Estimating Soil Moisture from Unmanned Aerial Vehicle and Machine Learning

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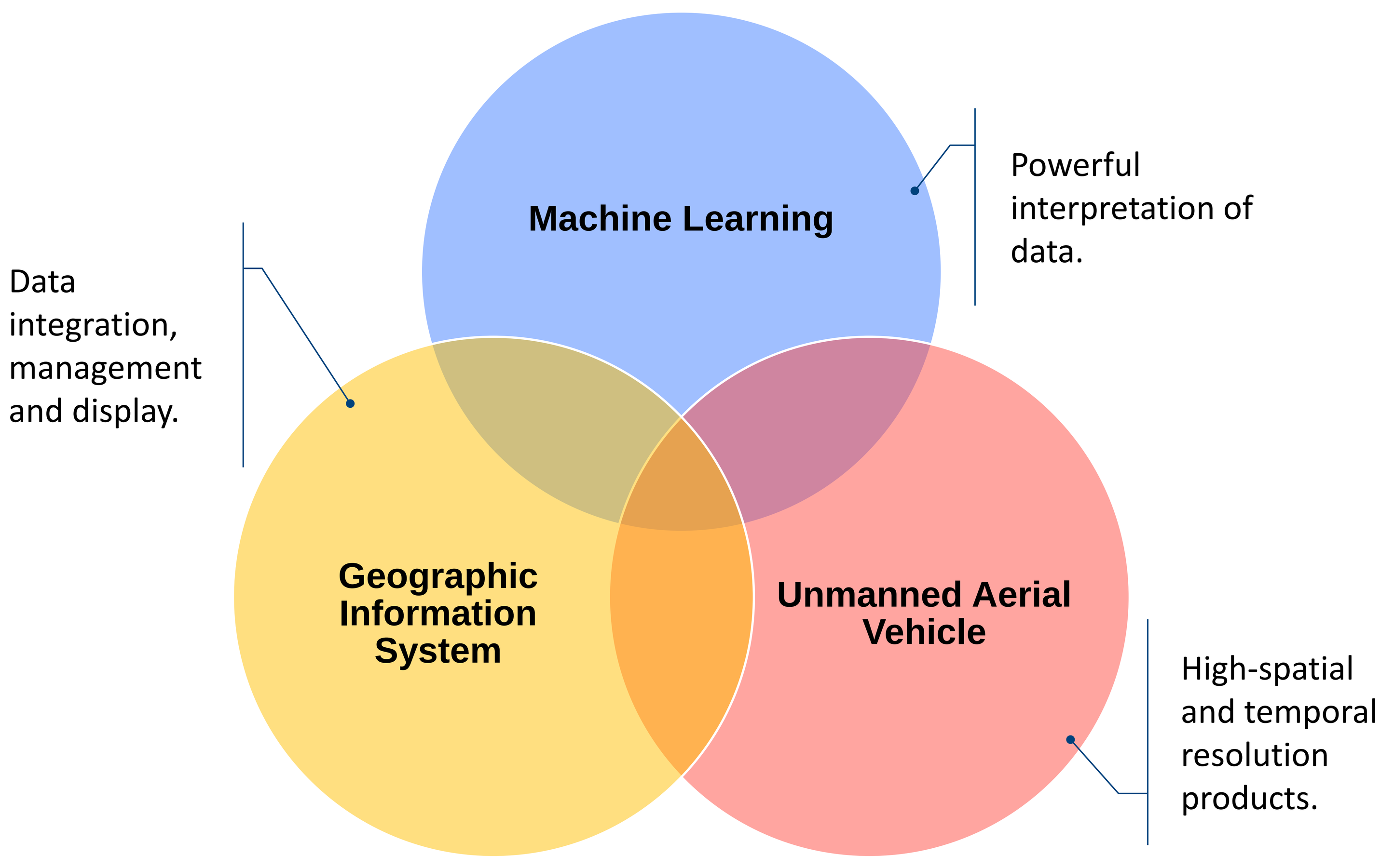
- We develop a robust **machine learning model** to estimate soil moisture with high resolution over the landscape from:
  - multispectral imagery from **unmanned aerial vehicle (UAV),**
  - topographic variables derived from digital surface model, and
  - meteorological variables.
- We demonstrate the ability to produced high resolution soil moisture maps for a watershed at the Merced Vernal Pools and Grassland Reserve (Merced, CA).

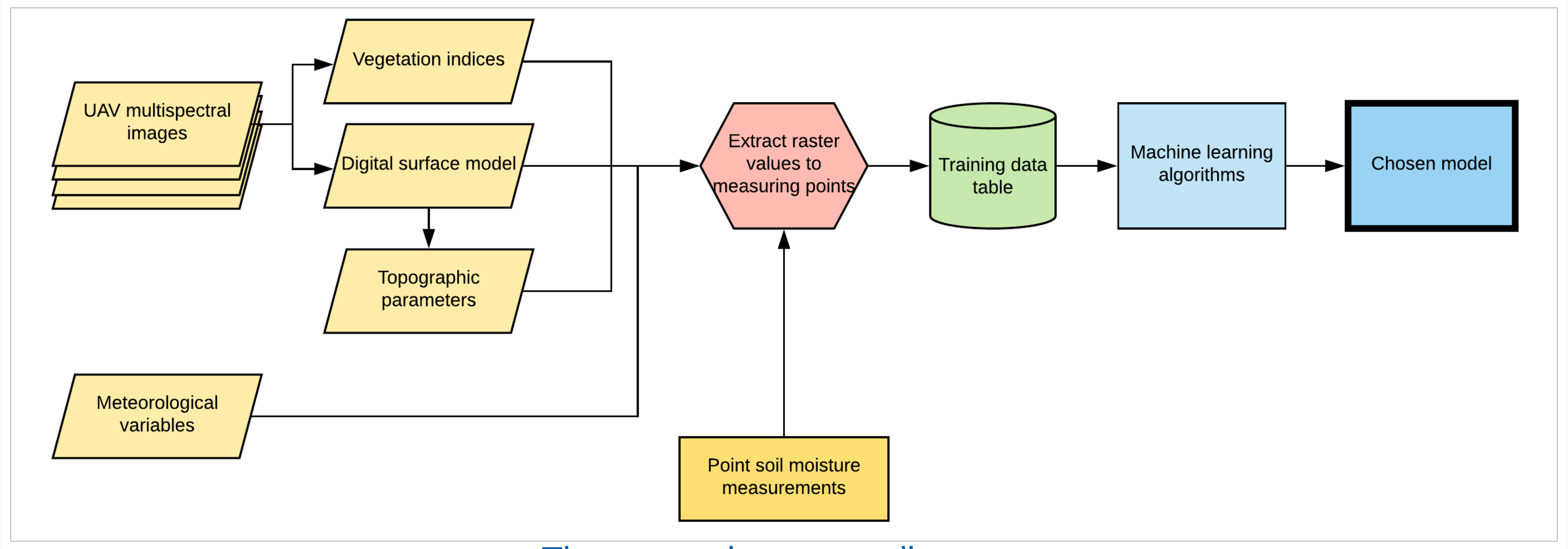
Introduction

- Several studies have used UAV based remote sensing to investigate soil water, but very few venture outside relatively homogeneous, agricultural plots.
- We set out with the hypothesis that the dynamics of **soil water status** across **heterogeneous terrain** can be adequately **described** and **predicted** by **UAV remote sensing** data and **machine-learning**.
- Remote sensing from UAV platform address several limitations of traditional remote sensing: UAV's have higher spatial resolution, frequent or on-demand image acquisition, and low operating costs.
- By fusing UAV remote sensing imagery, terrain variables and meteorological data with ground soil moisture measurement we construct a training database for a machine learning model.



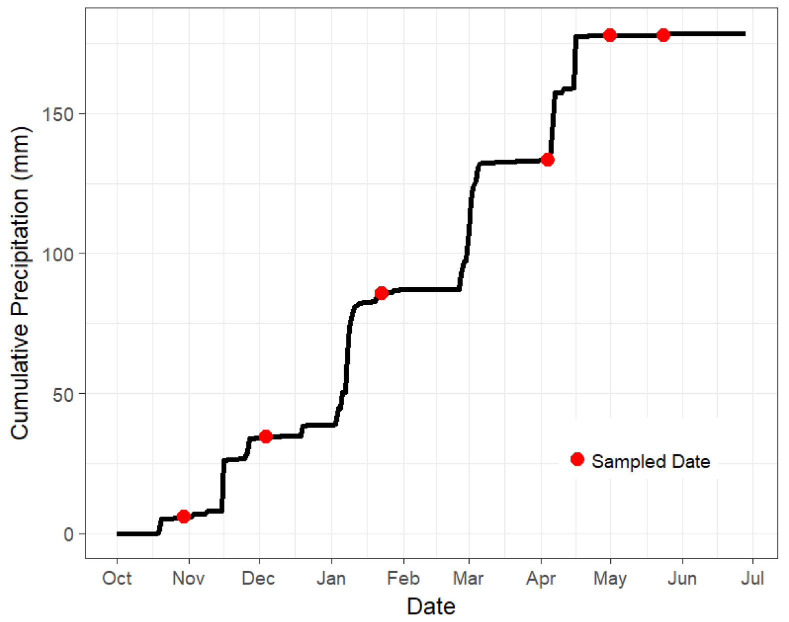
The main components of our research.

Methods



The research process diagram

- Image acquired throughout the 2018 water year using a fixed wing UAV with a *Parrot Sequoia* multispectral camera onboard.
- Images stitched and digital surface model produced photogrammetrically from stereo-images using *Pix4D* software.



Cumulative precipitation for 2018 water year. Sampling dates indicated with red points.

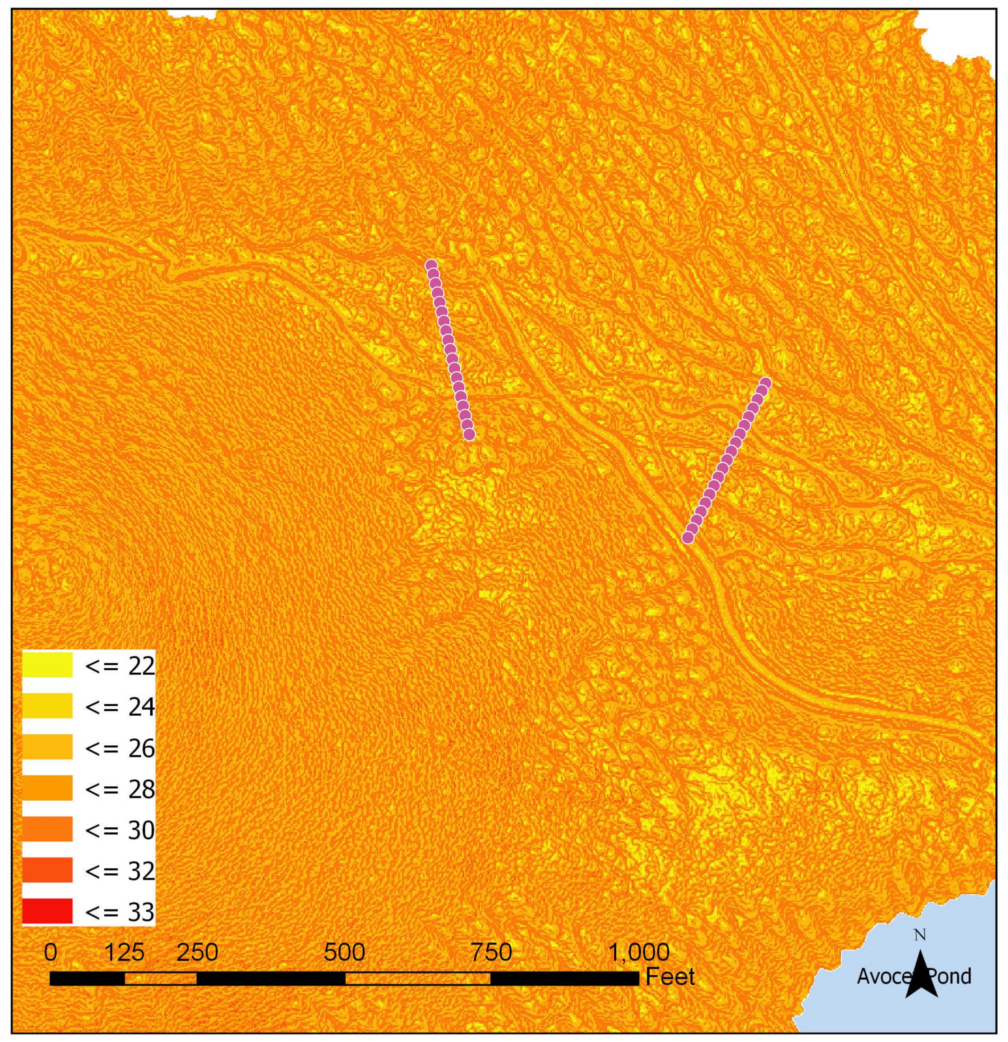
- Ground soil moisture measurement done with TDR instrument at precise sampling locations identified with Real Time Kinematic (RTK) GPS survey.
- Meteorological variables collected from California Irrigation Management Information System (CIMIS) website.

Photos of the study area.

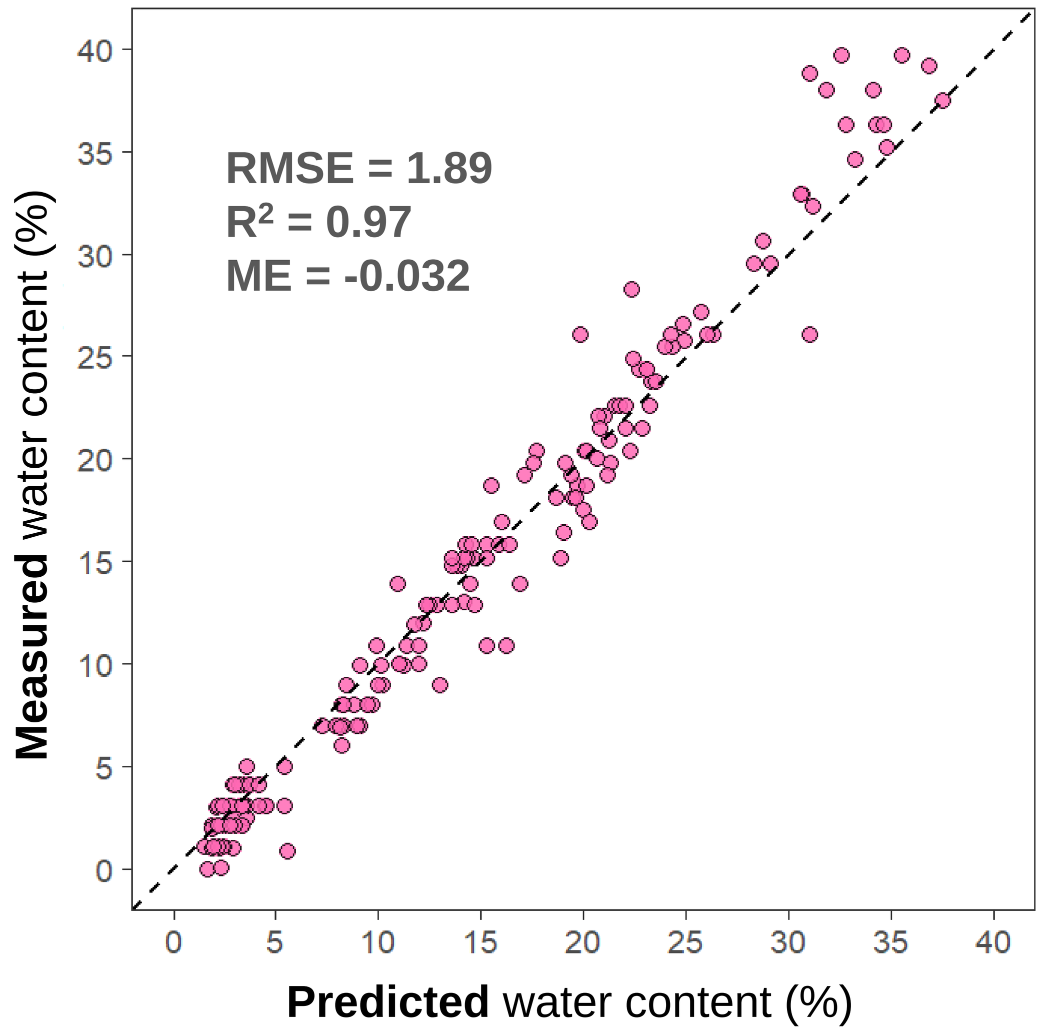
Description of the machine learning algorithm

- Algorithm: We compared Artificial Neural Networks, Support Vector Regression, Random Forests, and Gradient-Boosted models. *Boosted regression tree model was chosen*.
- Cross validation: Five times repeated 10-fold cross validation.
- Predictor variable selection: We implemented automatic variable selection using recursive feature elimination method
- Model performance metrics: Best model was selected based on root mean squared error (RMSE). In addition we assess the coefficient of determination and mean error of each model.

Results

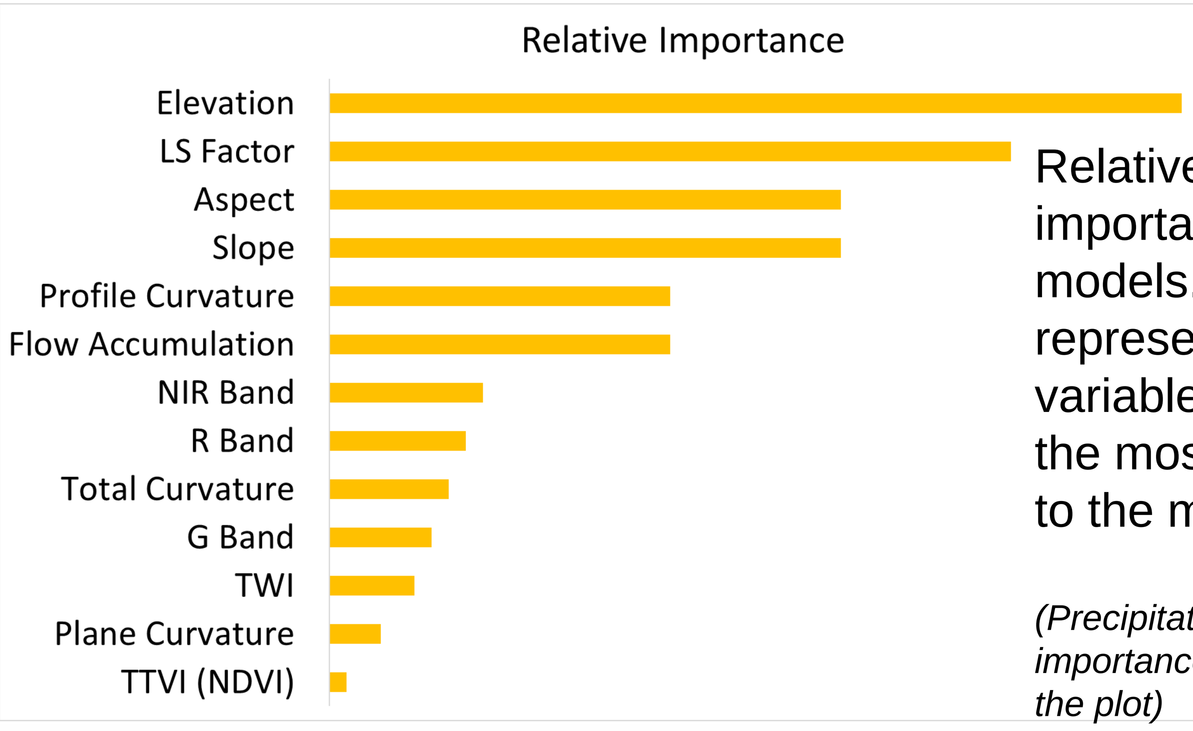


Model predicted volumetric soil water content map for January 23 of 2018. Purple points show the location of ground sampling.



One-to-one plot of measured versus model predicted soil moisture (percent volumetric water content).

The best model we developed predicted volumetric soil moisture content with RMSE of 1.9 and an R^2 of 0.97.



Relative variable importance in our top models. Longer bars represent predictor variables that contribute the most new information to the model.

(Precipitation has much higher importance and is not shown in in the plot)

The dynamics of soil water status across heterogeneous terrain may be adequately described and predicted by UAV remote sensing data and machine-learning.