Mapping Shrub Fractional Abundance (SFA): A Multi-Scale Remote Sensing and Machine Learning Framework for Arid Ecosystem Monitoring

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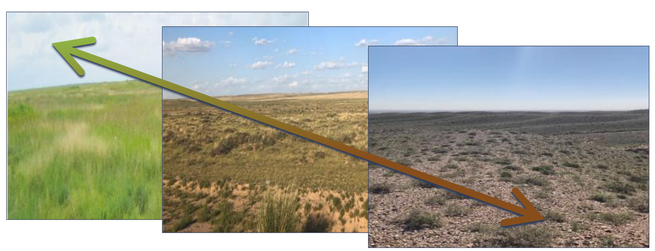
Introduction

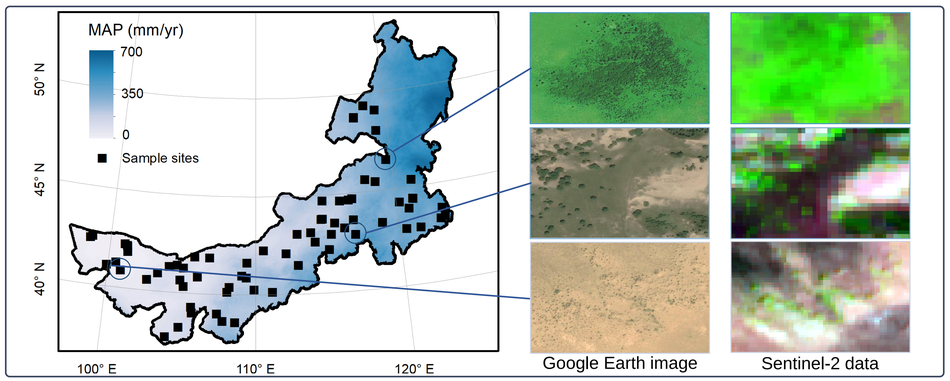
- Monitoring shrub fractional abundance (**SFA**) is essential for understanding ecosystem dynamics and supporting climate adaptation strategies;
- Current SFA monitoring methods **face challenges**, including labor-intensive fieldwork, limited UAV coverage, and mismatched satellite observation scales;
- Remote sensing **algorithms** struggle with shrubs' sparse distribution, small crown sizes, and spectral similarities to surrounding vegetation;
- Combining **multi-source remote sensing** data with machine learning enhances SFA mapping by integrating spectral and phenological insights;

- This study evaluates the use of Google Earth and Sentinel-2 imagery with machine learning to achieve **scalable SFA mapping** in arid and semi-arid ecosystems.



Adopted from (Shen et al., 2022, *Agric. For. Meteorol.*)

Study sites & Materials



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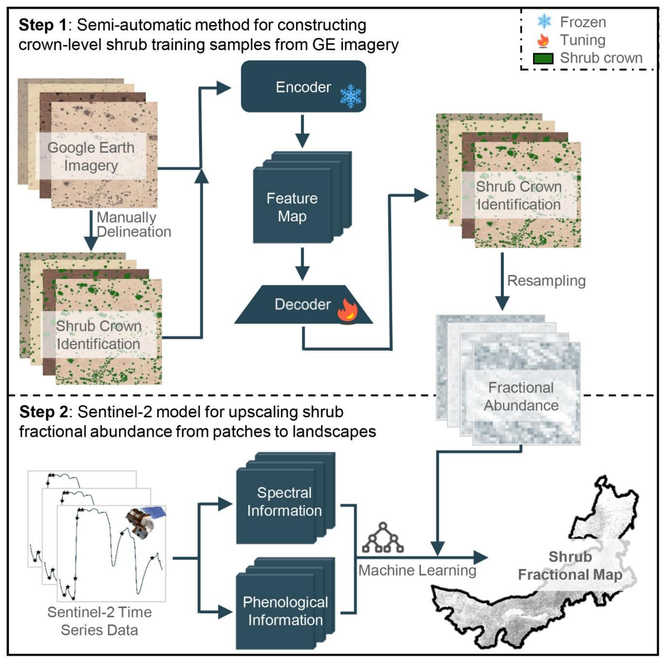
Methods

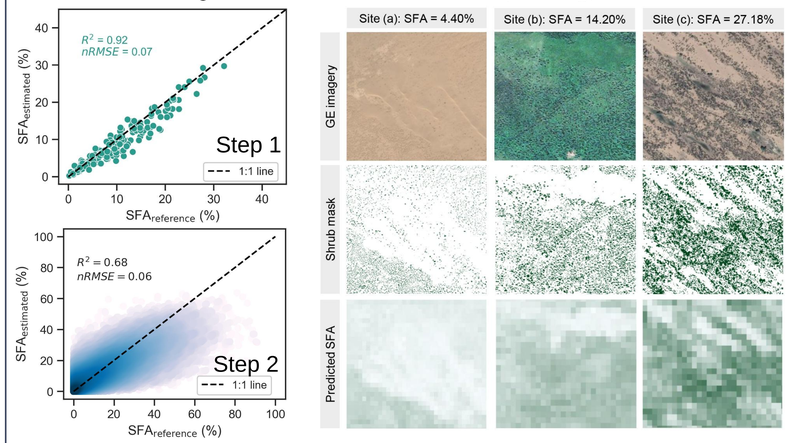
A two-step approach for scalable SFA mapping:

- **Step 1**: A deep learning model to generate crown-level shrub training samples from Google Earth imagery;
- **Step 2**: A machine learning model to upscale SFA from patches to landscapes using Sentinel-2 time-series data.

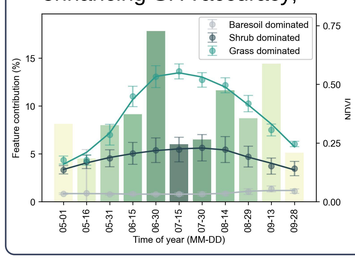


Results

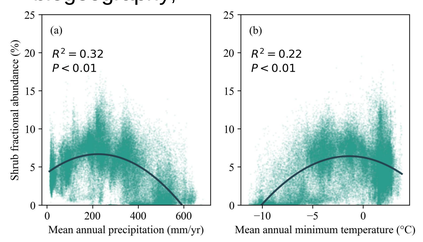
- The two-step approach achieved **high accuracy**, with R^2 = 0.92 for shrub crown segmentation and R^2 = 0.68 for upscaling;



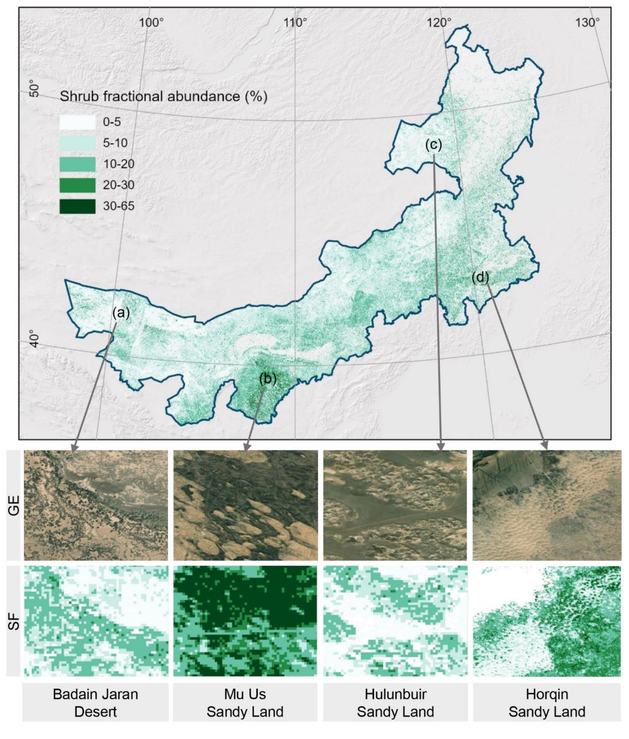
- Significance of **phenology** in enhancing SFA accuracy;



- **Nonlinear** effects of **climate** on SFA biogeography;



- Regional SFA map for Inner Mongolia (20m).



Summary

- A novel **two-step approach** combines high-resolution Google Earth imagery (0.5m) for precise shrub crown identification with Sentinel-2 time series data (20m) for scalable mapping;
- Sentinel-2 **phenological** data, particularly spectral information from May, July, and September, enhances the model's ability to differentiate shrubs from the background;
- The shrub fractional map improves monitoring and management of semi-arid ecosystems, supporting their **sustainability** in the face of global climate change.