An improved Newhall simulation for modeling soil moisture and temperature regimes

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Introduction

The Newhall Simulation Model (NSM) has been the go-to method for quantifying soil moisture regimes (SMR) and soil temperature regimes (STR) according to U.S. Soil Taxonomy for the last 20+ years. In that time, it has been implemented in numerous ways (e.g., COBOL, GW-BASIC, Java, and Python programming languages) but these implementations are frequently outpaced by the advancements in computer operating systems (e.g., Windows 10 compatibility issues with jNSM). The NSM has not been conceptually updated since its creation, meaning the assumptions, inputs, and outputs of the model do not reflect the most recent updates in Soil Taxonomy. We are developing a revised NSM using the R computing language (rNewhall) to allow for an expanded utility compatible with existing packages that already interface and display soil survey data available through NRCS and the National Cooperative Soil Survey Program (e.g., aqp, soiDB, sharpshoR).

Objectives

- Reproduce Newhall Soil Moisture model in R coding language (rNewhall)
- Modify rNewhall to predict daily soil moisture conditions
- Develop spatial version of rNewhall to predict detailed soil climate variables
- Evaluate model performance to focus future model development and design

Improving the Newhall Simulation Model

rNewhall Daily – Point

rNewhall was updated to simulate daily volumetric soil moisture (VWC) dynamics with a daily model of ET (Daily Thornthwaite following Pereira and Pruitt 2004) and precipitation. The soil profile was expanded to incorporate raster inputs for soil profile properties, climate data, and vegetation properties effecting ET and interception rates. rNewhall Daily – Spatial applies rNewhall Daily – Point on pixel-by-pixel basis, but incorporates spatial summaries of all soil and meteorological inputs. rNewhall Daily – Spatial is currently still under development and parameter testing.

The Newhall Simulation Model

This relatively simple water budget model incorporates monthly climate data with a soil profile to simulate moisture conditions. The current model divides the soil profile into eight layers irrespective of actual soil depth and uses a ‘cost’ matrix of wetting and drying to simulate water movement into the soil from the surface and water lost from the surface via ET (Newhall 1972; Newhall and Berdanier 1996; Van Wambeke 2000).

Modeled Daily Soil Moisture Dynamics

rNewhall Monthly was designed to replicate the original NSM, providing monthly estimates of soil moisture and soil temperature based on monthly meteorological data using R. It provides reproducible results to current java- and python-based NSM output and provides enhanced visualization and transferability by utilizing the R computing environment. Below, Figure A was generated by java-NSM and B) was reproduced by rNewhall. STR will initially be predicted by adding 1°C to mean annual air temperature derived from 800 m PRISM data.

Replicating Newhall Simulation Model in R

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rNewhall Shiny App

Shiny web application will provide interactive functionality, visualization, and connectivity to current soil survey resources. Mock-up of Newhall Shiny web application demonstrating how users can select map display option and select a region of interest (Panel A), set rNewhall simulation parameters (Panel B), and view and download results (Panel C).

Modeled Daily Soil Moisture Dynamics

- Climate variables derived from five Oklahoma mesonet meteorological stations for January 1, 2009 – December 31, 2009; http://www.wxdata.org
- Soil properties extracted from gSSURGO 10-meter grid; https://websoilsurvey.sc.egov.usda.gov
- Predictions of VWC more similar to measured values for soils in wetter landscapes
- Surface soils (0-10 cm) better reflect measured VWC than 20-30 cm slice
- SMR will be derived from moisture conditions in the soil moisture control section

Future Model Development

- Continue sensitivity testing to evaluate the effect of changes to accretion costs, antecedent precipitation, and plant interception
- Use gridded, modeled daily precipitation and temperature data (PRISM 800m) to create a spatial rNewhall output
- Incorporate spatial connectivity of landscape-scale water flow using topographic indices derived from SRTM DEM (e.g., wetness index, slope, landscape position, runoff simulation)
- rNewhall package forthcoming

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Link to poster & references