Evaluating Explanations of Land Cover Change Using Approximate Bayesian Computation

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Social impact of land cover

Sustainability

Food

Timber

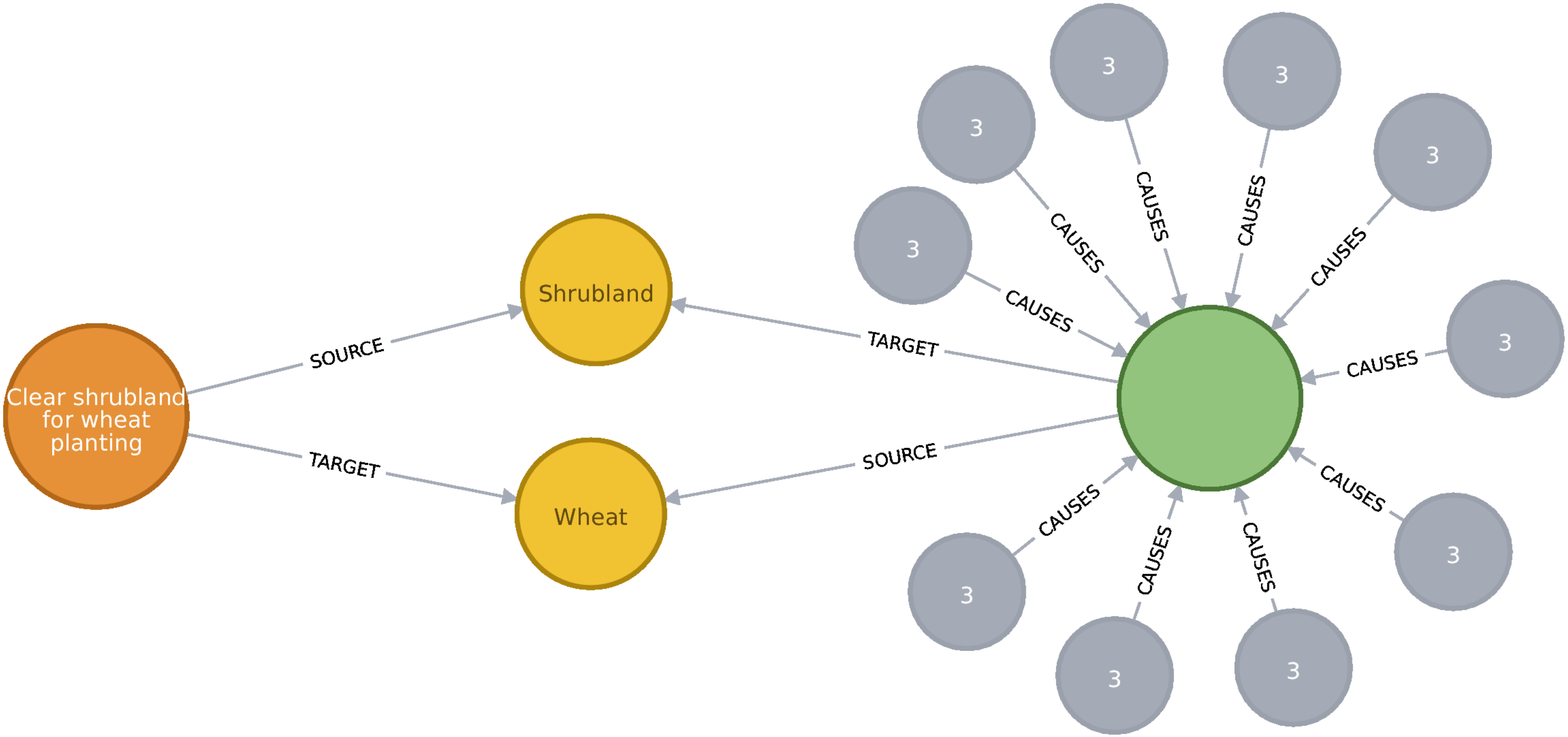
Biodiversity

Systemic Risk

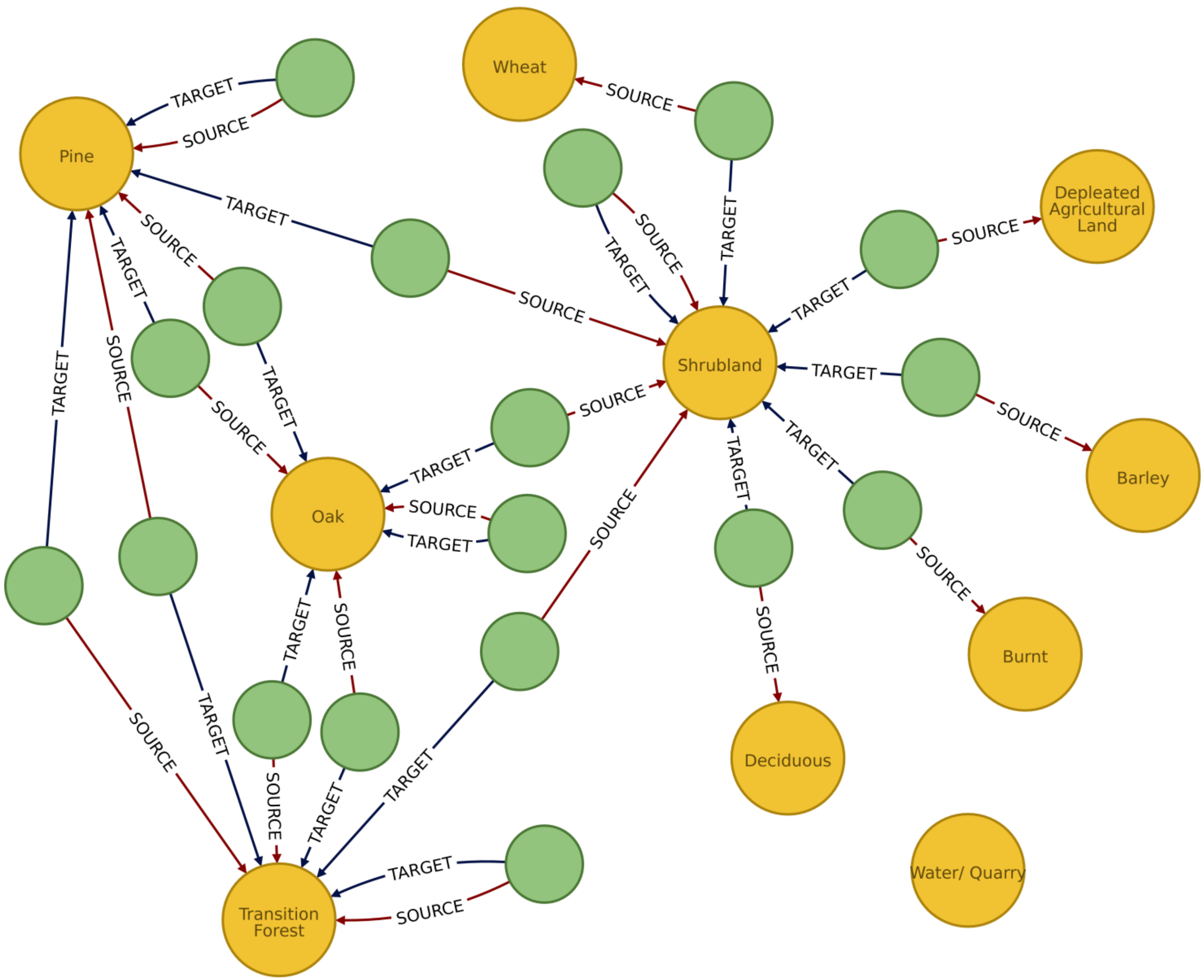
Wildfire susceptibility

Flood resistance

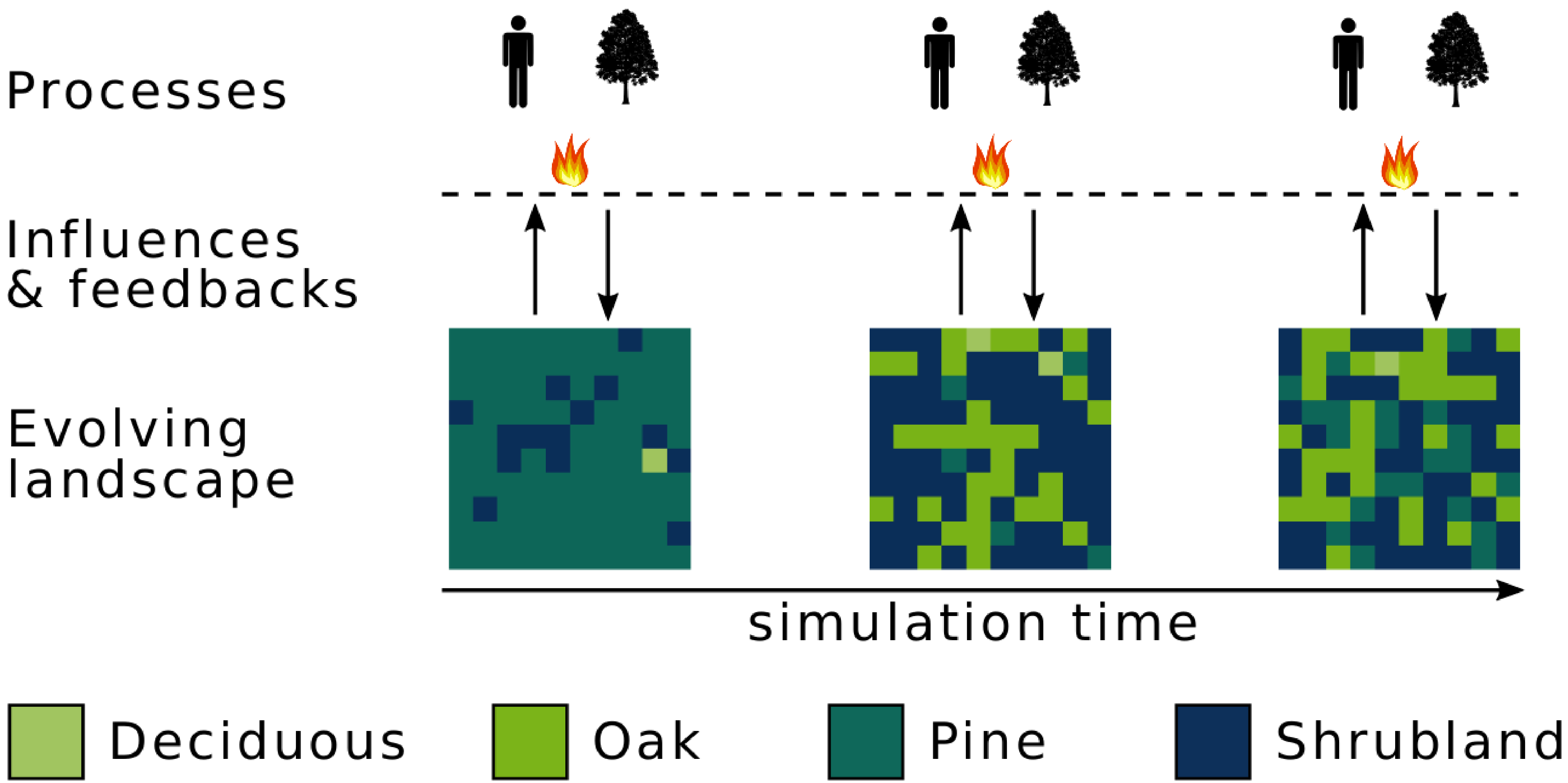
Land cover change as an ecological perturbation



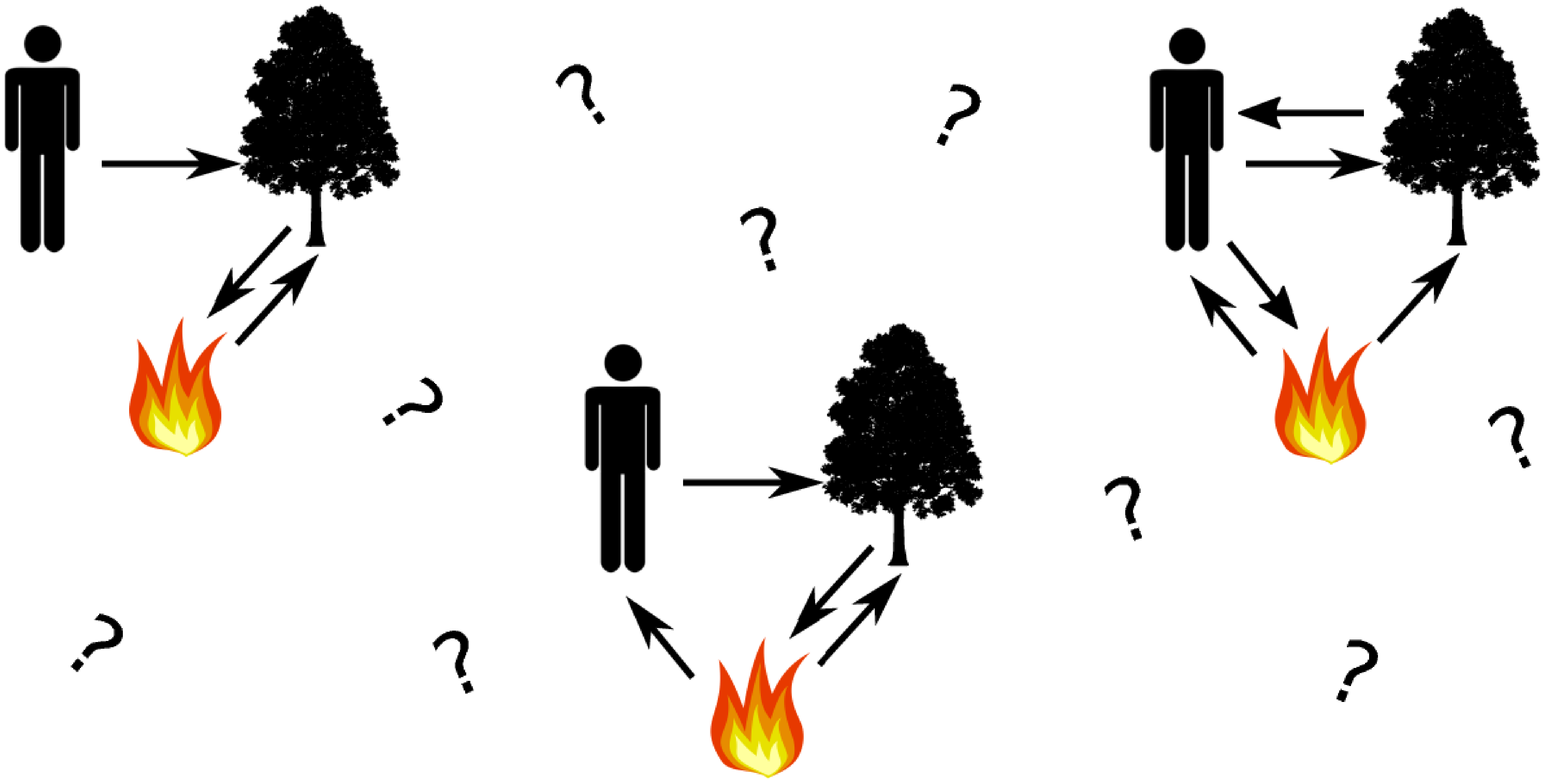
Complex interrelationships between states



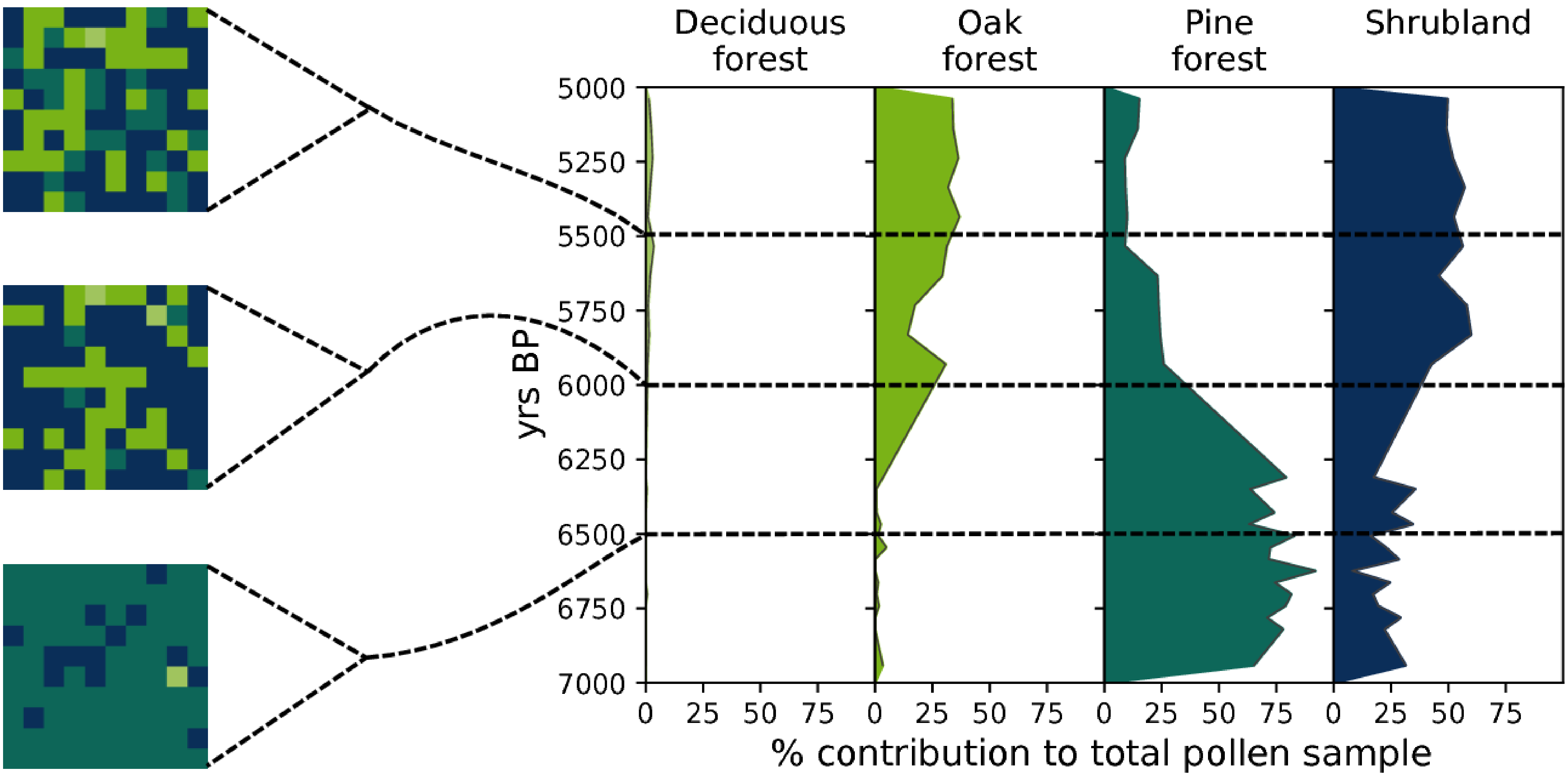
Observe emergent patterns in simulated landscapes



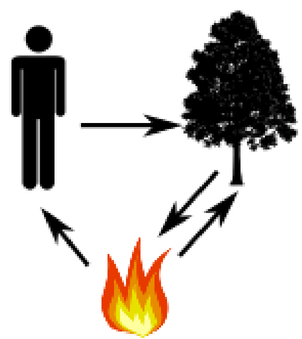
Which is the best model?



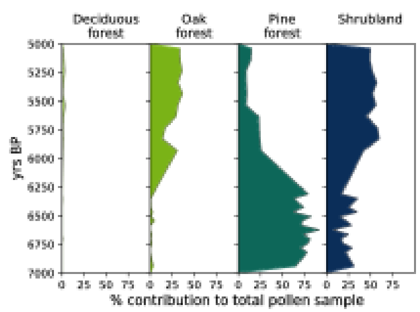
Model generates synthetic empirical data



The Bayesian Framework



$$\longrightarrow \mathcal{M}(t_a)$$



$$\longrightarrow \boldsymbol{Y}$$

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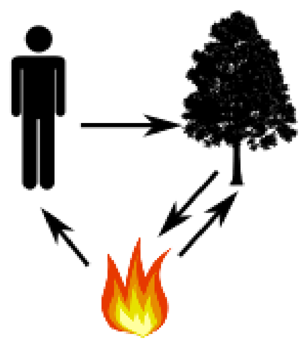

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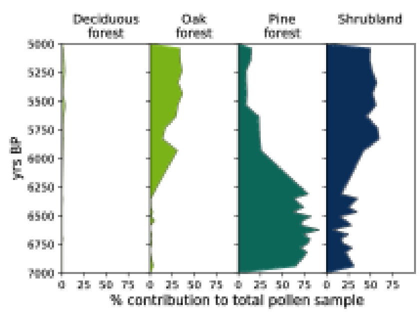


$$\longrightarrow \boldsymbol{Y}$$

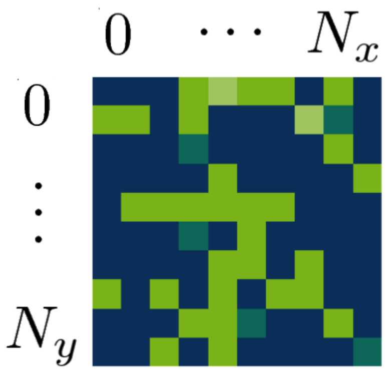
$$p\left(\mathcal{M}(t_a) \middle| \boldsymbol{Y}\right) = \frac{p\left(\boldsymbol{Y} \middle| \mathcal{M}(t_a)\right)\, \pi\left(\mathcal{M}(t_a)\right)}{p\left(\boldsymbol{Y}\right)}$$

Approximate Bayesian Computation

Given data and assumed model $Y \sim \text{Model}(\theta)$, tolerance threshold ϵ, and prior distribution $\pi(\theta)$:
for $1 \leq i \leq N$ **do**
    while $\rho(X, Y) > \epsilon$ **do**
        Sample θ^* from the prior: $\theta^* \sim \pi(\theta)$
        Generate data X from θ^*: $X \sim \text{Model}(\theta^*)$
        Calculate discrepancy $\rho(X, Y)$
    end while
    Store $\theta_i \leftarrow \theta^*$
end for

(Turner & Van Zandt 2012)

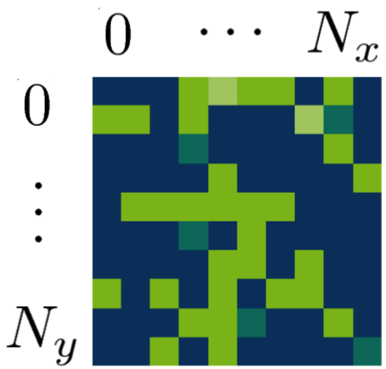
Summary statistics



$$\longrightarrow l_{ij}(t) \in \{\text{deciduous, oak, pine, shrubland}\}$$

$$\rho_\sigma(t) = \frac{1}{N_x N_y} \sum_{i,j} \delta_{\sigma, l_{ij}(t)}$$

Summary statistics



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$$\rho_\sigma(t) = \frac{1}{N_x N_y} \sum_{i,j} \delta_{\sigma, l_{ij}(t)}$$

$$\boldsymbol{X} = \begin{pmatrix} \overbrace{\rho_{\sigma_1}(0) \quad \cdots}^{\text{land cover proportions}} & \overbrace{\rho'_{\sigma_1}(0) \quad \cdots}^{\text{time derivatives}} \\ \rho_{\sigma_1}(1) \quad \cdots & \rho'_{\sigma_1}(1) \quad \cdots \\ \vdots \qquad\quad \vdots & \vdots \qquad\quad \vdots \\ \rho_{\sigma_1}(t_f) \quad \cdots & \rho'_{\sigma_1}(t_f) \quad \cdots \end{pmatrix} \Big\downarrow \text{time}$$

Quantify 'distance' between model output and pollen data

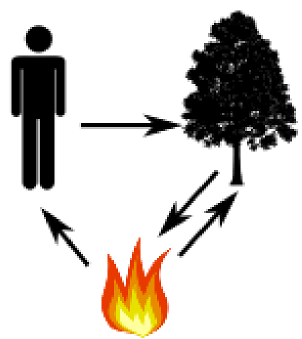
$$\boldsymbol{X} \rightarrow \{x_c(t)\}, \boldsymbol{Y} \rightarrow \{y_c(t)\}$$

$$d(\boldsymbol{X}, \boldsymbol{Y}) = \frac{1}{\#\ \text{columns} \times t_f} \sum_{c} \sum_{t=1}^{t_f} \frac{|x_c(t) - y_c(t)|}{(|y_c(t)| + |x_c(t)|)/2}$$

Average over columns

Symmetric Mean Absolute Percentage Error

The Bayesian Framework



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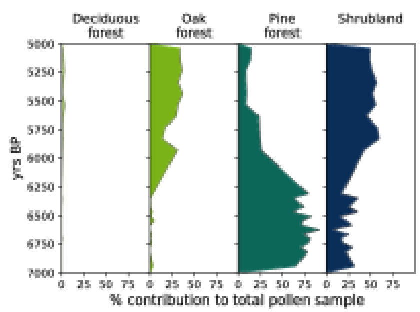

$$\longrightarrow \boldsymbol{Y}$$

$$p\left(\mathcal{M}(t_a)|\boldsymbol{Y}\right) = \frac{p\left(\boldsymbol{Y}|\mathcal{M}(t_a)\right)\,\pi\left(\mathcal{M}(t_a)\right)}{p\left(\boldsymbol{Y}\right)}$$

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