NATIONAL ACADEMIES *Sciences Engineering Medicine*

Greenhouse Gas Emissions from Wildland Fires: Toward Improved Monitoring, Modeling, and Management--A Workshop

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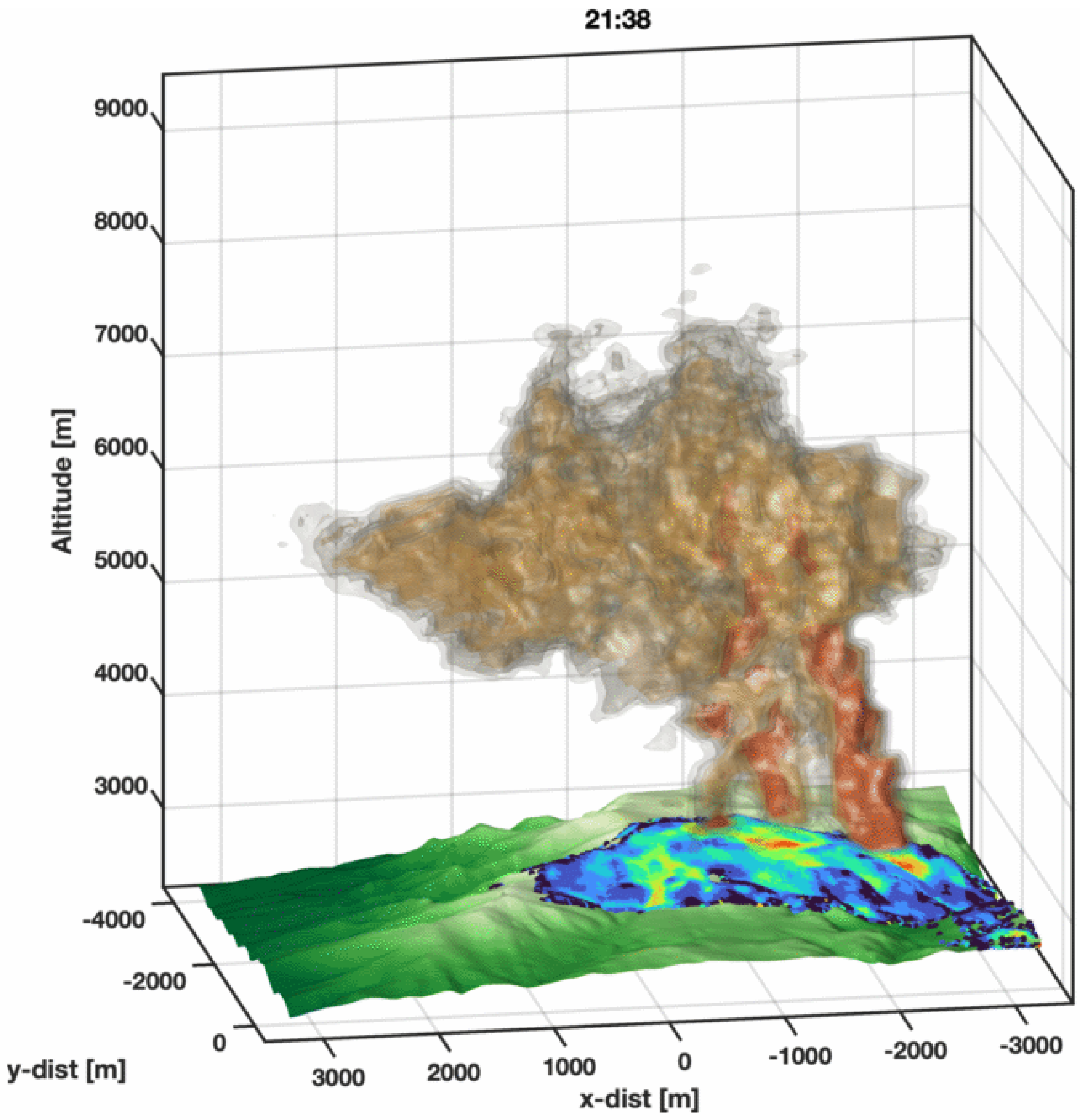
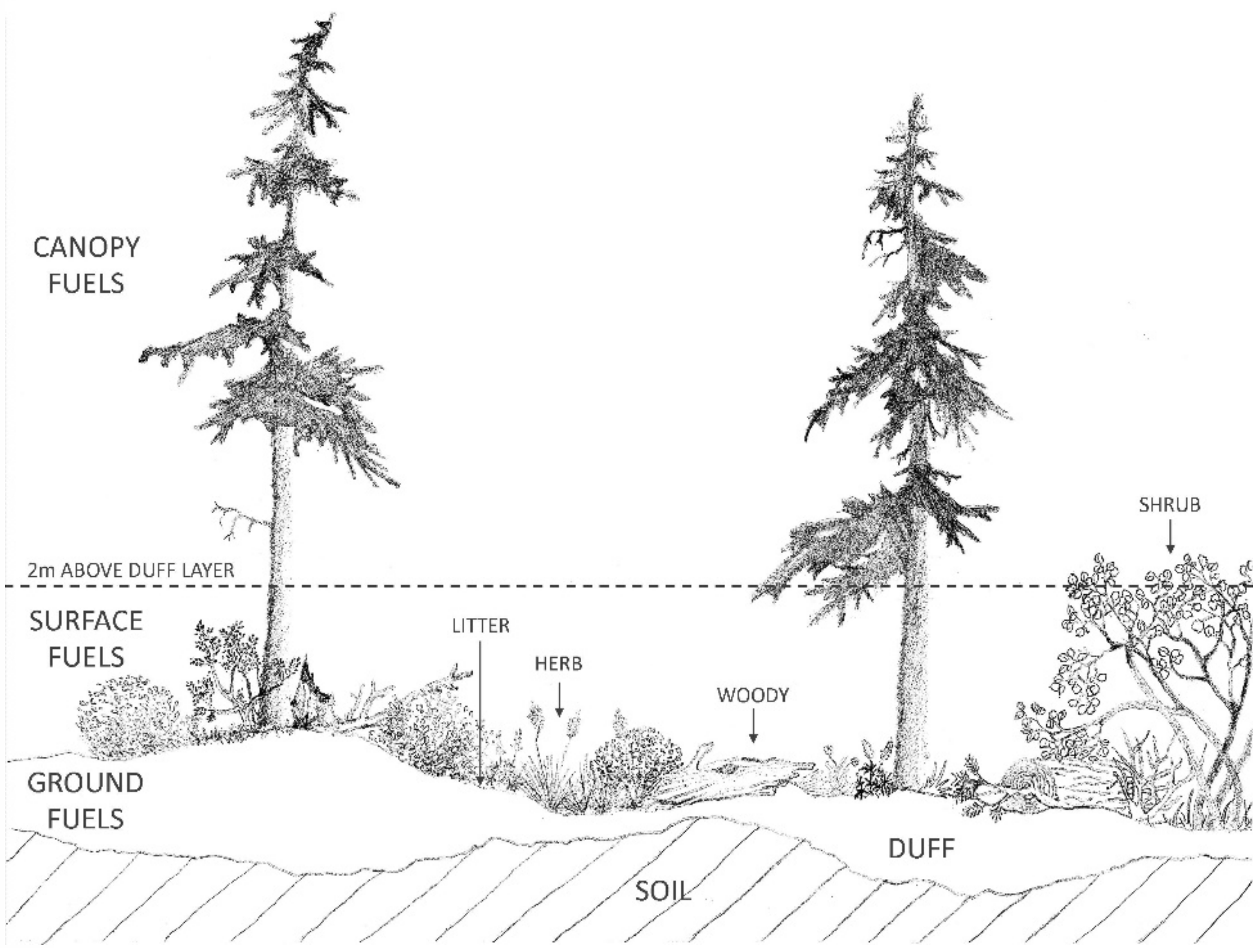
Wildland Fuelbeds are Complex





Vertical fuel strata in a wildland fuelbed (drawing by Ben Wilson from Keane [2015])

Prichard et al. (2022) Fuels and Consumption. In: *US Forest Service National Smoke Assessment*.

Lareau et al. (In Review) *IJWF*

Estimating Emissions: From Fuel to Smoke

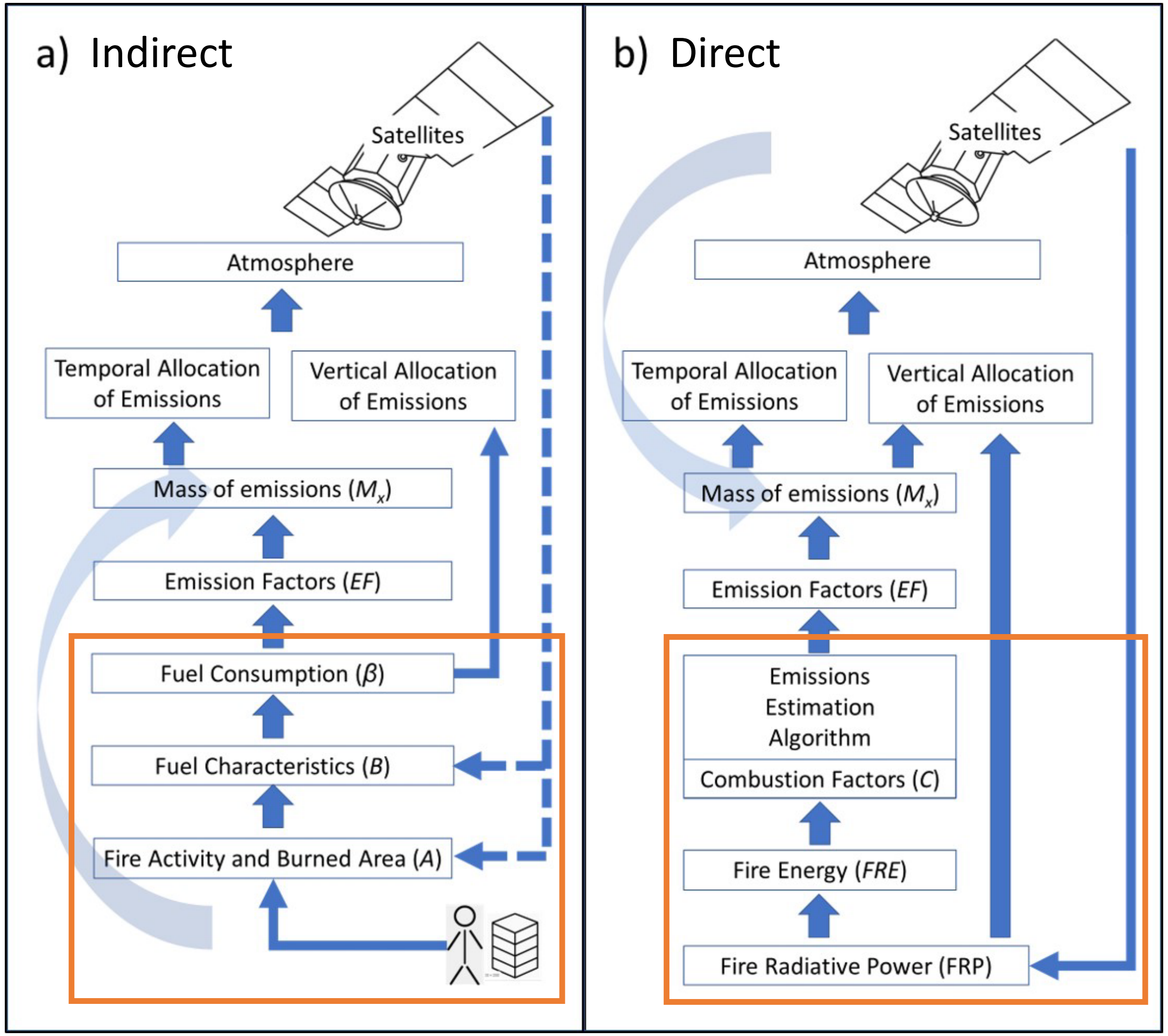
Atmospheric Approach (Carter et al. 2020)

- Observe atmosphere
- Infer fire sources based on concentrations and chemical transport modeling
- Top-down

Activity-based Approach (right)

- Observe variables on the ground that drive emissions
- Estimate fuel consumed (Mc) *indirectly* by differencing fuel loads measured or predicted both pre- and post-fire (a)
- Estimate fuel consumed (Mc) *directly* by measuring heat flux as fuel is combusted (b)
- Bottom-up

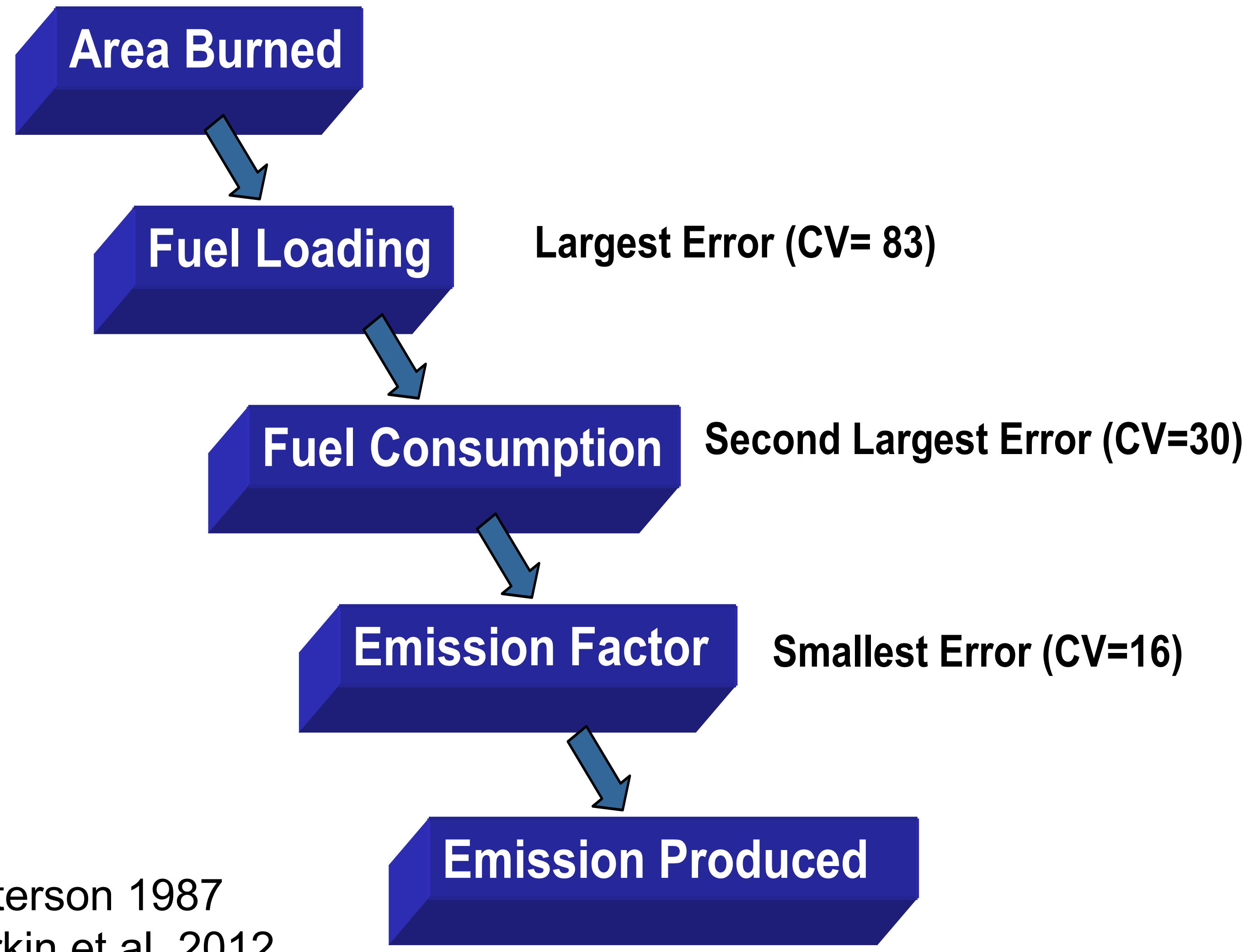
$$Mc = A \times B \times \beta \qquad Mc = \text{FRE} \times \text{C}$$



All approaches have uncertainty due to the complexity of fuels and combustion conditions

French and Hudak (In Press) Fuel consumption and emissions from biomass burning. In: *Fire, Smoke and Health.* AGU Book.

Sources of Uncertainty

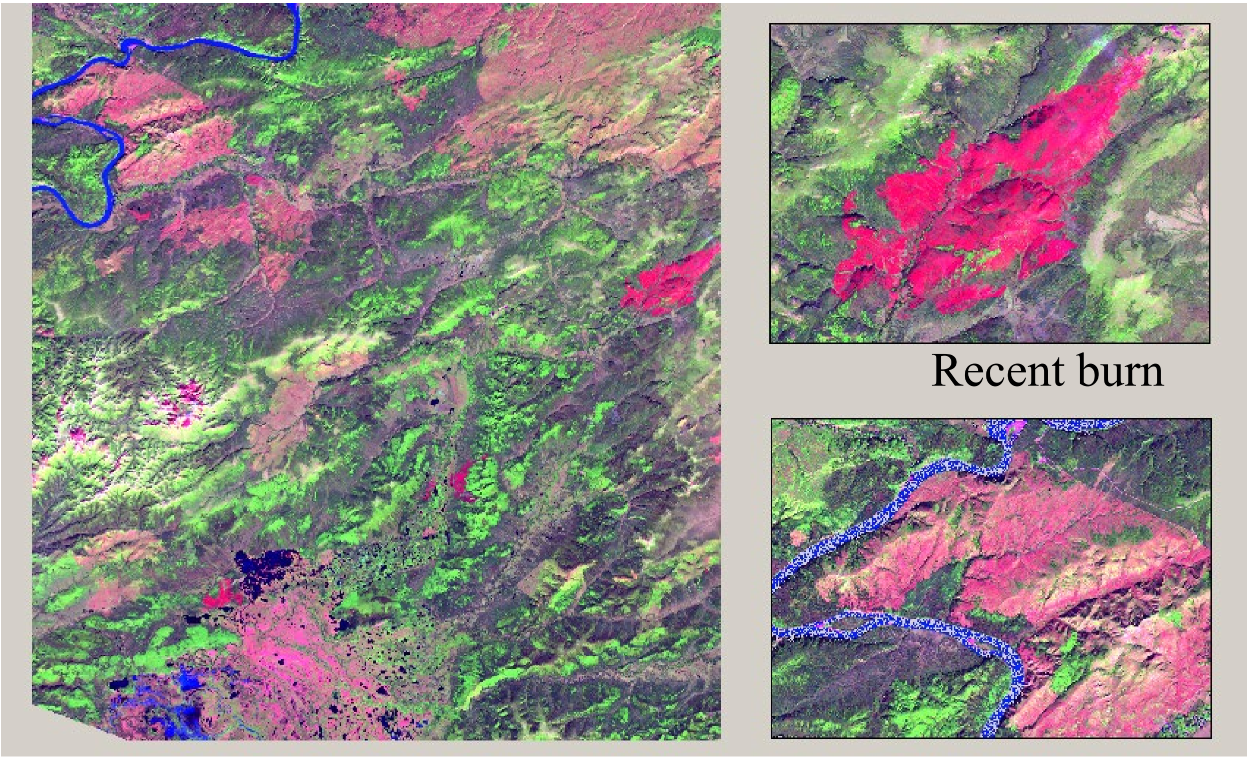


Peterson 1987
Larkin et al. 2012

Fuel loading and the proportion of the fuel that is combusted (consumption) have highest uncertainty

Mapping burn area (Where)

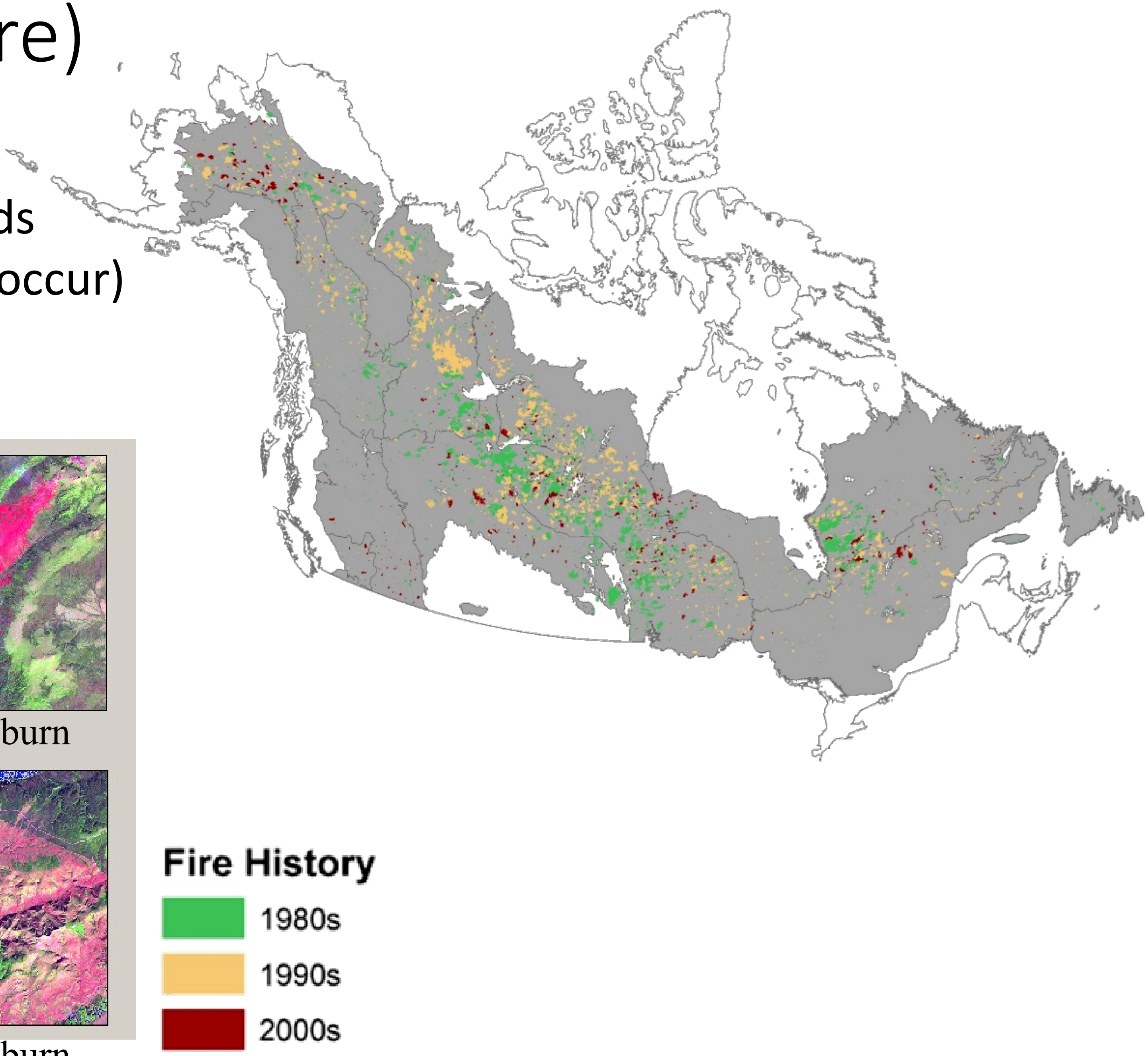
Burn area can be mapped from fire records (site-level maps of where and when fires occur) or with remote sensing



Recent burn

Older burn

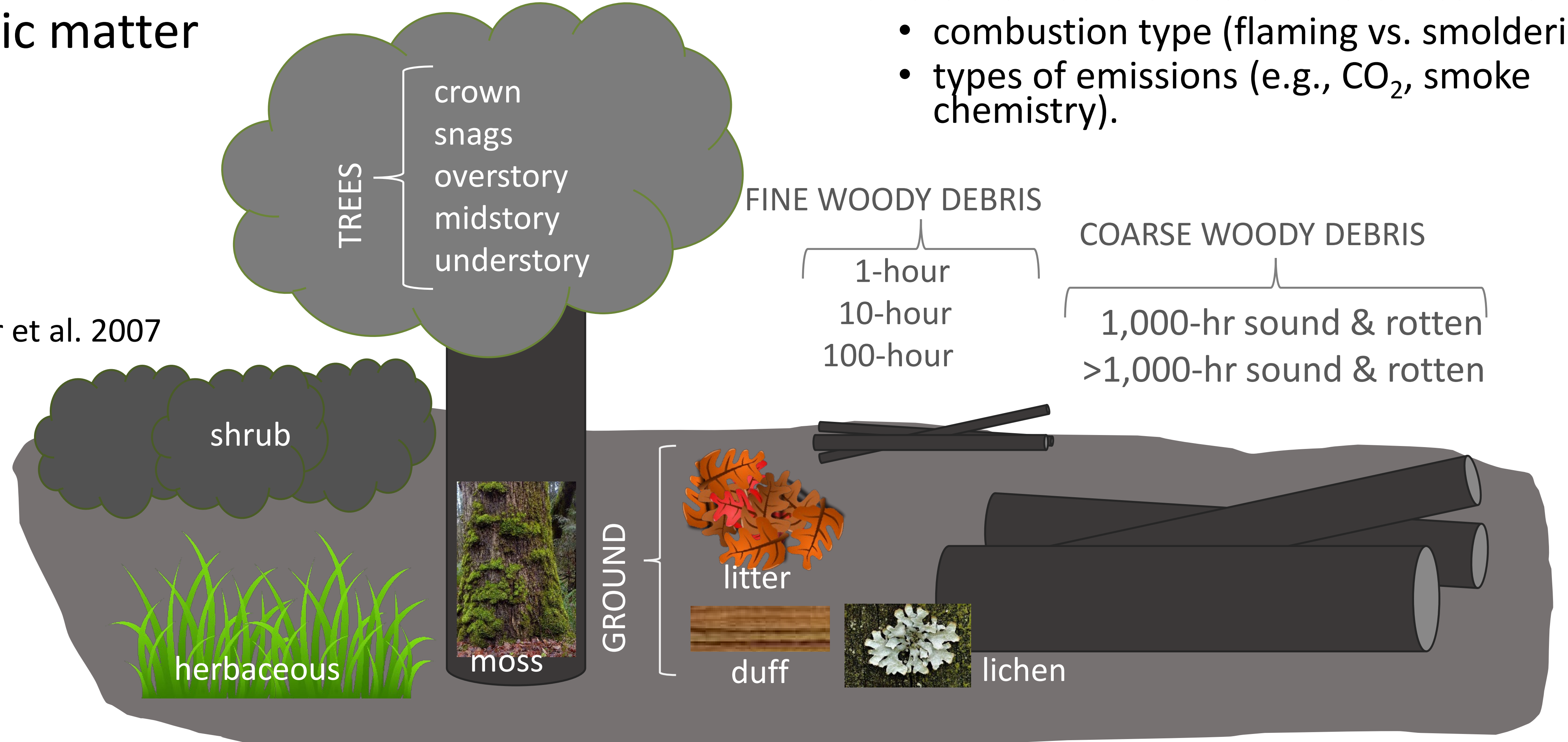
Landsat TM bands 7,4,3



The Fuelbed (What)

Fuel – Live and dead vegetation biomass that burns – includes aboveground live, dead surface material, and ground-layer organic matter

- Fuel structure is very important to fire behavior, consumption, and fire effects.
- Fuel composition can determine flammability and other factors relevant to emissions
  - combustion type (flaming vs. smoldering)
  - types of emissions (e.g., CO_2, smoke chemistry).

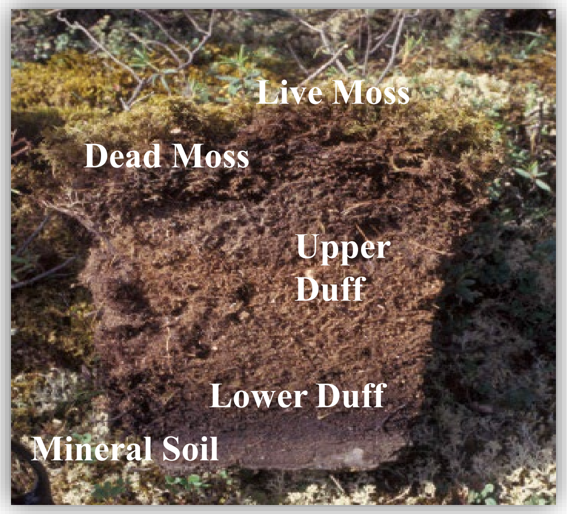


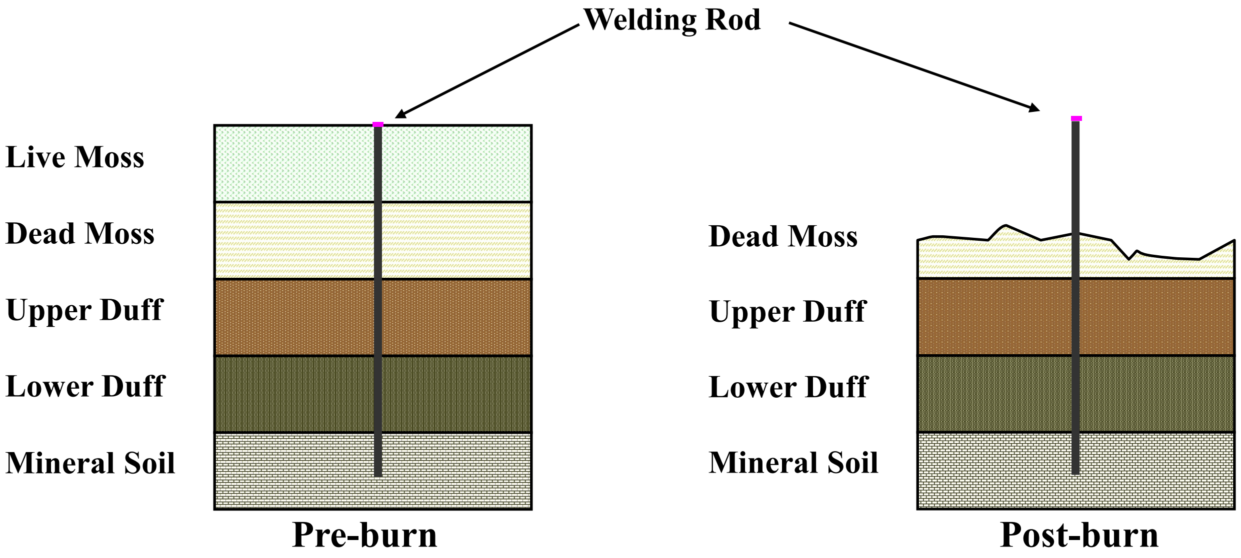
Ottmar et al. 2007

Combustion accounting (How)

- Collect information on fuel loadings:
  - Dead vegetation material (litter and coarse woody debris)
  - Live vegetation
  - Surface organic soil
- Predict fuel consumption:
  - fuel type, density (loading), moisture
  - other environmental factors

Pre-fire Fuel Inventory Post-fire

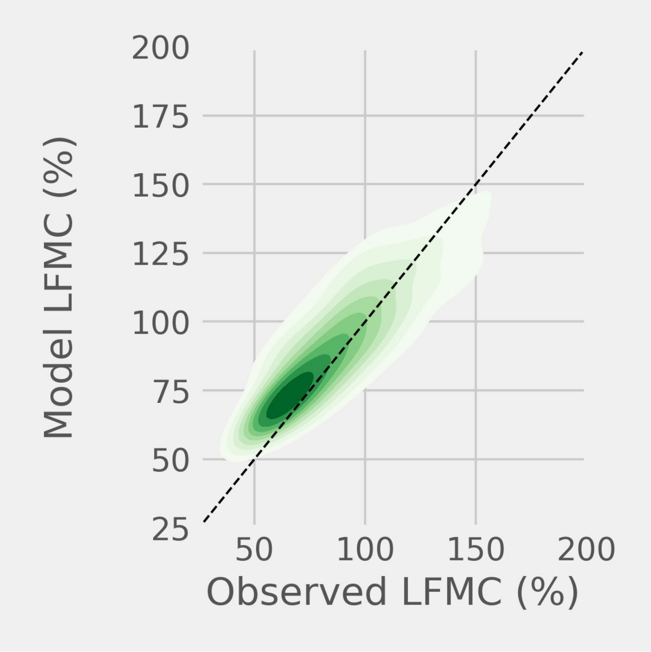


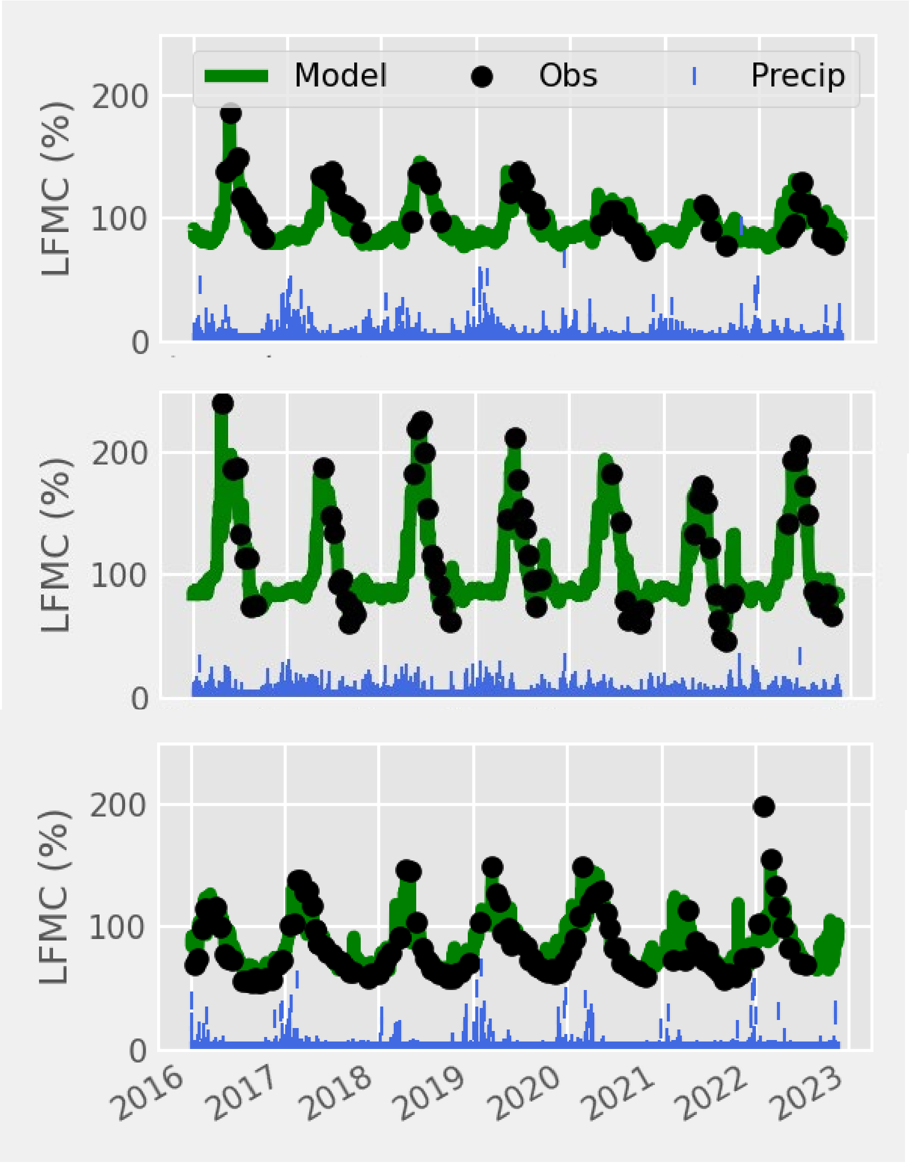


Better Measurements as Cal/Val for Improved Models

e.g., Fuel Moisture

- Fuel moisture is estimated using a machine learning model using OpenET data trained on samples collected from the National Fuel Moisture Database.
- With OpenET we can begin to map and distribute Fuel Moisture data at temporal and spatial scales relevant for management





e.g., <u>Plant Litter</u>

Better Measurements as Cal/Val for Improved Models

Driver of fire spread and consumption	***Often largest surface fuel component***

Current methods…

Large uncertainties from field-based models and data samples

Remote sensing limitations: low sensitivity of both active and passive remote sensing systems particularly ***under canopy cover***

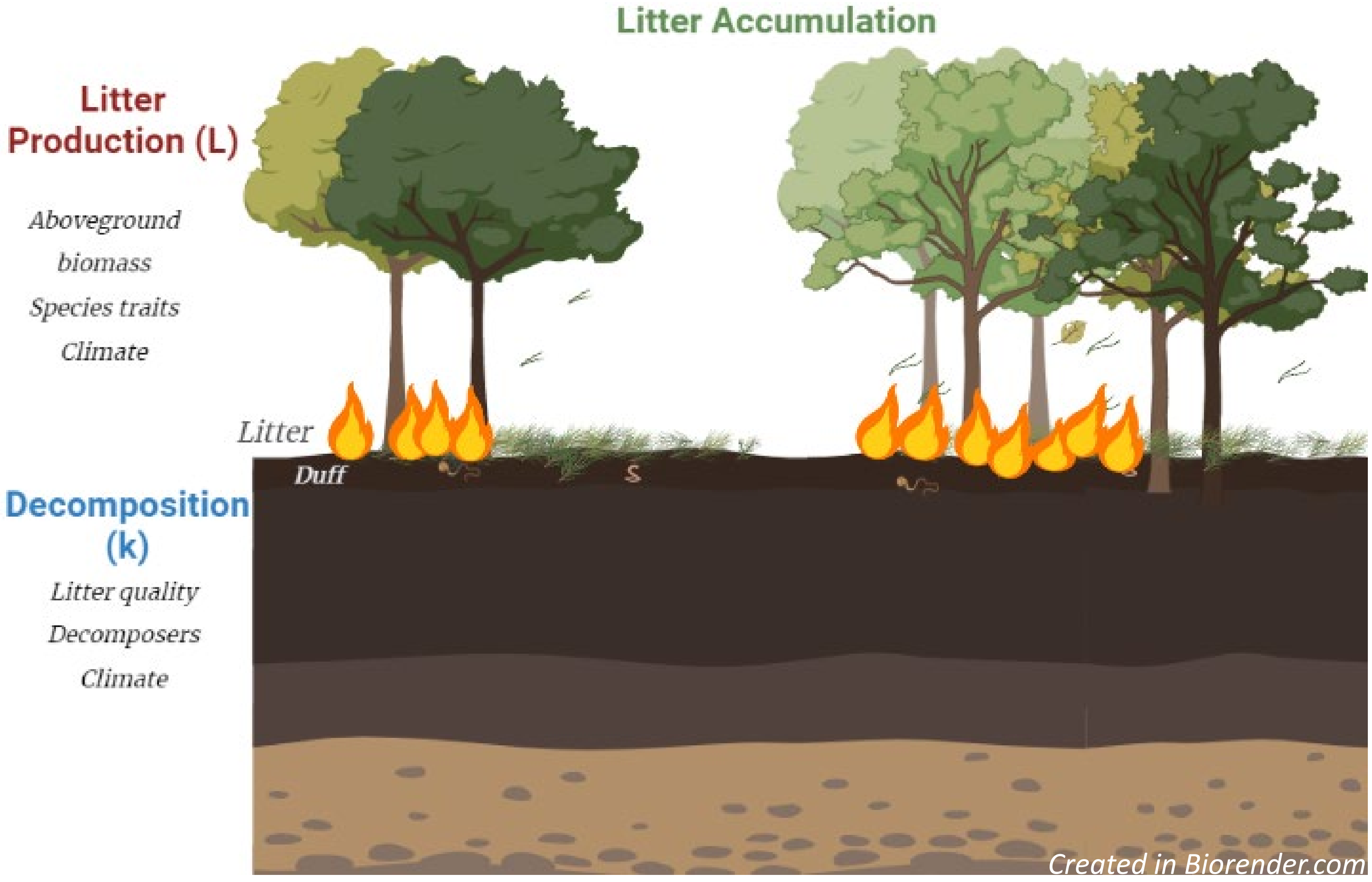
Sánchez-López et al. (2023) *Ecological Modelling* 481: 110369

Litter accumulation process

Tree litter is unevenly distributed over the forest floor depending on tree distribution

An equilibrium between **litter production** and litter **decomposition** is reached after a few years since fire

In fire-maintained pine forests of the Southeastern US, **litter accumulation** and its distribution over the forest floor are mainly driven by **Time Since Fire (TSF)** and aboveground biomass (i.e., **litter production**)



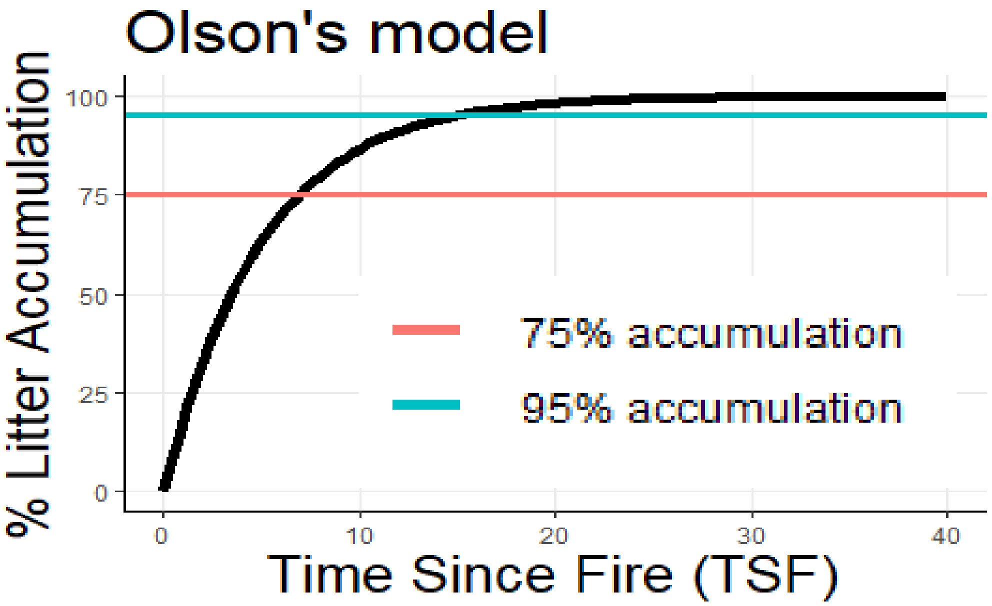
Sánchez-López et al. (2023) *Ecological Modelling* 481: 110369

Spatially explicit implementation of the Olson model, informed by airborne lidar

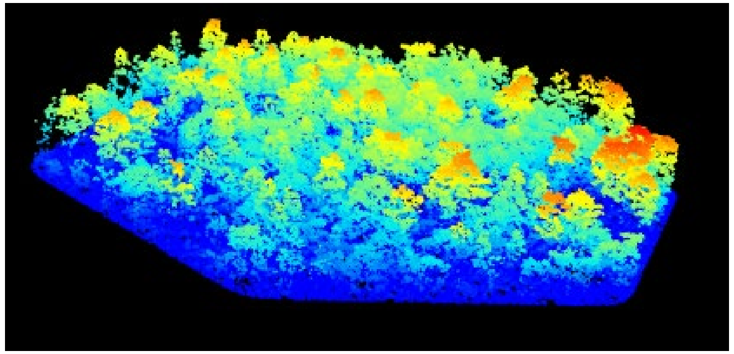
$$B\,(t) = \frac{L}{K}\left(1 - e^{-Kt}\right) + B^0 e^{-kt}$$

- $B\,(t)$ → *litter biomass at time* t (kg m^{-2})
- L→ → ***litter production rate (kg m^{-2} yr^{-1})***
- t→ time of accumulation since last fire
- k→ *decomposition rate* (yr^{-1})
- B^0 → *litter remaining after the last fire* (kg m^{-2})

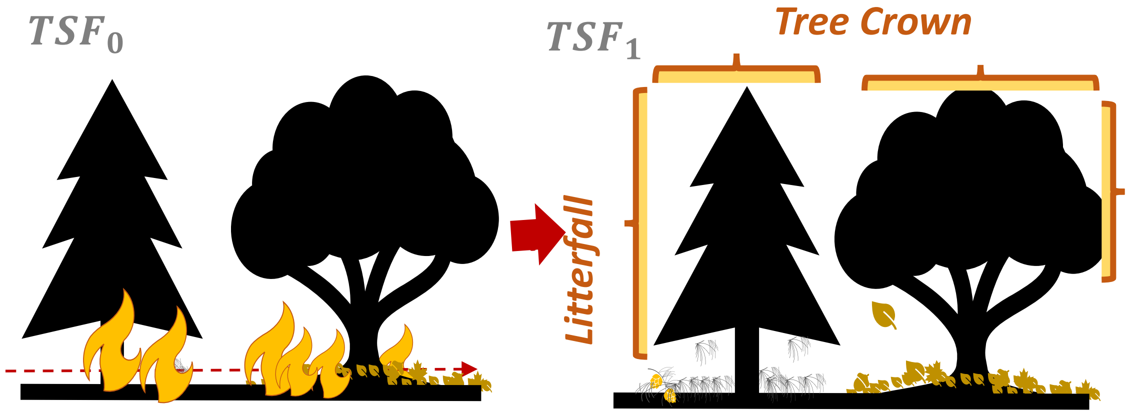
(Olson, 1963)



Stand-level model to predict litter accumulation



Spatially explicit, site dependent model based on tree crown cover and litterfall estimates



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