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Modeling and Mapping Urban Evapotranspiration in the Lower Boise River Basin

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Abstract

Surface water demand is primarily controlled by the evapotranspiration (ET) rate, but ET rates are not regularly measured in urban environments. This complicates crucial aspects of efficient water management. I hypothesize the average annual urban ET rate is significantly lower than the surrounding agricultural ET rate, which is commonly used interchangeably with the urban rate. To test this hypothesis, I will map, model, and compare ET of urban and adjacent agricultural landscapes. Using a locally calibrated model and remote sensing data, satellite imagery will be used to create a spatially and temporally distributed ET dataset to analyze the regional ET rates.

Modeling and Mapping Urban Evapotranspiration in the Lower Boise River Basin

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INTRODUCTION

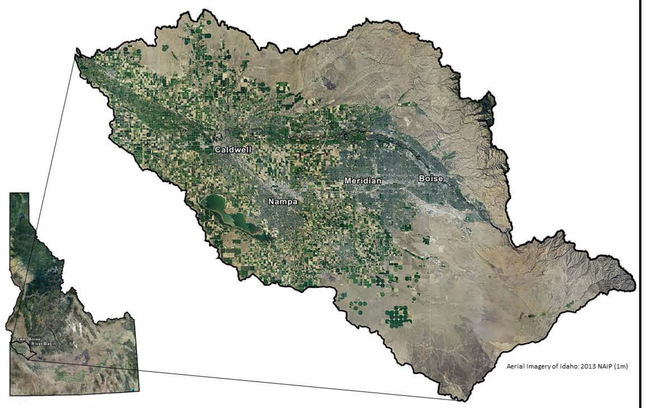
In this study, we seek to model, map, and interpret trends of evapotranspiration in semiarid urban environments. The amount of water a landscape needs is primarily controlled by the rate of evapotranspiration(ET), which is the amount of water consumed through surface evaporation and plant transpiration. Measuring ET is a complex task and specific instrumentation is cost prohibitive and estimates are often poorly constrained. This is especially true for urban landscapes where ET is either assumed to be zero or equivalent to surrounding non-urban land. The lack of good estimates of urban ET limits our ability to use finite water resources efficiently.

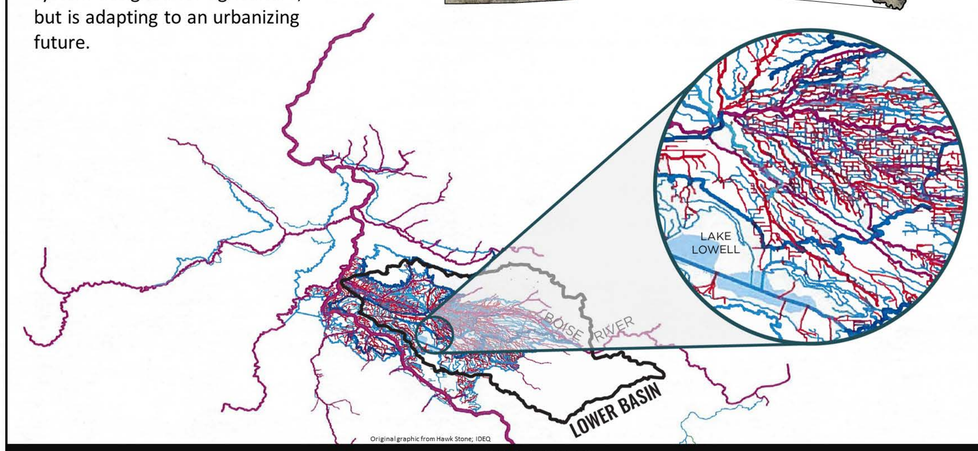
This study has four research objectives:

1) **Develop a GIS model to spatially map and classify evapotranspiration at very high resolutions in urban environments.**
2) **Apply the model to the semiarid Lower Boise River Basin**
3) **Compare seasonal trends of urban and non-urban ET rates**
4) **Analyze the impact of landscape change on ET rates**

STUDY AREA

The Lower Boise River Basin is located in West Central Idaho. The Boise River runs through the Treasure Valley, which is one of the fastest growing areas in the country and is projected to grow to more than 1 million people within the next few decades. The ~650,000 current occupants rely on the capture, delivery, and use of seasonal snowpack to thrive in the semiarid climate. The current system is a complicated network of reservoirs, canals, and drains. It is a system designed for agriculture, but is adapting to an urbanizing future.





METHODS

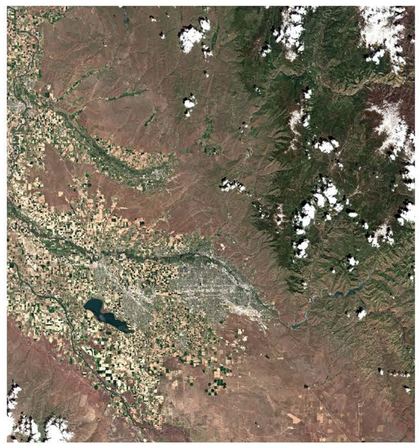
This study uses high resolution imagery in conjunction with a derived enhanced vegetation index to calculate actual ET(e.g. Nouri et al., 2012; Nouri et al., 2013; Nagler et al., 2013), based on a calibrated reference ET. It is an adaptation of METRIC(Modeling Evapotranspiration at high Resolution with Internal Calibration), developed by Dr. Rick Allen at the University of Idaho (Tasumi and Allen, 2007).

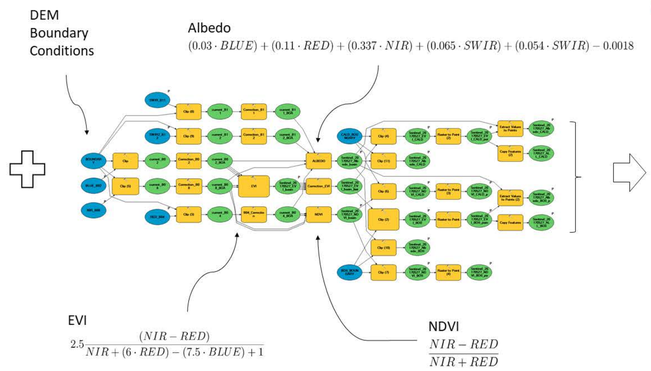
1) **Download and preprocess images(atmospheric correction and band scaling).**
2) **Create NDVI, EVI, and Albedo images with associated pixel attribute tables(Bands = Blue, Red, NIR, SWIR).**
3) **Export attribute tables and climate data to Arcpy ET modeling script.**
4) **Rasterize ET product tables and spatially distribute point values using ordinary spherical kriging.**
5) **Derive statistical seasonal relationships between land classifications and modeled ET.**

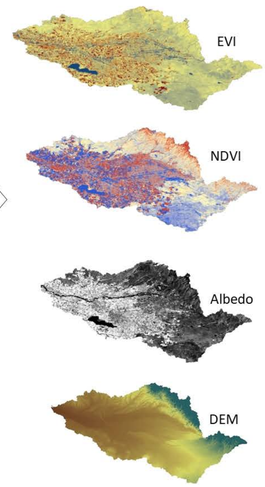
MODELS AND RESULTS

Image Processing Model

Sentinel 2A Satellite Imagery → **GIS Processing** → **Table and Image Outputs**







ET Model

ET Calculations → **ET Raster Output**

Processed Image Table Values

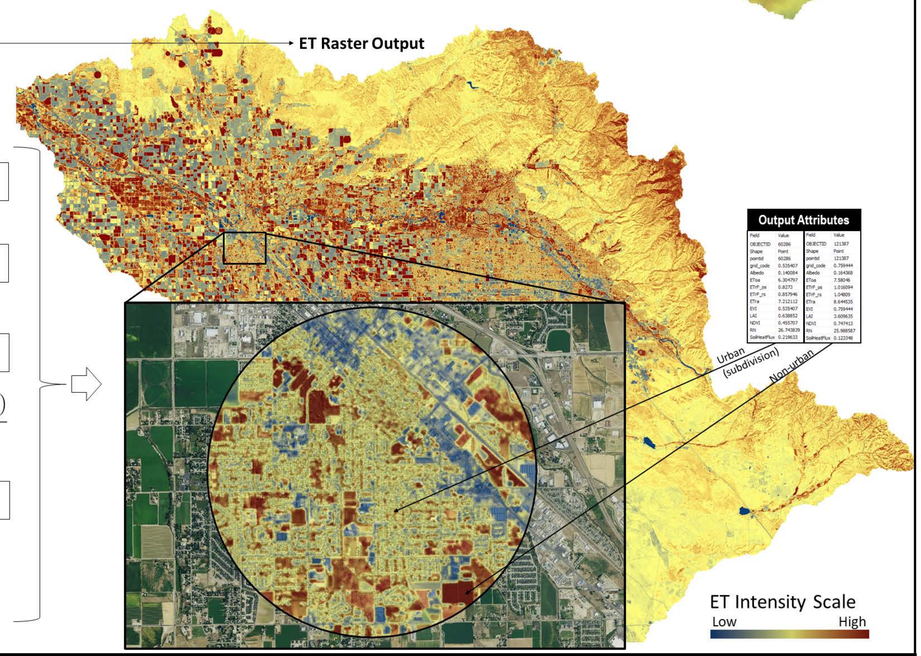
Climate Data

ASCE Reference ET

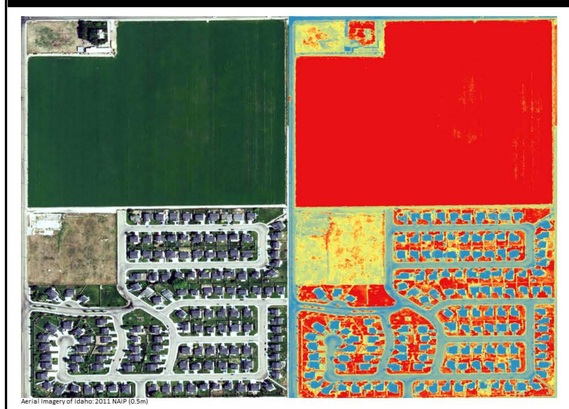
$$ET_{ref} = \frac{0.408 \cdot \Delta \cdot (R_n - G) + \gamma \cdot \frac{C_n}{T+273} \cdot U_2 \cdot (e_s - e_a)}{\Delta + \gamma \cdot (1 + C_d \cdot U_2)}$$

ET Calibration and Calculation

$$ET_a = ET_{ref} \cdot k_c$$
$$ET_{evi} = ET_{ref} \cdot k_1 \cdot (1 - e^{-2.25 \cdot EVI}) - k_2$$



INITIAL FINDINGS AND IMPLICATIONS



The initial model output clearly shows classifiable mapping of ET in urban landscapes; granting the ability to differentiate between commercial and residential areas. Classifications can be created and used to generate maps and statistics. It will also allow seasonal statistics to be calculated between images, over the length of the water year.

The image on the left shows the potential water demand between an agricultural field and an adjacent subdivision on the same day. There is a clear intensity difference between the two areas, but their timing and length of growing season varies greatly(crops are more intense over a shorter growing season, where grass is less intense and more consistent over a longer season.). The cumulative ET over each area will show the difference in seasonal consumption. These comparisons will be made, along with all relevant statistics, upon data set completion.

REFERENCES

Nagler et al. 2013. Estimating riparian and agricultural actual evapotranspiration by reference evapotranspiration and MODIS enhanced vegetation index.

Nouri et al. 2012. A review of ET measurement techniques for estimating the water requirements of urban landscape vegetation.

Nouri et al. 2013. Remote sensing techniques for predicting evapotranspiration from mixed vegetated surfaces.

Tasumi, M., and R.G. Allen. 2007. Satellite-based ET mapping to assess variation in ET with timing of crop development.

Image Credit

USGS National Hydrological Boundary data
Basin image showing Canals, drains, and rivers from Hawk Stone at IDEQ
Basin imagery shown is from NAIP 2013 Idaho, Sentinel 2017, and SPOT 2017
All other content is original from Curtis Crandall