NeutralLandscapes.jl: a library for efficient generation of neutral landscapes with temporal change

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Soon to be a paper, maybe. TK authors, MKB,VB,RS,TP

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1 Introduction

Neutral landscapes are increasingly used in ecological and evolutionary studies to provide a null expectation spatial variation of a given measurement. Originally developed to simulate the spatially autocorrelated data (Gardner *et al.* 1987; Milne 1992), the have seen use in a wide range of disciplines: from landscape genetics (Storfer *et al.* 2007), to landscape and spatial ecology (Tinker *et al.* 2004; Remmel & Fortin 2013), and biogeography (Albert *et al.* 2017).

We present `NeutralLandscapes.jl`, a package in `Julia` for neutral landscapes. The two primary packages used to simulate neutral landscapes are `NLMR` in (the `R` language) (Sciaini *et al.* 2018) and `NLMpy` (in Python; Etherington *et al.* 2015). Here we demonstrate that `NeutralLandscapes.jl`, depending on the method, is orders of magnitude faster than previous neutral landscape packages.

As biodiversity science becomes increasingly concerned with temporal change and its consequences, its clear there is a gap in methodology in generating neutral landscapes that change over time. In addition we present a novel method for generating landscape change with prescribed levels of spatial and temporal autocorrelation, which is implemented in `NeutralLandscapes.jl`

2 Software Overview

This software can generate neutral landscapes using several methods, enables masking and works with other julia packages.

fig. 1 shows a replica of Figure 1 from Etherington *et al.* (2015), which shows the capacity of the library to generate different types of neutral landscapes, and then apply masks and categorical classifcation to them.

2.1. Interoperability

Ease of use with other julia packages

Mask of neutral variable masked across quebec in 3 lines.

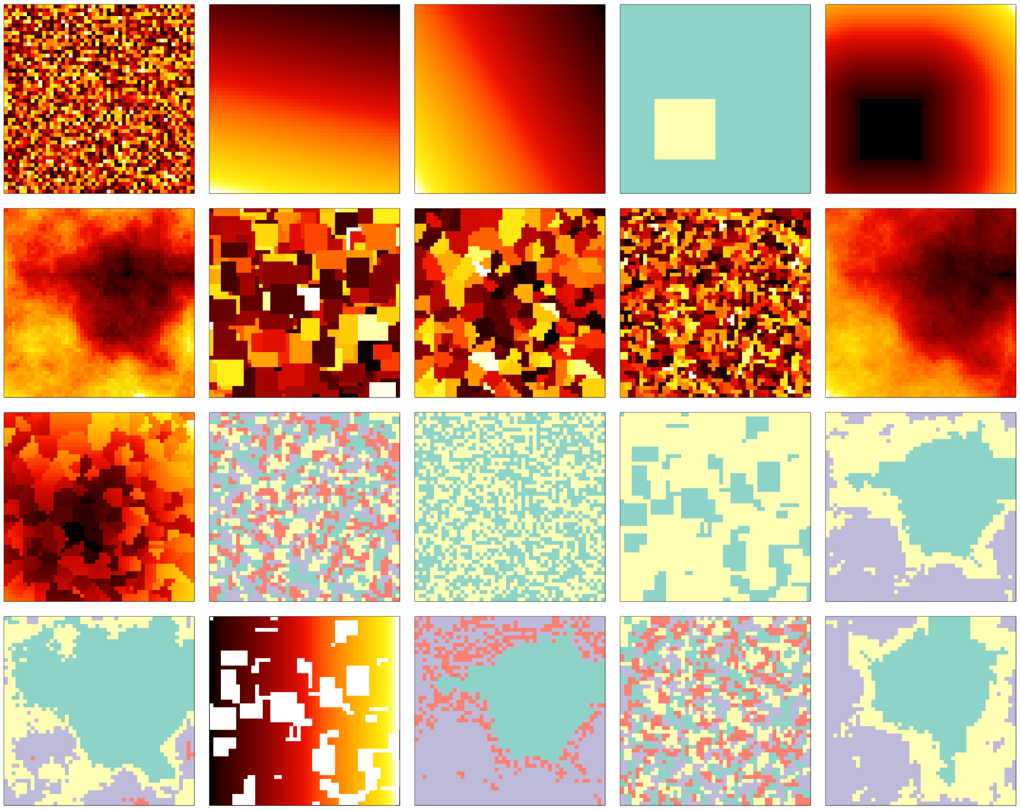

Figure 1 Recreation of the figure in `nlmpy` paper and the source, supplied in less than 40 lines of code.

```
using NeutralLandscapes
using SimpleSDMLayers

quebec = SimpleSDMPredictor(WorldClim, BioClim; left=-90., right=-50., top=75., bottom=40.)
qcmask = fill(true, size(quebec))
qcmask[findall(isnothing, quebec.grid)] .= false

pltsettings = (cbar=:none, frame=:box)

plot(
    heatmap(rand(MidpointDisplacement(0.8), size(layer), mask=qcmask); pltsettings),
    heatmap(rand(PlanarGradient(), size(layer), mask=qcmask); pltsettings),
    heatmap(rand(PerlinNoise((4,4)), size(layer), mask=qcmask); pltsettings),
    heatmap(rand(NearestNeighborCluster(0.5), size(layer), mask=qcmask); pltsettings),
    dpi=400
)
```

3

Benchmark comparison to `nlmpy` and `NLMR`

It's fast. As the scale and resolution of raster data increases, neutral models must be able to scale to match those data dimensions.

4

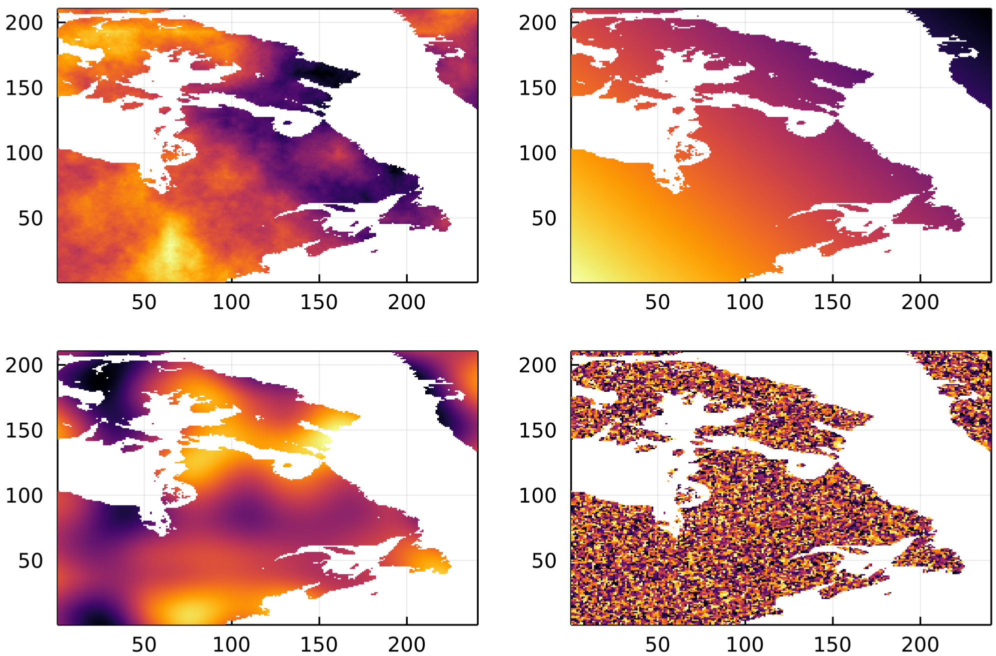

Figure 2 todo

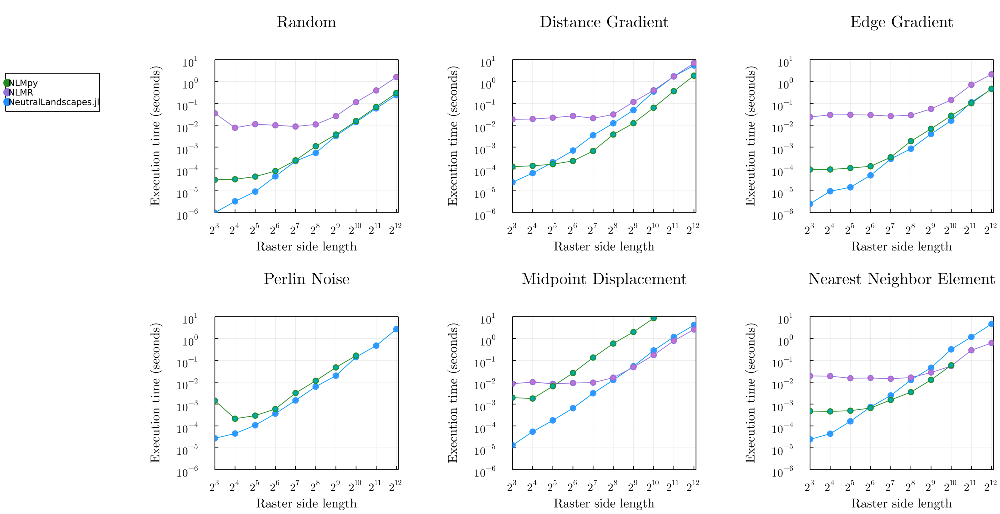

Figure 3 todo

Generating dynamic neutral landscapes

We implement methods for generating change that are temporally autocorrelated, spatially autocorrelated, or both.

$M_t = M_{t-1} + f(M(t-1))$

4.1. Models of change

4.1.1 Directional

4.1.2 Temporally autocorrelation

r: rate, v: variability, U matrix of draws from standard Normal$(0, 1)$

$f_T(M_{ij}) = r + vU_{ij}$

4.1.3 Spatial autocorrelation

r: rate, v: variability, $[Z(\delta)]_{ij}$: the (i, j) entry of the zscore of the δ matrix

$f_S(M_{ij}) = r + v \cdot [Z(\delta)]_{ij}$

4.1.4 Spatiotemporal autocorrelation

$f_{ST}(M_{ij}) = r + v \cdot [Z(\delta)]_{ij}$

4.2. Rescaling to mimic real data

5 Discussion

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