Land sharing is better for farmland bird conservation in France : a spatio-temporal Bayesian analysis of bird community to disentangle the land sparing land sharing debate.

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Ecological context

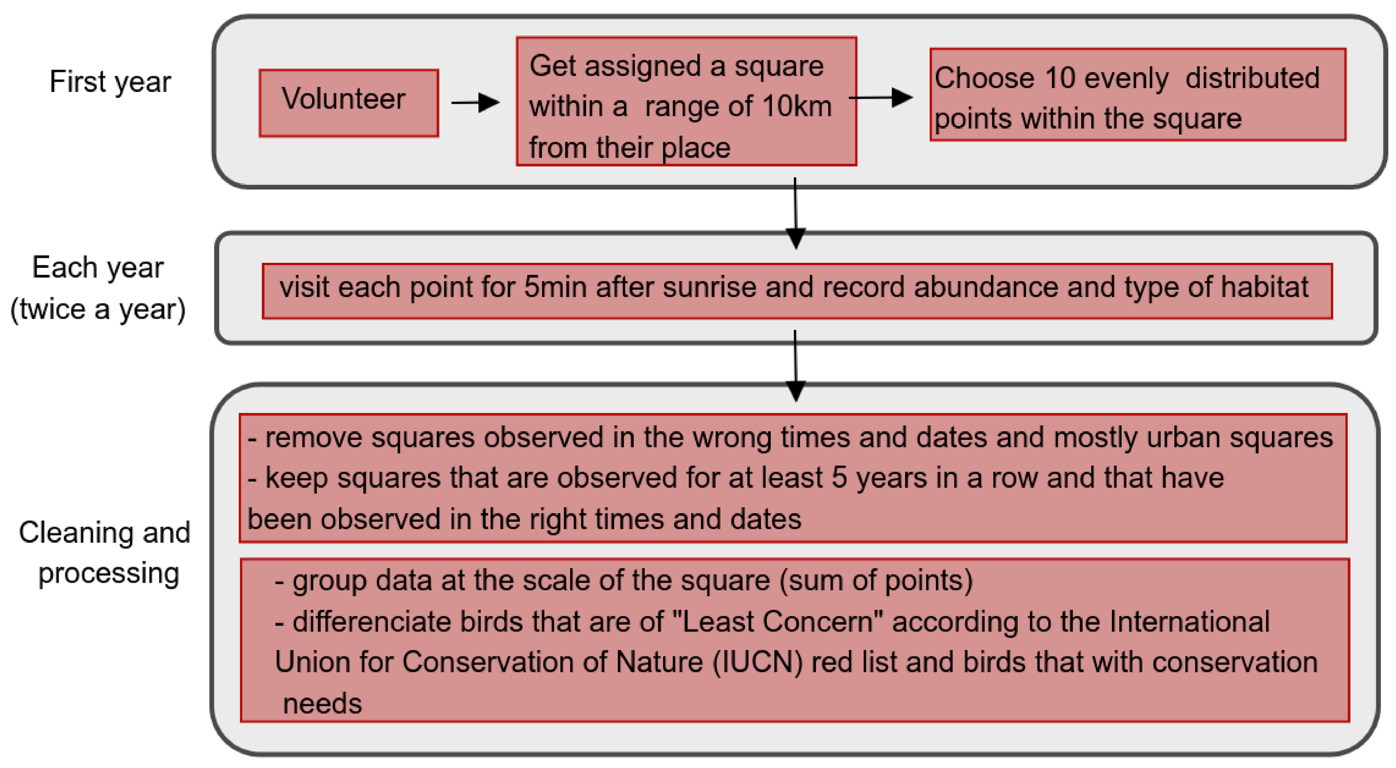
Breeding Bird Surveys (BBS) are long-term, large-scale, international avian monitoring programs designed to assess the trends of bird populations. Key features of the BBS include: standardized protocol, volunteer participation, geographical coverage, data collection and trend analysis. In our case we will look at the French protocol named STOC [1] for Temporal Monitoring of Common Birds. It gives data from 2001 to 2020 all around France.

- **Land sparing**: big fields and big forests, no intersection between two kinds of patches, each patch is usually big, not a lot of diversity of land uses.
- **Land sharing**: small patches of fields with trees and hedges between them, a lot of diversity in the land uses (for example permaculture).

Goal: Show how land sharing and sparing landscapes as well as climate will influence birds with conservation issues (in the red list of IUCN).

Materials & Methods

STOC protocol – bird data



Environmental data - covariates

Climate data (Wordclim):

- **Minimum and maximum temperature** last spring and summer
- **Total rainfall** last spring

Landcover (CORINE):

- **Proportion of each type of land use in the square** (agricultural, forest, urban, water and natural) → PCA to reduce the number of covariates.
- **Amount of forest in a 10km radius around the square**.
- Number and type of agricultural patches in a radius of 10km around the square center → **Shanon index for each square on the diversity of agricultural land uses**.

Hypothesis and insights on the land sharing/sparing covariates:

- A lot of forest around the square, as well as a low Shanon index reveals a land sparing landscape.
- A high Shanon index reveals a land sharing landscape.

Model

We model bird counts using a negative binomial regression model, which accounts for over dispersion in the data. The expected abundance at location s and year t is defined as:

$$\log \lambda(s,t) = \beta_0 + \sum_k \beta_k X_k(s,t) + \sum_{i,j} \beta_{i,j} X_i(s,t) X_j(s,t) + Sp_s + Tp_t,$$

where $X_k(s,t)$ denote environmental covariates (e.g climate, land cover), Tp_t is an autoregressive model and Sp_s is a Matérn random field.

$$Tp_t = \phi Tp_{t-1} + \varepsilon_t$$
$$\varepsilon_t \sim \mathcal{N}(0, \tau^{-1})$$

ϕ is the autocorrelation parameter and τ is the precision parameter.
For the spatial Matérn random field, the covariance is as following (as in [2]):

$$\mathrm{Cov}(Sp_s, Sp_{s'}) = \sigma^2 \frac{1}{2^{\nu-1}\Gamma(\nu)} (\kappa \|s - s'\|)^{\nu} K_\nu(\kappa \|s - s'\|)$$

- σ^2 is the marginal variance of the process
- ν smoothness parameter (usually set to 1)
- κ a scale parameter (linked to the range ρ of the process by: $\rho = \sqrt{8\nu}/\kappa$)
- K_ν modified Bessel function of the second kind

Inference: We use the R package R-INLA [3] to make inference

Model component	Prior distribution
Spatial random field	PC prior on range and σ: $\mathbb{P}(\text{range} < 100{,}000) = 0.99$, $\Pr(\sigma > 1) = 0.01$
SPDE smoothness	Fixed to $\alpha = 2$
Temporal random effect	PC priors on ρ and σ: shrinkage toward $\rho = 0$ and small σ
Fixed effects	$\mathcal{N}(0, 10^6)$
Negative binomial dispersion	$\log(\theta) \sim \mathrm{Gamma}(1, 0.00005)$

Table 1: Summary of prior distributions used in the INLA spatio-temporal models. PC: Penalized Complexity

Results

We use a stepwise selection procedure to find which variable explain the best birds count.

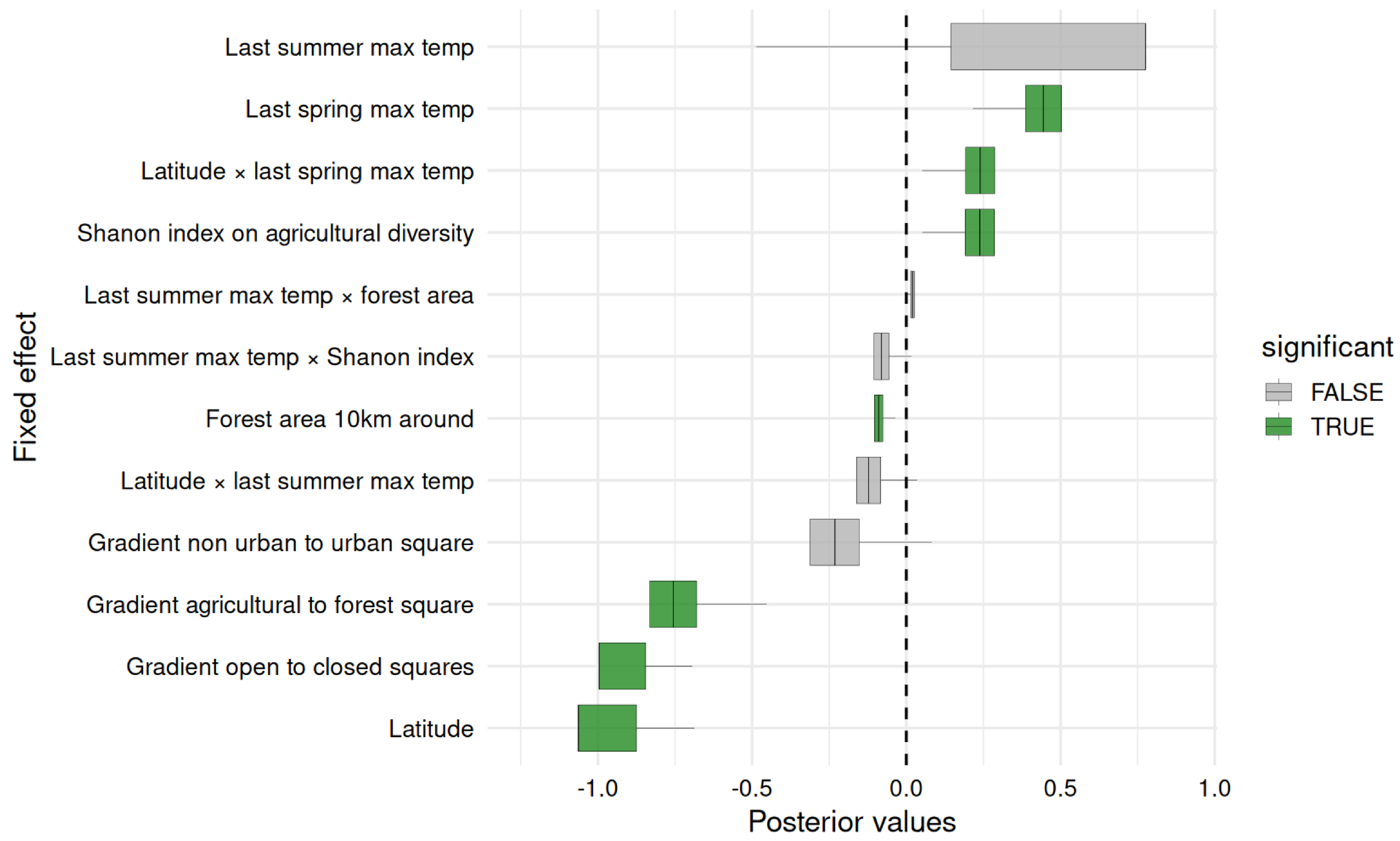


Figure 1: Fixed effects of the best model according to stepwise model selection for birds ins the IUCN red list.

	mean	sd	0.025 Q	0.975 Q
1/overdispersion	0.40	0.03	0.36	0.46
Range for spatial (m)	48306	7718	34622	64924
Stdev for spatial	2.12	0.15	1.84	2.42
Precision for year	24.37	19.27	4.22	75.13
Rho for year	0.79	0.15	0.41	0.97

Table 2: Random effects of the best model according to stepwise model selection for birds ins the IUCN red list.

For birds on the red list of IUCN land sharing seems to be the good practice to conserve the population.

Discussion

The model fit is generally good, but there are avenues for improvement:

- We did not account for detection bias.
- Pesticide data should be included in the model, but such data are not available for the study period.

In the French context, land-sharing landscapes enhance the abundance of threatened bird species. However, this effect appears less pronounced under high temperatures, particularly in the Mediterranean region, which makes the impacts of global warming in this context challenging to predict.

[1] B. Fontaine, C. Moussy, J. C. Carricaburu, J. Dupuis, E. Corolleur, L. Schmaltz, R. Lorrillière, G. Loïs, and C. Gaudard. Suivi des oiseaux communs en France 1989-2019 : 30 ans de suivis participatifs, 2021. Pages: 45 pages.

[2] E. Krainski, V. Gómez-Rubio, H. Bakka, A. Lenzi, D. Castro-Camilo, D. Simpson, F. Lindgren, and H. Rue. *Advanced Spatial Modeling with Stochastic Partial Differential Equations Using R and INLA*. Chapman and Hall/CRC, 0 edition, Dec. 2018.

[3] H. Rue, A. Riebler, S. H. Sørbye, J. B. Illian, D. P. Simpson, and F. K. Lindgren. Bayesian Computing with INLA: A Review. *Annual Review of Statistics and Its Application*, 4(Volume 4, 2017):395–421, Mar. 2017. Publisher: Annual Reviews.