Landscape Metrics

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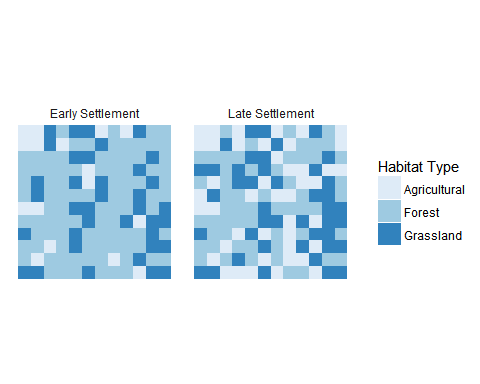
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## Introduction

Landscapes have many properties that are important to know and describe. Many are intuitively fairly easy to articulate, but much more difficult to explicitly quantify in ways that can be analyzed. Patchiness, connectivity, evenness, and diversity all fall into that category.

Landscape metrics like diversity indices and patch statistics are attempts at defining as quantitative metrics these more nebulous concepts. By applying them to landscapes, it becomes possible to describe those landscapes in ways that can be connected to our western scientific frameworks of knowing and verifying knowledge.

## Methods



*Figure 1: The landscape being analyzed at a resolution of 1 km2 per cell at two points in time, classed into three types. The outermost cells are not part of the landscape, but are included for calculation of edge-related metrics.*

Metrics were calculated for the same 100 km2 landscape at two different points in time, "early settlement" and "late settlement." On a per-patch-type scale, the metrics calculated were the proportion of the landscape, the number of patches, the mean size of a patch, and the edge:area ratio. On the landscape scale, the metrics calculated were patch number, Shannon-Wierner Diversity Index, and Shannon-Wierner Evenness Index.

Patch boundaries and identification for all metrics were defined using immediate orthogonal neighbors only and considered only the cells within the landscape, not the additional cells surrounding the landscape. Edge metrics did take into the cells immediately adjacent to the landscape.

### Proportion of landscape

The proportion of the landscape in each patch type gives an extremely rough idea of diversity. It takes into account only the number of cells classed as a type with no regard for their spatial relationships and distribution. It was calculated as:

### Patch count

The patch count of a type on the landscape takes into account cell adjacency and gives an approximation of the clumpiness of cell types across the landscape. Cells are not considered as individuals but instead are given and identity as a group of cells of the same type which form a continuous set of neighbors according to the adjacency rule used. Patch count for a cell type is simply the number of unique patches which share that type.

### Mean patch size

Mean patch size represents additional information about the dispersion of cells on the landscape, providing some information about how cells are distributed across patches of the same type. It was calculated as:

### Patch edge:area ratio

The ratio of edge length to patch area approximates the complexity of the interfaces between patches. It was calculated as:

### Shannon-Wierner Diversity Index

The Shannon-Wiener Diversity Index (SHDI) is a measure of diversity on the landscape as a function of cell type proportions and cell type richness or count. It was calculated as:

### Shannon-Wierner Evenness Index

The Shannon-Wiener Evenness Index (SHEI) is a measure of how evenly distributed the diversity is, derived from SHDI as:

## Results

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Stage | Patch Type | Landscape Proportion | Patch Count | Mean Patch Size | Edge:Area Ratio |
| Early | Grassland | 0.26 | 17 | 1.53 | 3.08 |
| Early | Forest | 0.62 | 7 | 8.86 | 1.40 |
| Early | Agricultural | 0.12 | 9 | 1.33 | 3.17 |
| Late | Grassland | 0.30 | 18 | 1.67 | 2.97 |
| Late | Forest | 0.41 | 13 | 3.15 | 2.29 |
| Late | Agricultural | 0.29 | 19 | 1.53 | 3.10 |

*Table 1: Summary of patch-scale statistics for the two stages of the landscape.*

|  |  |  |  |
| --- | --- | --- | --- |
| Stage | Patch Count | Shannon-Wiener Diversity Index | Shannon-Wiener Evenness Index |
| Early | 33 | 0.901053 | 0.8201738 |
| Late | 50 | 1.085731 | 0.9882746 |

*Table 2: Summary of landscape-scale statistics for the two stages of the landscape.*

There are appreciable differences in the two stages of the landscape at the patch scale. Patch proportions shift, decreasing the preponderance of forest while increasing the amount of agricultural land. Patch counts dramatically increased, suggesting a much more fragmented landscape. Mean patch size dropped for forest and grew for agriculture, reflecting their gain and loss of area, respectively. Edge:area stayed similar for agriculture and grassland but increased for forest, implying that forest patch edge complexity increased, likely as a result of forest conversion to other types.

At the landscape scale, similar themes played out. Late settlement has a significantly higher patch count than early settlement as a result of fragmentation. The late settlement stage also has higher SHDI and SHEI values, in keeping with increased patchiness and greater conversion of the dominant patch type to a rarer patch type.

## Discussion

These results do make sense in light of human activity. Humans have historically acted on ecosystems to convert them into "productive" land. Increasing the amount of agricultural land by expanding it into what was previously forest would have the effect of increasing patchiness and evenness of the landscape and mean patch size of agricultural land while decreasing the mean patch size of forest.

As settlement continued, the patchiness increased, which means that species dependent on large, intact patches are likely negatively impacted. The increase in edge complexity of forest also increases the invasibility of those patches. Disturbances would be affected depending on their type: those that are usually intra-patch will likely be less intense and more spatially restricted whereas those that move between patches will likely be more intense.

It is never enough to consider a single metric. For example if asking the question of how habitat of a certain type has changed, it is not enough to ask simply if the proportional area of that habitat has shifted because increased area could mean that patches have expanded or that new patches have arisen. By combining proportional area with patch count, it becomes clearer where on the landscape the changes have happened, and by adding in considerations of edge:area ratio, the approximate changes in amount of edge versus interior habitat can be figured.

Neither landscape is inherently, objectively better. If considering diversity and evenness to be important scores, then the late settlement stage wins out. However, for many key concepts of ecosystems, it is important to have relatively large, intact patches with interiors distinct from ecotones. In those cases, the early stage landscape scores higher on patch metrics like mean patch size and edge:area ratio. Additionally, ecosystems on landscapes have only been evolving around agricultural influences for tens of thousands of years, so increased agricultural lands are likely to cause significant stress and introduce disturbances which "natural" landscape types may react unfavorably or unpredictably to. In my naturalist bias, I would favor the least anthropogenic influence, however the stated goals of management entities may lead them to prefer the later settlement stage if the natural landscape types are still functioning reasonably well because it accommodates human use.

This particular suite of metrics represents a sort of bare minimum for evaluating landscapes. Some of them, like patch proportion, have very little utility on their own. There are none that I would consider using without at least one other to clarify interpretation. Mean patch size needs the patch count and preferably some distribution statistic to be made sense of. Patch count must be understood through some measure of area, whether proportional or mean or something else. Even edge:area ratio cannot be used alone to undertand ecotones because there's no information regarding amount.