

Effect of stump harvesting on emergence of natural broadleaves on a coniferous planting site

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Project report

Likelihood-based inference for hierarchical/mixed statistical models

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Background

In Finland, interest towards utilizing stumps from final cutting areas for bioenergy has increased lately. The effects of stump removal for the following stand establishment are somewhat unclear, although discussed a lot in public. One of the main silvicultural effects is the unnecessarily high share of disturbed soil surface for planting and its effect on emergence of broadleaved trees. Those broadleaves cause additional costs in further stand management. Unfortunately, there exist little data where this phenomenon could be analysed.

Aim of the project

The main interest was on how harvesting stump affect the emergence of broadleaves on one coniferous planting site.

Hypothesis

The hypothesis was that stump harvesting increases the number of broadleaves.

Data and their structure

The data were collected in an experiment carried out on a Norway spruce planting site in southern Finland. The experiment contained three different levels; block level (3), treatment plot level (12) and measurement plot (48) level. There observations on measurement plot level formed the lowest part of the hierarchy. Each treatment plot contained four measurement plots and each block contained 4 treatment plots.

Dependent variable

The number of broadleaves on measurement plot. It could be handled either as a count variable or as a transformation to density of broadleaved stems per area unit.

Independent variables

Treatments: stumps harvested or left on site

Planting method: manual planting tube or planting machine EcoPlanter

Thickness of humus layer on measurement plot was taken as fixed as well.

Model 1

The number of trees on measurement plots was transformed into density per hectare. Natural logarithmic transformation was needed to get the shape of the distribution better. A small displacement constant ($\text{Lndensity} = \ln(\text{density} + \lambda)$) was added in the transformation to avoid problems with a single measurement containing zero value in response. The block level contained only three objects which random effect was negligible. I took the block level out from further analysis.

The constructed model was follows:

$$\text{Lndens}_{ijk} \sim N(XB, \Omega)$$

$$\text{Lndens}_{ijk} = \beta_{0ijk} \text{Cons} + \beta_1 \text{harvested}_{jk} + \beta_2 \text{EP}_{jk} + \beta_3 \text{humus}_{ijk}$$

$$\beta_{0ijk} = \beta_0 + v_{0k} + u_{0jk} + e_{0ijk}$$

$$\begin{bmatrix} v_{0k} \end{bmatrix} \sim N(0, \Omega_v) : \Omega_v = \begin{bmatrix} \sigma_{v0}^2 \end{bmatrix}$$

$$\begin{bmatrix} u_{0jk} \end{bmatrix} \sim N(0, \Omega_u) : \Omega_u = \begin{bmatrix} \sigma_{u0}^2 \end{bmatrix}$$

$$\begin{bmatrix} e_{0ijk} \end{bmatrix} \sim N(0, \Omega_e) : \Omega_e = \begin{bmatrix} \sigma_{e0}^2 \end{bmatrix}$$

Because of the small data, the plot level variance went negative and was rounded to zero. Both block and plot and plot level random effect became negligible and thud I drifted out from the topic of the course. What I did was just a standard linear regression without block level and plot level random effects.

The

Model 2

I found out that it's hopeless to continue with random effects, so I decide to start playing with spatial structures just for fun. Every measurement on the lowest level, i.e. measurement plots has either one or two neighbours which were included in the constructed CAR-structure. I changed the response to the original count variable, which could be used as a Poisson response. The data required just a bit adjustment to include the CAR-structure. Every observation on the lowest level belonged to the neighbourgood structure.

A noninformative prior draw the variance very close to zero. The variance however is somewhat difficult to interpret. I also tried a slightly informative prior for the variance which "helped" MCMC a bit. Model parameters simulated with a noninformative prior were as follows:

$$C14_i \sim \text{Poisson}(\pi_i)$$

$$\log(\pi_i) = \beta_{0i} \text{Cons}_i + 2.67881(0.38974) \text{EP}_i + 0.93252(0.21542) \text{harvested}_i + 0.09413(0.01077) \text{humus}_i$$

$$\beta_{0i} = 0.10753(0.23017) + \mu_{0, \text{Obs}(i)}^{(2)}$$

$$\left[\mu_{0, \text{Obs}(i)}^{(2)} \right] \sim N(\bar{\mu}_{0, \text{Obs}(i)}^{(2)}, \Omega_u^{(2)} / \mathbf{r}_{\text{Obs}(i)}^{(2)}) : \Omega_u^{(2)} = \left[0.00022(0.00013) \right]$$

$$\bar{\mu}_{0, \text{Obs}(i)}^{(2)} = \sum_{j \in \text{neighbour}(\text{Obs}(i))} w_{\text{Obs}(i), j} \mu_{0j}^{(2)} / r_{\text{Obs}(i)}^{(2)}$$

$$\text{var}(C14_i | \pi_i) = \pi_i$$

$$\text{Deviance}(MCMC) = 413.66440(48 \text{ of } 48 \text{ cases in use})$$

Above the beta2 for "harvested" may be significantly positive, but in separate simulation it behaved in different ways. I can't trust on it too much.

Conclusions

I was not able to find clear evidence to support my hypothesis.

Small data set may make inference difficult if you are using mixed modelling.

Lesson learnt: Don't play with too difficult models, except for educational purposes.