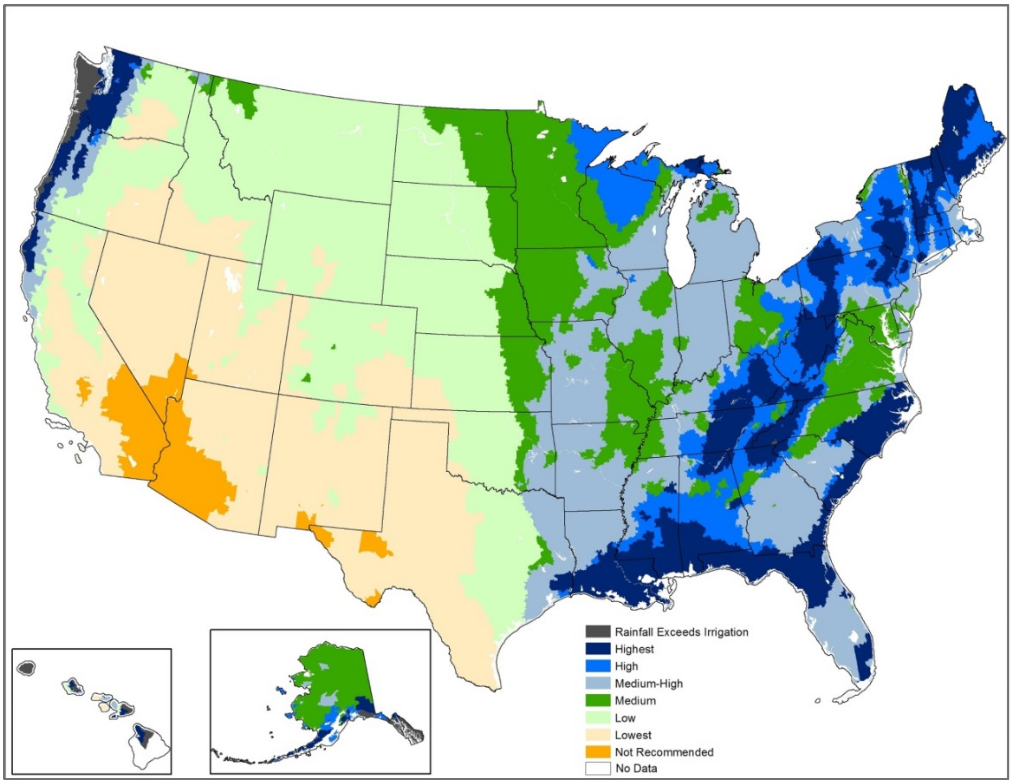

Figure 4. Final map of rainwater harvesting potential for irrigation

4.0 Map Limitations

The data used to develop the maps have limitations. Daily precipitation is best for determining how much rainfall is available for harvesting. The maps were based on historical, monthly average rainfall. This does not account for monthly or yearly variations such as large rain events or rainy periods/years or dry times/years. For example, if all rain falls at the beginning of the month, there may not be enough harvested rainwater for irrigation at the end of the month.

5.0 Path Forward

By using the rainwater harvesting maps in concert, federal agencies can determine where rainwater harvesting is regulated and supported and what areas have good potential for harvesting rainwater. For example, an agency can determine potential applications for rainwater harvesting projects and then map their building inventory over the appropriate rainwater harvesting potential map. A list of suitable sites can be developed to prioritize the sites with the best potential for implementing rainwater harvesting projects.

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