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Modeling Plant Migration in a Varying Landscape

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Introduction

Climate change is causing a shift in habitats poleward, potentially too rapidly for some plant species to track. Modeling plant migration will aid in identifying which plants are in danger of being outpaced by climate change.

Integro-Difference Equations (IDE's) can describe population growth and spread over time.

Population density — Dispersal — Demography transitions

$$\mathbf{u}^{t+1}(x) = \int_{-\infty}^{\infty} [\mathbf{K}(x-y, y) \circ \mathbf{B}(\mathbf{u}^t(y), y)]\mathbf{u}^t(y)\,dy$$

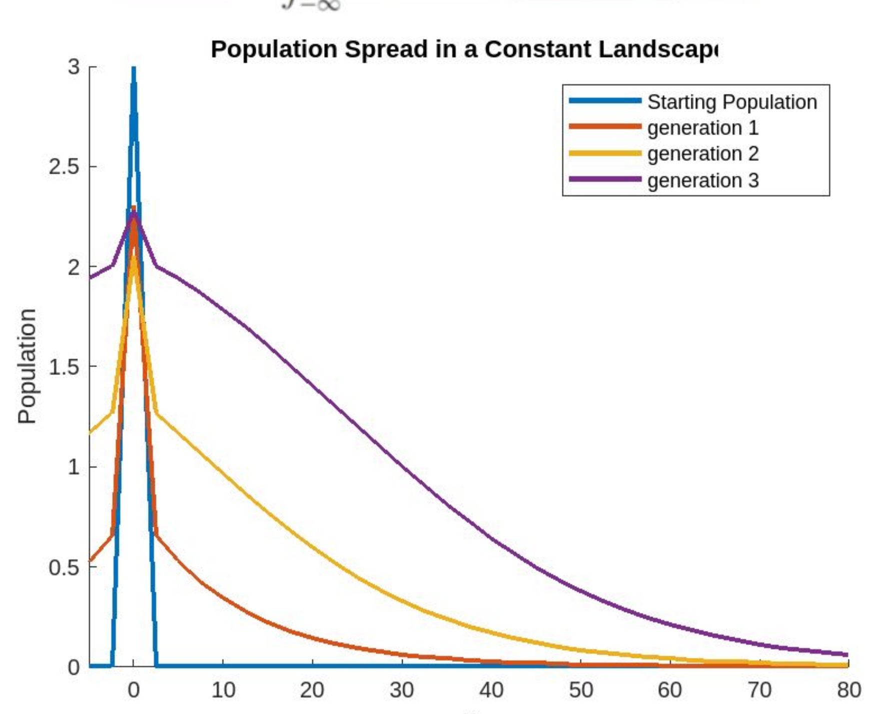

Fig. 1 IDE's describe how a population spreads out over time.

To investigate how population spread rates differ in heterogeneous environments, I apply an extended model that incorporates ecological diffusion, which describes seed dispersal in a landscape that varies in quality, instead of randomly diffusing (See Fig. 2).

My objective is to determine if varying the landscape can lead to faster plant migration.

Methods

I used a homogenization technique to simulate how plant populations would spread under a varying landscape. I defined the landscape with patches of high and low motilities, or movement. Dispersers spend more time in areas with low motility, leading to higher seed deposition. A varying landscape may predict faster migration because areas of high motility help the population disperse quickly, while areas of high seed deposition help the population establish and grow. Both are needed for rapid migration.

After defining a landscape with one patch of low motility, I calculated how far the population spread with this landscape compared to a constant landscape. I then created a landscape with many patches in it and made similar comparisons.

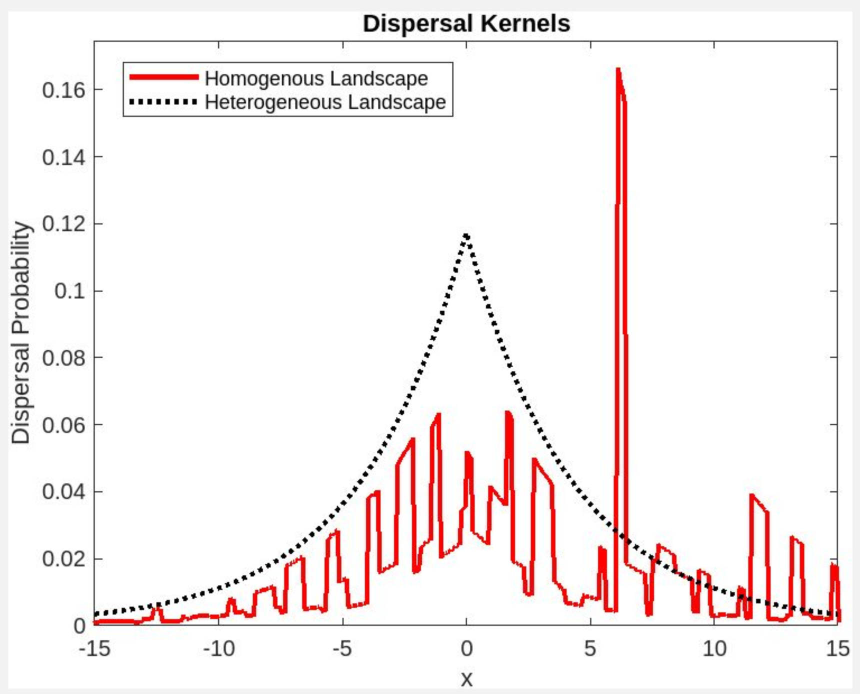

Fig 2. Dispersal in a landscape that varies in quality (red) can be very different from dispersal in a constant landscape (black).

Results

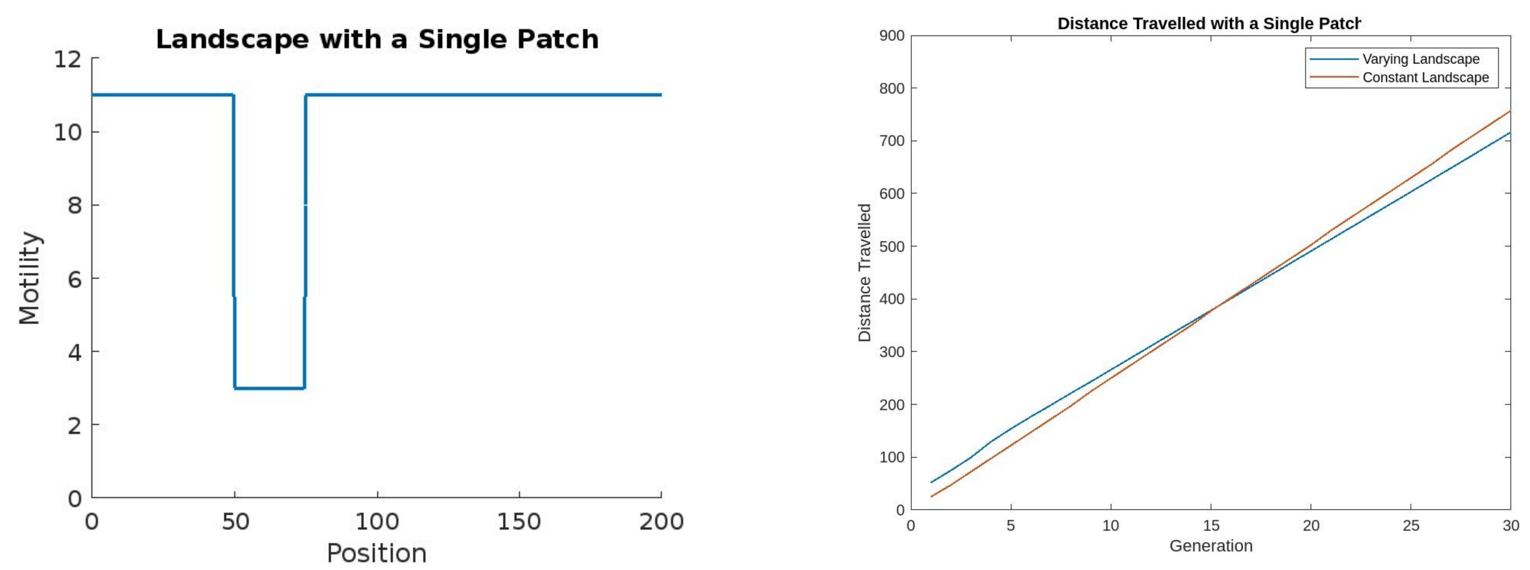

Fig 3. The varying landscape with a single patch of low motility (left) leads to faster spread on a short scale, but slower spread on a long scale (right).

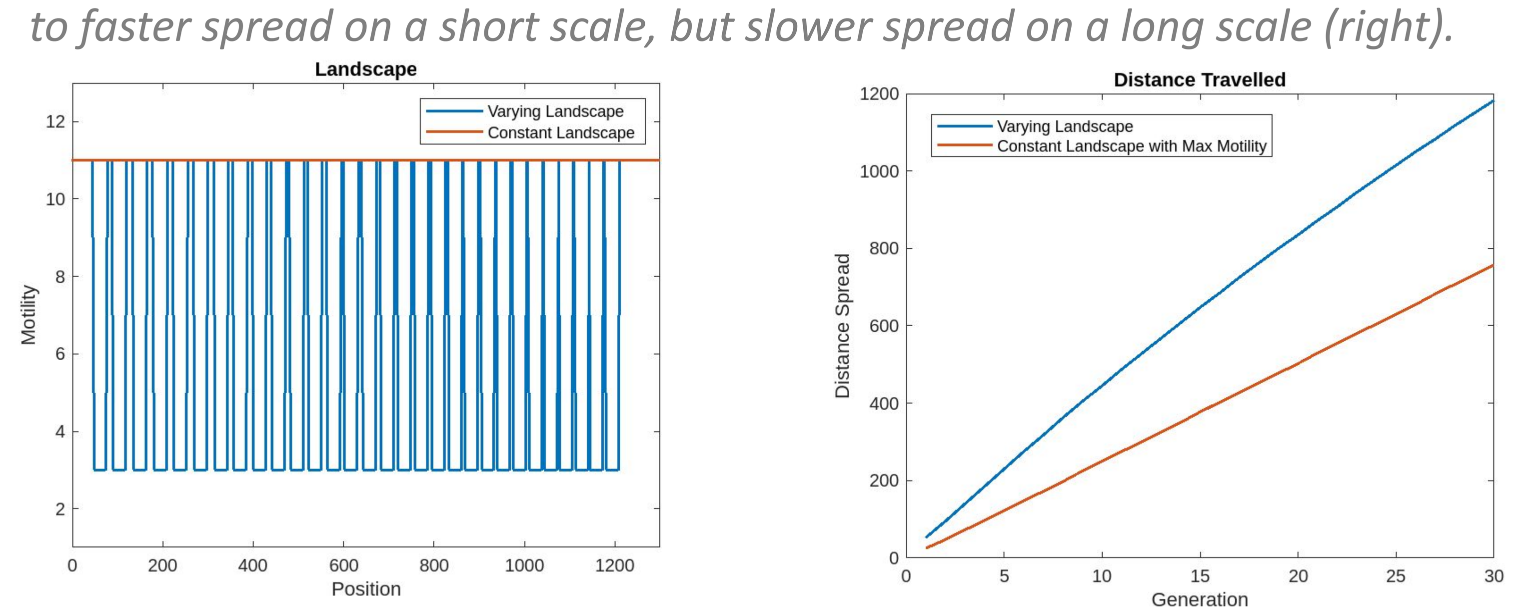

Fig 4. I calculated the best location for each patch to create an optimal landscape for spread speed (left). By placing patches next to each other, the population can use them as stepping stones to jump farther than otherwise possible (right).

Conclusions

- Adding one patch to a landscape can increase spread speed on a short scale.
- A varying landscape with a series of patches can yield a higher spread speed compared to the constant landscape over a large scale. To achieve the fastest spread, there needs to be a balance of areas with high and low motilities.
- Future work includes performing sensitivity analysis on the parameters, creating more complicated landscapes to optimize spread speed, and parameterizing the model to real systems to assess if the theoretical results are reasonable in nature.

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