PUTTING A NUMBER ON RESTORATION SUCCESS: A NEW TIME-SERIES APPROACH

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BACKGROUND & OBJECTIVES

- To reach international goals for ecological restoration, upscaling and adaptive management is required
- To achive this, scientist need better quantitative tools for assessing and comparing restoration outcomes[1]
- We present a novel approach to model restoration of communities relative to a reference, aimed at providing better statistical estimates of the following:

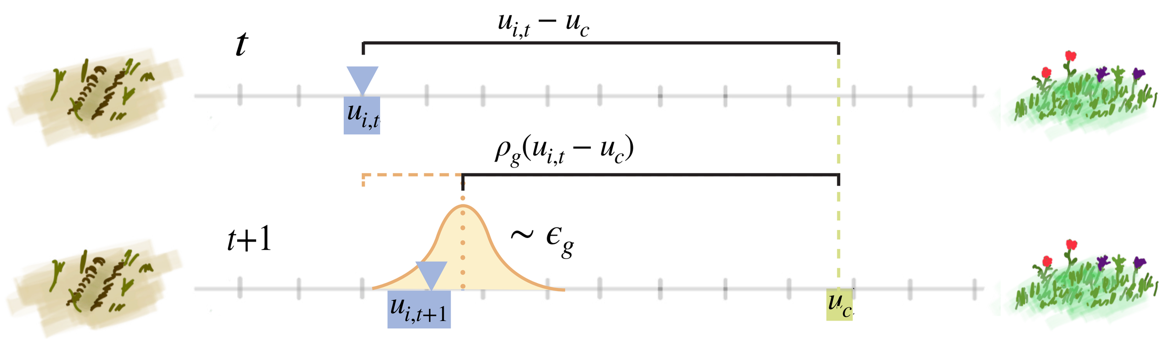
Fig. 1. Alpine road restoration, Dovrefjell, Norway. Source:HJERKINPRO restoration project, NINA.

1. ***Time to recovery*** after a restoration intervention
2. ***Uncertainty*** associated with time estimate
3. ***Compare effectiveness*** of different treatments

THE MODEL

1. A **disturbance gradient** is approximated by estimating the **latent predictor variable** (*u*) that best explain differences in species composition between all restored and control sites.
2. The temporal change in LV values (u_s) for **restored sited** is modeled as a **mean-reverting** (AR-1) process relative to the control mean (u_c), with terms shared per treatment group *g*:

$$u_{i,t+1} = \rho_g(u_{i,t} - u_c) + u_c + \epsilon_g \qquad 1 > \rho_g > 0 \qquad \epsilon_g \sim \mathcal{N}(0,\sigma_g)$$



CASE STUDY

We tested a "proof of concept" implementation of our method on the following experimental restoration ecology dataset:[2]

DATA

- `80` permanent **`vegetation plots`** sampled over **`12 years`** after disturbance
- `5` **`treatment groups`** (g=5) of increasing disturbance (10 plots each) + 20 **`control`** plots

MODEL FITTING

1. GLLVM fitted using the **R** package **gllvm**[3]
2. AR-1 model fitted to the estimated site scores as a multivariate autoregressive state-space model using the **R** package **MARSS**[4]

RESULTS

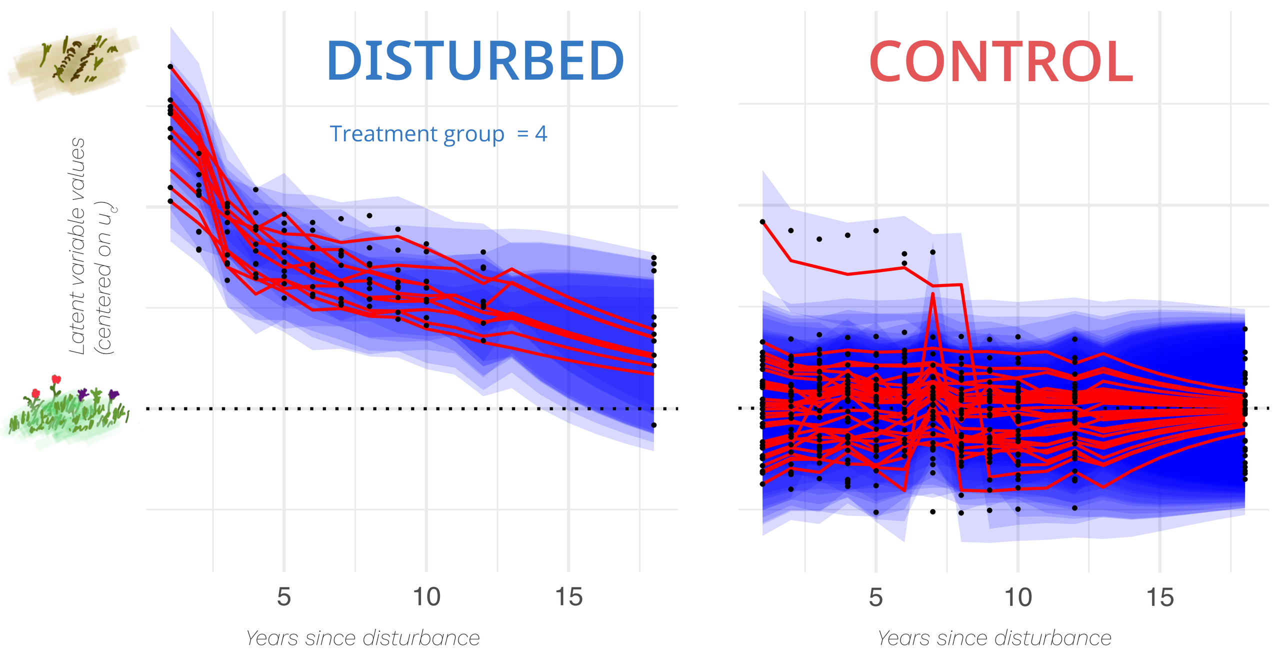


Figure 1. Fitted values for the time series model (red lines) on the latent variable values (black dots), for experimentally disturbed sites (left) and pristine control sites (right). Dotted line = mean of the latent variable scores for the control sites (u_c). Shaded area = 95% confidence interval.

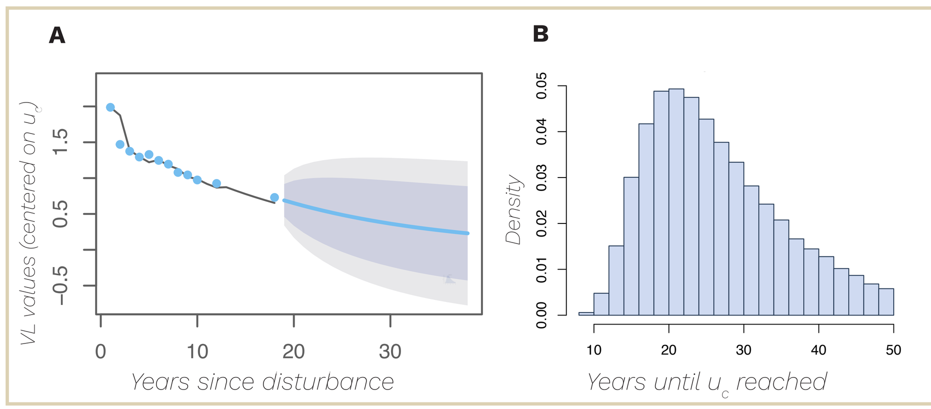


Figure 3. A: 20 year forecast for an example vegetation plot (site 1, group 1), based on the time series model. Blue line = forecast. Shaded areas = 80% and 95% prediciton intervals. **B**: Simulation histogram of number of years unti u_c is reached, based on the model fit. N=10 000

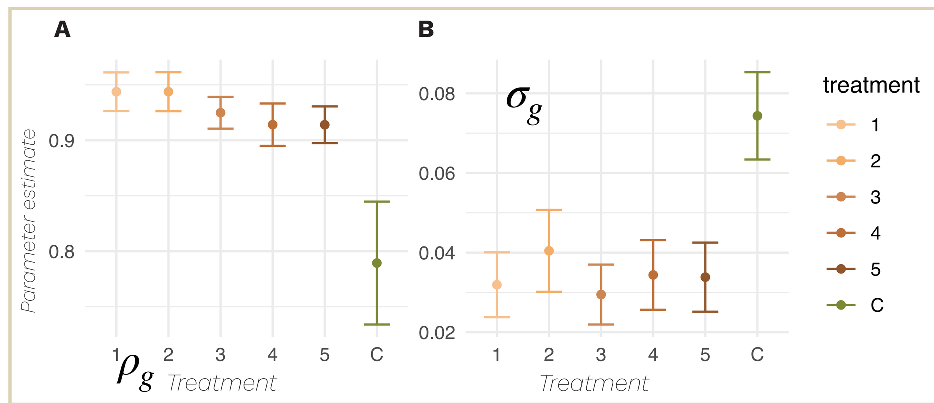


Figure 4. Parameter estimates for the different treatment groups and the control plots (1-5 in increasing dgree of disturbance) (c). A: Autoregressive parameter (rho). B: variance of the noise parameter (sigma).

WHAT ARE (GL)LVMs?

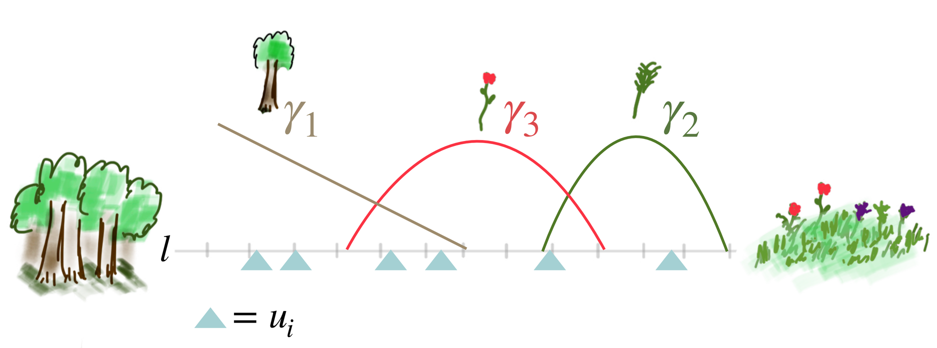
- A framework for **model-based ordination** and **joint species distribution modeling**[3]
- Latent variables = the random effect predictors estimated to best explain species covariances in the dataset.
- L.V.s have the same interpretation as ordination axes in e.g. NMDS, but are model-based!
- Link-scale responses of species to L.V.s can be both linear and quadratic.
- Like GLMs, allows for specification of response distribution (poisson, binomial etc.)
- Allows for residual plots, AIC etc.

BASIC MODEL

$$g(\mu_{ij}) = \alpha_i + \beta_{0j} + \sum_{l=1}^{L} u_{il}\gamma_{jl}$$

Link function: g; Abundance of species ***j*** in site ***i***: μ_{ij}; Site intercept: α_i; Species intercept: β_{0j}; Value (site score) of site i for latent variable l: u_{il}; Coefficient (loading) of species j for latent variable l: γ_{jl}

CONCEPTUAL REPRESENTATION



CONCLUSIONS

1. Case study seems to effectively **capture different temporal dynamics** between control and resored sites (fig. 2
2. Offers possibility for **forecasting and prediction** (Fig. 3)
   - NB: MUST be taken with a grain of salt, as uncertainty does not propagate between models
3. Differing estimates i.e. of the "attraction" to the reference (ρ) and the random noise (σ) allows for **comparison between treatment groups** (Fig. 4)

NEXT STEPS

- Incorporate the time series model presented here into the estimation of the latent variables as a "proper" one-step model
  - > Necessary for correctly estimating parameter uncertainty etc.
- More model flexibility to account for different study designs
- Create user-friendly software for ecologists
- Test in real-world restoration settings

Interested? Contact me:

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REFERENCES

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