FVS …
and what comes next.

David Diaz
Center for Advanced Forestry Systems
June 12, 2025

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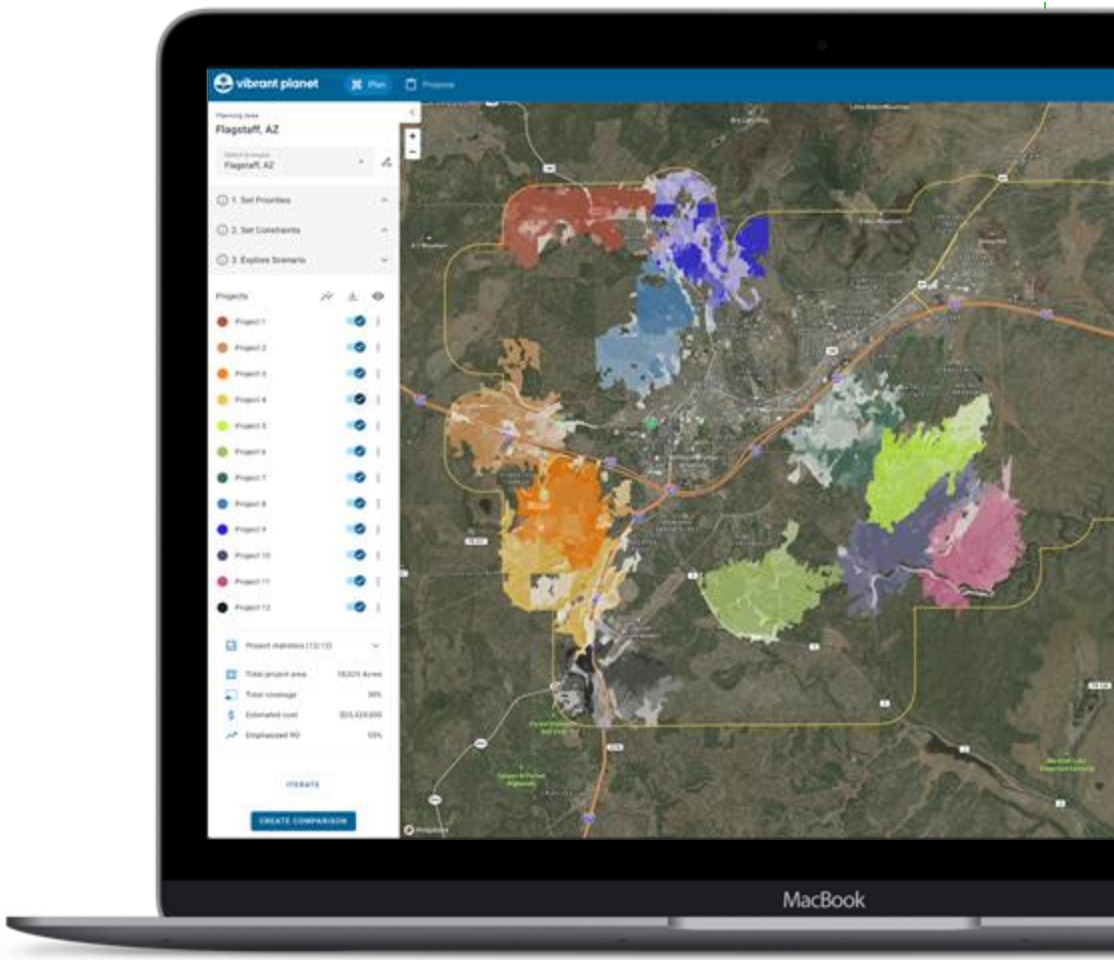
Vibrant Planet

The first common operating system for fire and forest resilience planning

Vibrant Planet

Adaptive community and wildland management—a “living” plan

- Empower decision makers to move with precision and speed
- Monitor current conditions/hazards with best data and science
- Enable statewide and regional standardization with localization
- Intuitively communicate the cost-effectiveness of risk reduction and/or restoration outcomes alongside detailed tradeoff and efficiency analytics
- Enable collaborative uses from day 1.



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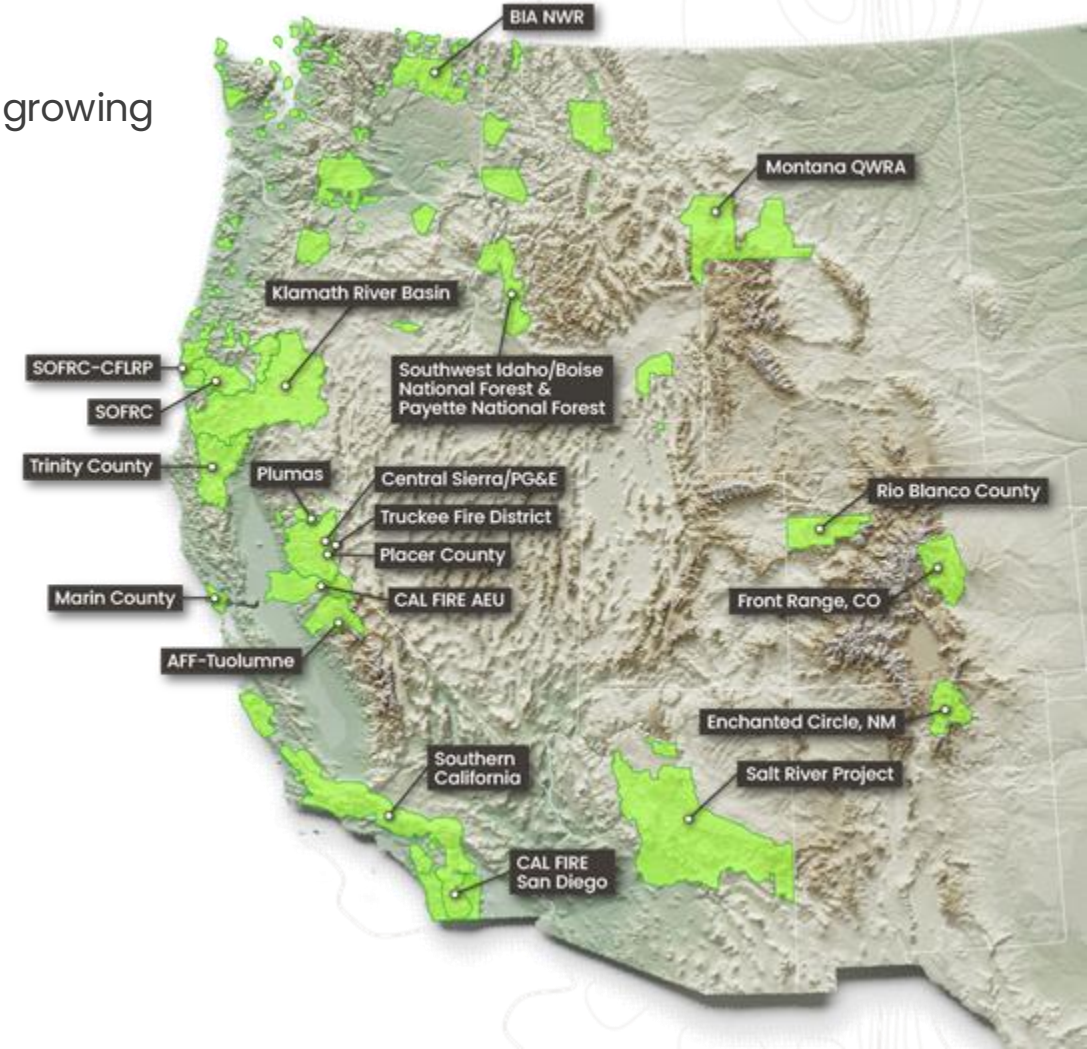
Vibrant Planet

Currently deployed across 70M acres and growing

- Architected to serve multiple decision scales and designed for a wide range of audiences.
- Built upon modern ML workflows to leverage remote sensing and trusted forest + fire modeling and prioritization systems.
- Rapid generation of CWPPs and QWRAs.



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Today's Focus

Challenges & Solutions for Next-Generation Growth & Yield

- Motivating Use Case
- Reproducible & Scalable Computing
- Benchmarking Model Performance
- Improving Default FVS Performance
- Plugging in New Models
- Governance of Community-Supported Software

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Motivation

As a forest/community decision-maker:

- ➔ I need to see how the assets and resources we care about respond to a spectrum of treatment and disturbance events …
- ➔ so that I can identify the most cost-effective ways to achieve our risk mitigation and/or restoration goals while limiting undesirable tradeoffs.

As a forest/fire analyst:

- ➔ I need a scalable, reliable, and cost-effective pipeline to execute millions of simulations of a variety of management and disturbance scenarios …
- ➔ so that I can deliver impact metrics that enable managers to evaluate the effectiveness and tradeoffs of alternative management scenarios.

Reproducibility Challenges

- Fortran77
- FVS is more than a dozen divergent implementations of the same core functionality (growth, mortality, regen, disturbance events) in regional variants.
- Production target narrowly focused on desktop GUI for Windows OS. Tries to solve most G&Y life cycle via GUI, handled internally instead of interfacing with purpose-built external libraries that are more widely used and better maintained.
- Limited adoption of software engineering best practices (CI, unit and integration testing) and development patterns (branching and pull requests). Breaking changes and backward incompatibility occur often with changes to FVS codebase.
- While FVS is open-source on GitHub, community contributions are limited to one person, and even FMSC staff face barriers to contributing code.
- FMSC capacity to fix bugs and issues is severely limited and we should probably expect it to get worse rather than better for the next several years.

Reproducibility Challenges

Essential FVS:
A User's Guide to the
Forest Vegetation Simulator

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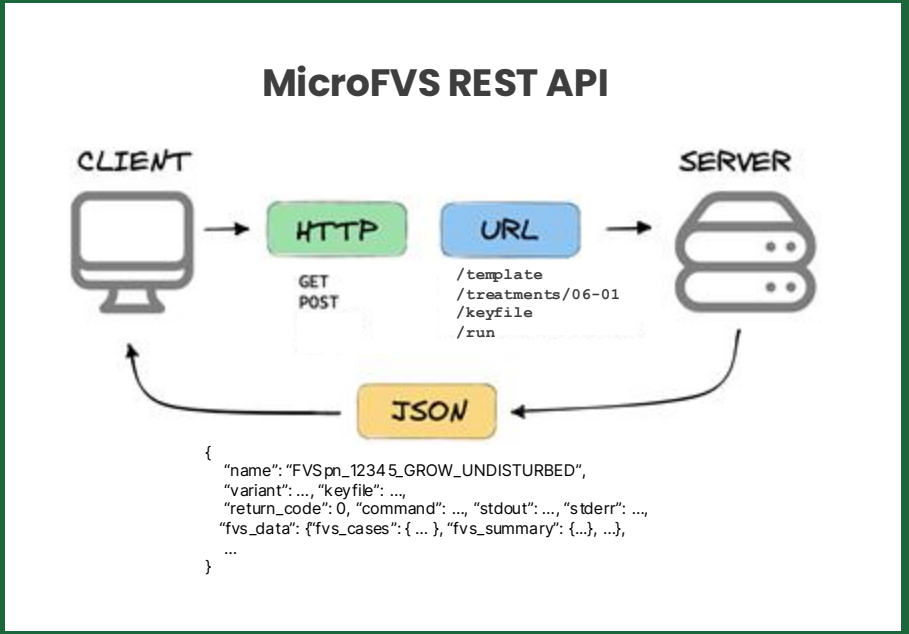
Reproducibility Solutions

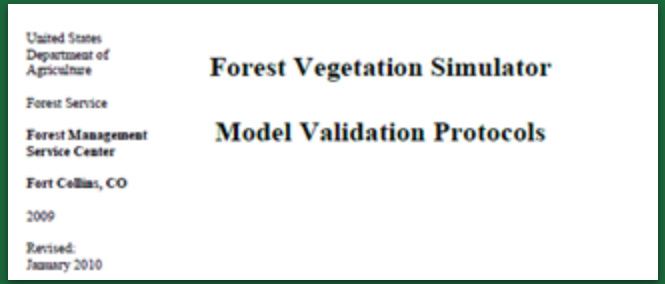
- Build & Scale: Containerized FVS environment built from source that can be deployed and autoscaled with cloud computing.
- Robust: Automated unit & integration tests to catch breaking changes before merging updates.
- MicroFVS Web API: Clearly defined inputs, outputs, and reusable building blocks. Sensible defaults provided if not given by user.



Adapted from "What is a REST API" by mannhowie.com

Benchmarking Challenges

- Core workflow and results of FVS validation protocols are either not being followed or not being documented.
- Numerous studies showing systematic bias in multiple regions with FVS defaults (overestimation of growth and/or underestimation of mortality)
- Widespread application of (Climate-)FVS for policy, carbon, and strategic analyses by FVS novices. Journal peer review isn't working.



United States Department of Agriculture

Forest Service

Forest Management Service Center

Fort Collins, CO

2009

Revised: January 2010

Forest Vegetation Simulator

Model Validation Protocols

Cawrse et al. (2010)

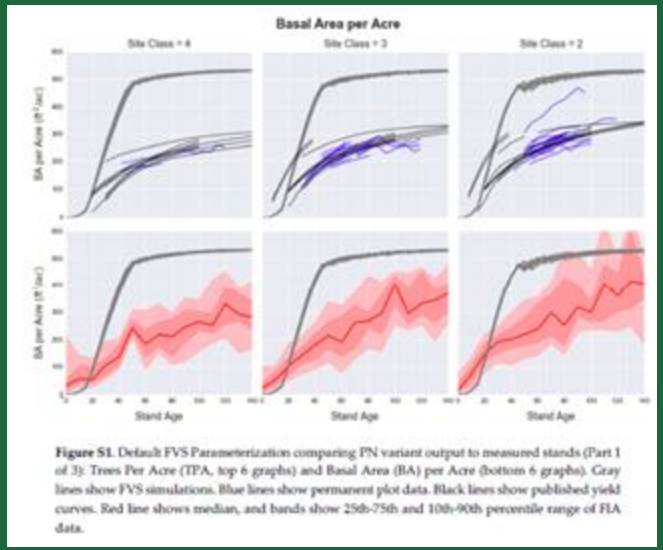


Figure S1. Default FVS Parameterization comparing PN variant output to measured stands (Part 1 of 3): Trees Per Acre (TPA, top 6 graphs) and Basal Area (BA) per Acre (bottom 6 graphs). Gray lines show FVS simulations. Blue lines show permanent plot data. Black lines show published yield curves. Red line shows median, and bands show 25th-75th and 10th-90th percentile range of FIA data.

Diaz et al. (2018). "Tradeoffs..."

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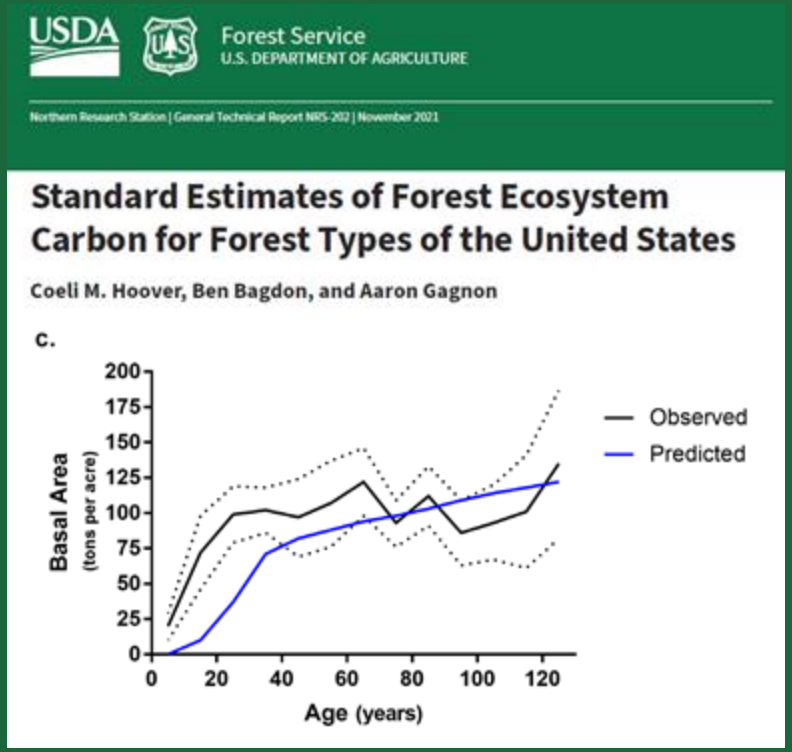
Benchmarking Solutions

- FIA data stream should serve as the foundation for evaluating how well incremental and long-run simulations perform against field observations across US.
- Automate and extend FVS Validation Protocols so performance of current models and proposed changes can be quantified and documented.
- A shared proving ground is necessary (but not sufficient) to enable community development and limit redundancy.



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FVS Default Challenges

- Growth and mortality parameters have not been refit in most regions for decades, despite widespread empirical evidence that forest growth and mortality rates are changing. It is not clear how well predictions matched observations at the time they were fit either.
- FVS growth and mortality coefficients can currently only be changed in Fortran77 source code and used after re-compiling.
- FVS does not consistently break or offer clear error messages with invalid input data.
- FVS docs give unintentionally misleading illusion of stochastic capability to reflect model uncertainty.

FVS Out of the Box—Assembly Required

Don Vandendriesche[1]

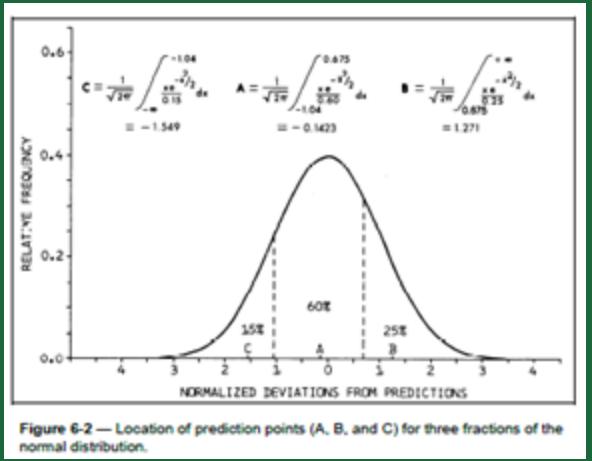

Figure 6-2 — Location of prediction points (A, B, and C) for three fractions of the normal distribution.

Dixon et al. (2025). "Essential FVS..."

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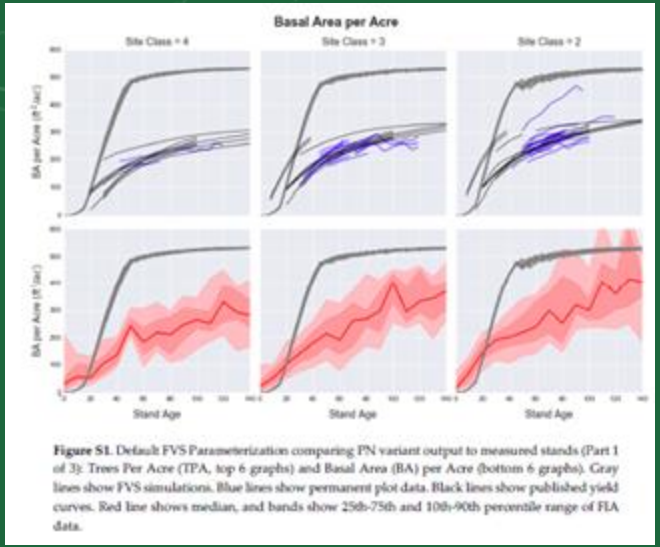
FVS Default Solutions

v0: Bend FVS with Keywords

Employ SDIMAX, BAIMULT, MORTMULT keywords to bend FVS into sensible range.



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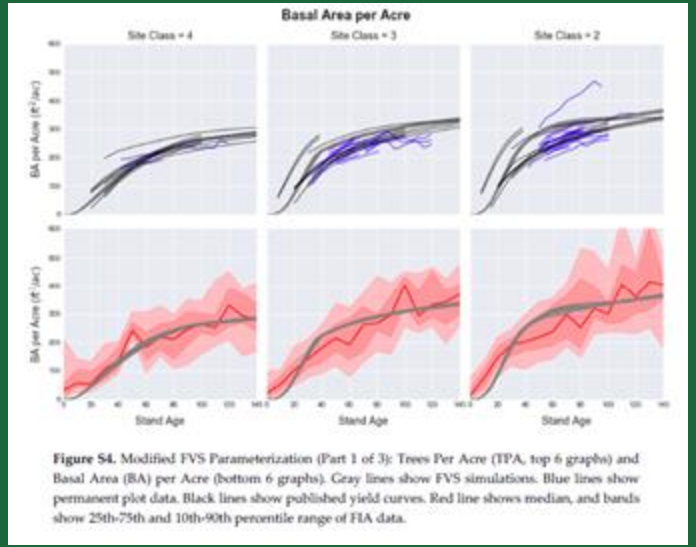

Figure S4. Modified FVS Parameterization (Part 1 of 3): Trees Per Acre (TPA, top 6 graphs) and Basal Area (BA) per Acre (bottom 6 graphs). Gray lines show FVS simulations. Blue lines show permanent plot data. Black lines show published yield curves. Red line shows median, and bands show 25th-75th and 10th-90th percentile range of FIA data.

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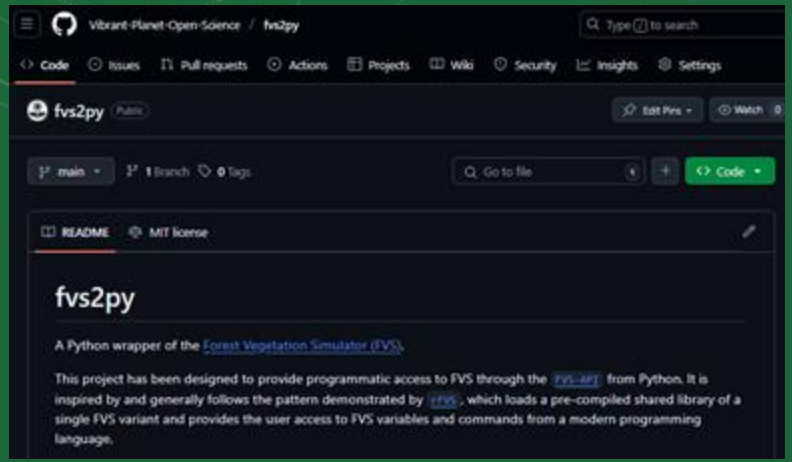
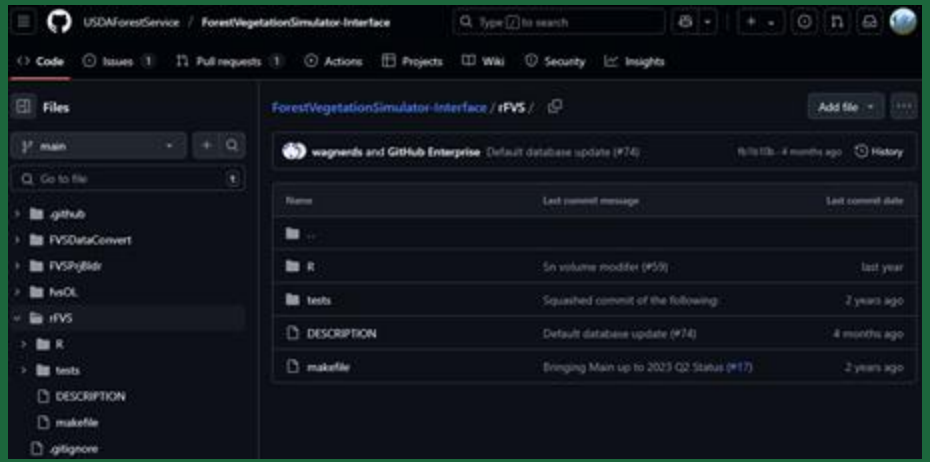
FVS Default Solutions

v1: Focus on extending FVS API to avoid major refactor

Make targeted extensions of existing FVS API in Fortran to allow getting and setting of growth and mortality coefficients at runtime from rFVS or fvs2py.



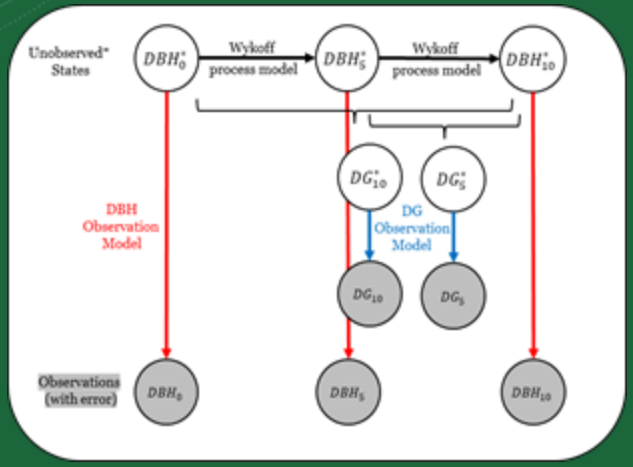


FVS API can allow Fortran routines to be ignored or have params modified directly. Custom models can estimate growth, mortality, regen, injecting predictions as changes to FVS trees in memory at runtime.

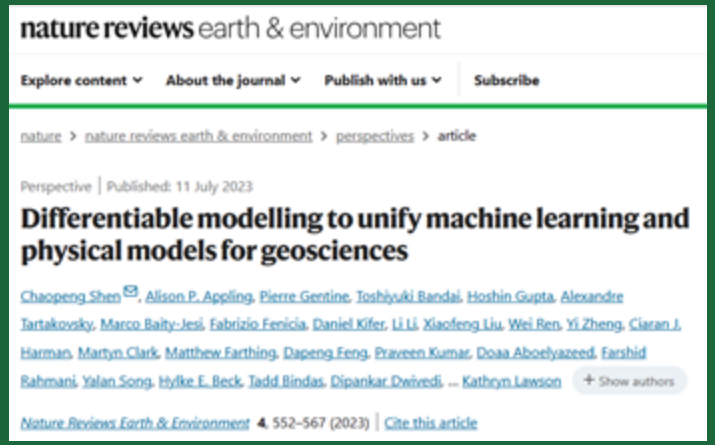
FVS Default Solutions

v2: Replicate FVS step-functions outside of Fortran

Code growth and mortality routines in modern statistical libraries and assimilate new data. Integrate new model forms and coefficients either through FVS refactor or replacement at runtime using FVS API.



Diaz & Ettl (2024) in https://research.fs.usda.gov/treesearch/68919



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Differentiable modelling to unify machine learning and physical models for geosciences

Chaopeng Shen, Alison P. Appling, Pierre Gentine, Toshiyuki Bandai, Hoshin Gupta, Alexandre Tartakovsky, Marco Baity-Jesi, Fabrizio Fenicia, Daniel Kifer, Li Li, Xiaofeng Liu, Wei Ren, Yi Zheng, Ciaran J. Harman, Martyn Clark, Matthew Farthing, Dapeng Feng, Praveen Kumar, Doaa Aboelyazeed, Farshid Rahmani, Yalan Song, Hylke E. Beck, Tadd Bindas, Dipankar Dwivedi, ... Kathryn Lawson + Show authors

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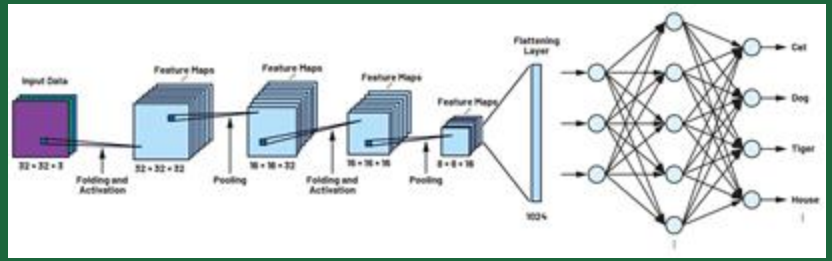
Plugging in New Models

Beyond FVS

- Stable API and automated benchmarking in an open-source repo allow community development and iteration while maintaining data contract with users.
- G&Y engine can be abstracted to a black box that maps tree + stand initialization data and simulation configs to schema-compliant outputs.
- New models are free to bring new data, features, algorithms to bear so long as they can be derived from existing FVS inputs (e.g., lat/lon) or be submitted to API as optional inputs by users.

https://blog.ml.cmu.edu



https://www.embedded.com/understanding-convolutional-neural-networks/

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Governance

FVS and what comes next.

- ➔ US GOV is so far unable or unwilling to adopt modern software development patterns or enable community contributions. Any modifications to FVS source code need to be built on forks rather than expecting PRs and issues to be addressed by FVS maintainers.

- ➔ We will all benefit (including US GOV) by enabling community contribution to a shared G&Y framework, but that needs to involve clear standards and expectations and honoring them in practice. This will require a steering group of core contributors and maintainers who would ideally lead definiition of a roadmap for priority development tasks that will benefit the community.

- ➔ The size, scope, and ambition of this group and effort can be scaled according to capacity and funding while prioritizing basic service remains available or at least reproducible.

Thank you.

Find me

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