Landscape metrics:

Western red cedar forest, near Priest Lake, Idaho. Photo taken in 1921. Forest History Society.

Quantifying landscape configuration

Reading: Chapter 5

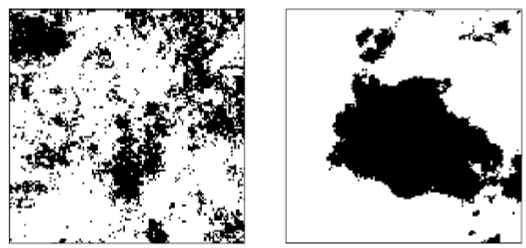
Types of landscape metrics:

1. Patch area (patch number, patch density, total patch type area, core area)
2. Patch perimeter (edge density, total patch length, edge contrast)
3. Patch shape (perimeter to area ratio, elongation index, shape indices, fractal dimension)
4. Core area metrics (core area is defined as the area within a patch beyond some specified edge distance or buffer width)

Types of landscape metrics (continued):

5. Diversity and Evenness (proportional area of patch types)
6. Isolation/proximity indices (deals with the spatial context of the patch, not the patches themselves; nearest neighbor, proximity)
7. Contrast metrics (refers to the magnitude of difference between adjacent patch types with respect to attributes)
8. Interspersion metrics (tendency of aggregation)
9. Connectivity (refers to the degree to which a landscape facilitates/impedes ecological flows)

What is meant by the term landscape configuration?



Example of different types of landscape configuration. In both cases the shaded habitat covers 33% of the landscape. T, G & O. 2001. Figure 6.7. Location matters!

Metrics covered during this section will include:

Percolation

Network analysis

Edge evenness (Interspersion-Juxtaposition)

Contagion

One question related to landscape configuration is how much "friendly habitat" is necessary for a species or disturbance to cross a landscape or portion of a landscape? This cover type need not necessarily be habitat per se.

1. **Percolation theory** has been used to assess this problem. Percolation theory comes from physics and is the study of random movement through porous materials.

Percolation theory has been applied to ceramics, metallic films, membranes and soil physics. Those who have had an advanced soils course or soil physics have probably been introduced to the idea.

Theories

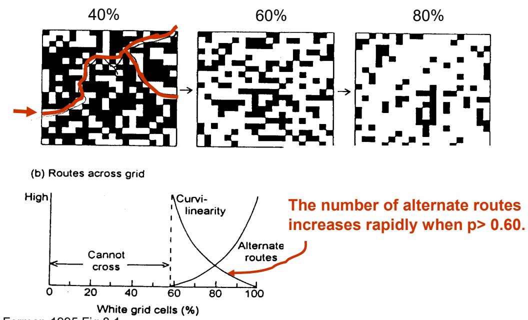
1. **Percolation theory –** random movements through porous materials

2. **Neutral models** have also been used to address this question. Actual landscapes can be compared to the neutral model to see how the potential for movement through a landscape compares to a random arrangement with the same proportion of patch types. (Chapter 6 in Turner 2001)

A neutral model is a spatially random arrangement of porous and non-porous "habitat" which have a given proportion in the landscape (p).

Probability of finding a percolating patch

Percentage of the landscape in 'friendly' habitat



Forman 1995 Fig 8.1

Another means to have movement across landscapes is through corridors.

1. One means to evaluate corridors is through network analysis.

2. Networks are a series of interconnected corridors composed of nodes and linkages (corridors that connect nodes).

Networks are a means to emphasize the connections more than the habitat.

Corridors may not necessarily be "habitat".

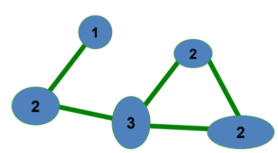
Consider the debate of SLOSS (Single large or several small). It is related to the importance of habitat over connectivity.

Networks may approach 3 basic forms:

linear (ex. railroad system)

dendritic (ex. stream system)

rectilinear (ex. hedgerows)



Numbers indicate the number of linkages per node (habitat patch).

Network Connectivity indices can be developed based on the relationships between numbers of linkages (L) and numbers of nodes (V).

The number of linkages originating at each node is a good indicator of network pattern.

Note: It is important to indicate here that the value of corridors is highly controversial in the literature.

Many feel they are the only way to maintain connectivity in our increasingly fragmented world. Others think that they are ineffective and perhaps even harmful.

The quantification of a network can start through the measurement of:

-node density (number of nodes per unit area)

-linkage density (number of links per unit area)

-linear density (total length of lines per unit area)

The degree to which all nodes in a system are linked by corridors is referred to as **network connectivity** (Forman and Godron 1986, p 417).

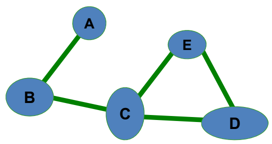
Quantification of Connectivity

$\gamma = L / L_{max}$

$= L / 3(V-2)$

Range = 0 to 1, with higher values indicating greater connectivity

Where L = the number of links in the network, and V = the number of nodes



$\gamma = 5/ 3\,(5-2)$
$= 5/9$
$= 0.556$

Forman & Godron 1986

Edge Diversity & Interspersion-Juxtaposition

Recall that **landscape composition**, as a function of the number and relative proportion of classes in the landscape, can be measured by its **richness** (the number of class types).

However, it is more commonly expressed by a **landscape composition diversity index (LCDI),** such as the Shannon-Weiner Diversity Index (SHDI)(McGarigal and Marks 1995):

LCDI = SHDI = $- \sum_{i=1}^{m} p_i \ln p_i$

Edge Diversity

The **Edge Diversity Index (EDI)** is an index of similar origin but it is determined by the amount of each type of cell-to-cell adjacency at the patch boundary.

If you have 3 patch types (A, B & C), you would have the 6 following potential types of cell-to-cell adjacencies:

A:B A:C
B:A B:C
C:A C:B

Edge Diversity

In order to address the issue of spatial location of cells and to quantify **landscape configuration**, it is common to consider the extent and diversity of edge types.

The importance of edges can be simply measured by **edge density** (Amount of Edge/Area).

The diversity of edge types can be assessed by an **edge diversity index** (EDI) computed as:

EDI $= - \sum_{j=1}^{m-1} \sum_{k=j+1}^{m} e_{jk} \ln e_{jk}$

Edge Evenness & Interspersion-Juxtaposition

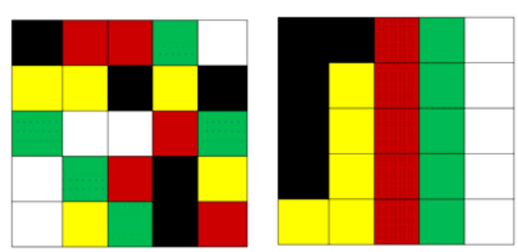
As the number of possible different types of adjacencies between m classes is 1/2 (m)(m-1), it is possible to compute an **edge evenness index** by the ratio:

Edge Evenness Index (EEI) = EDI / ln [1/2 (m)(m-1)]
which varies from 0 to 1.

This is the **Interspersion-Juxtaposition Index (IJI)** of McGarigal and Marks(1995).

Recall that this index only utilizes the patch boundary cells and not the patch interior cells. Therefore, it is concerned with patch distribution, rather than cell (pixel) distribution as is **Contagion**.

Which of these landscapes has the greater edge diversity?



How could these cells be arranged to increase edge evenness (IJI)?

Example of IJI

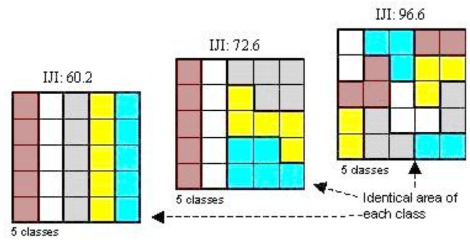


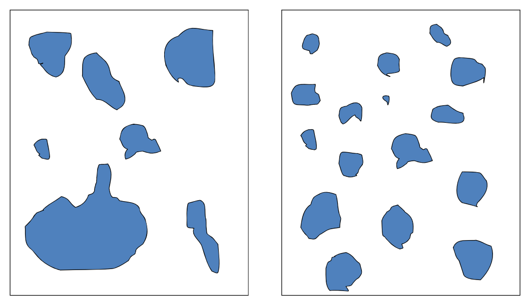
Figure 1.7: Interspersion and Juxtaposition Index

What is the ecological interpretation value of all these edge diversity and evenness (IJI) metrics?

Contagion

1. Contagion measures the interspersion or aggregation of landscape elements (patch types) across the landscape. However, it is actually based on **cell adjacencies**, not patch adjacencies. Therefore, it is only applicable to raster images.
2. Lowest contagion will occur for landscapes where the patch types are well distributed throughout the landscape.
3. Because it is based on cell adjacency, landscapes composed of large patches will necessarily have higher contagion than those composed of small patches, all other things being constant.

Contagion



Which landscape has the most contagious patch distribution?
Which is the "best" patch distribution?

Contagion- computation

In order to consider all possible adjacencies, including those inside a patch, it is often useful to build a total adjacency matrix where its elements (P_{jk}) represent the probability of a cell of class j being adjacent to a cell of class k. It is possible to evaluate the diversity of the adjacency matrix by computing an **Adjacency Diversity Index (ADI)** as:

ADI $= - \sum_{j=1}^{m-1} \sum_{k=1}^{m} P_{jk} \ln P_{jk}$

Contagion- computation

There are 2 primary ways to calculate **contagion**.

One can measure the deviation from the maximum ADI (entropy) possible for a given number of patch types by (Farina 1998):

Contagion = 2 ln m – ADI

where m= total number of patch types

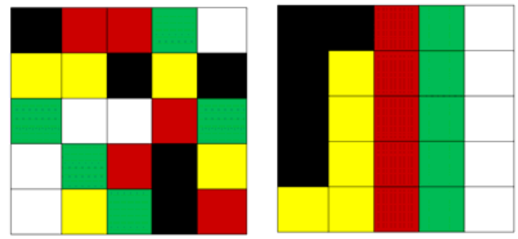
Contagion- computation

Some authors relate adjacency diversity index (ADI) to the maximum possible ADI which is 2 ln m. This is the **Contagion Index** of McGarigal and Marks (1995).

Contagion Index= 1+ ADI / 2 ln m

M&M (1995) multiply by 100 thus the index varies between 0 and 100.

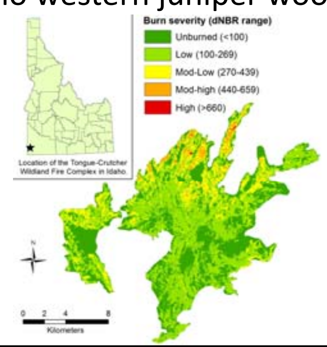
Which of these landscapes has greater contagion?



How could these cells be arranged to increase contagion?

What is the ecological interpretation value of contagion indices?

Burn severity patterns in southern Idaho western juniper woodlands



Strand et al. 2013

Landscape composition

Artemisia tridentata spp. *vaseyana* sere

Artrv open (S1)

Artrv closed (S2)

Early woodland (P1)

Mid successional woodland (P2)

Developed woodland (P3)

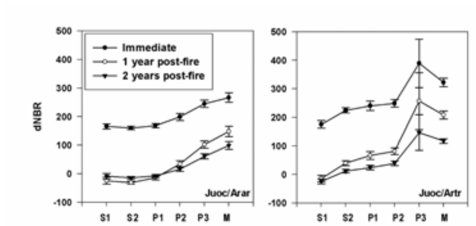
Mature woodland

Research objectives

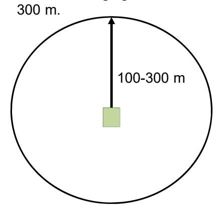
1) Evaluate how the magnitude of remotely sensed burn severity index can be predicted by the pre-fire vegetation type and structure at the landscape scale along the steppe/woodland successional gradient, immediately, 1 and 2 years post-fire;

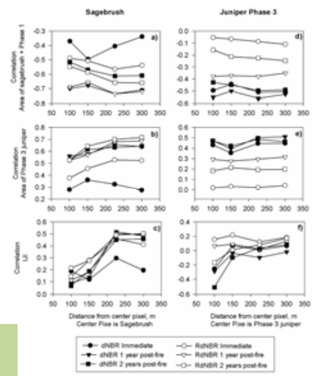
2) Evaluate the relationship between burn severity and the surrounding landscape pattern of pre-fire vegetation at distances ranging from 100 to 300 m.

Burn severity along successional gradient



2) Evaluate the relationship between burn severity index and the surrounding landscape pattern of pre-fire vegetation at distances ranging from 100 to 300 m.





Conclusion: Sagebrush incur higher burn severity if surrounded by developed woodlands

Which metrics?

- Over 60 different metrics have been developed
  - Most metrics are calculated on the same variables: the number of different types of patches, the proportions of different patch types, perimeter, edge length, and similar characteristics.
  - Many are not independent
- Riiters and others (1995) applied 55 metrics to 85 diverse maps of land use and land cover for the United States. They used factor analysis and principal components analysis to identify the 5 metrics that accounted for the most variation**:**
  - Average patch perimeter-area ratio: a measure of the shape complexity
  - Shannon contagion: a measure of patch aggregation
  - Average patch area normalized to the area of a square of the same perimeter: a measure of patch shape complexity
  - Patch perimeter-area scaling: a fractal estimator of patch shape based upon ratio of perimeter to area
  - Number of classes: a count of the number of different types of patch types

Summary

1. **Landscape connectivity** can be evaluated from 2 perspectives:

   -arrangement of habitat patches- **percolation**
   -arrangement of corridors (non-habitat)- **network analysis**

2. **Contagion** and **Interspersion-Juxtaposition** indices give another measure of landscape pattern which are different than those related primarily to composition. They focus on the dispersion of patch types in the landscape and edge-to-edge diversity, respectively.

3. The indices covered today are **pixel-based** metrics.

Summary (continued)

4. **Contagion** quantifies all cell adjacencies.

   -Thus it tends to emphasize inter-patch cell adjacencies when the patches are large with respect to the cell size.

   -**Contagion** tends to increase as the patch size increases.

5. **Interspersion-Juxtaposition** emphasizes the cells at the patch boundaries.

   I-J tends to increase as the “diversity of patch adjacency” increases. When some patch types tend to be consistently next to the same patch types, I-J tends to decrease.

Recommendations

- The grain of the data should be 50 to 25% of the area of the smallest features of interest (if possible, ensure that smallest patch has more than 3-4 pixels)
- The extent should be 2 to 5 times greater than the largest patch on the landscape (Hunsaker et al. 1994)
- Apply metrics to patches larger than 3 or 4 cells, since most patch-level characteristics are fixed for small patches (Hunsaker et al. 1994, Riiter et al. 1995)
- Select scales, sampling, classes and metrics relevant to the ecological question being addressed

What’s next?

- Lab on calculation of metrics
- Lab using the FRAGSTATS software to compute metrics