Lecture 7: Ordination of vegetation
I. Direct Gradient Analysis

• Classification vs. Ordination
• Direct gradient analysis
  – One dimensional
  – Multi dimensional approaches
  – Toposequences
Ordination

• “...an arrangement of units in a uni- or multi-dimensional order...” as opposed to “a classification in which units are arranged in discrete classes.”

  Goodhall 1953

Same as “Ordnung” of Ramensky (1930).

• The arrangement of plots to show floristic relationships between stands of vegetation or between species. The arrangement is in an “ordination space” in as compact a manner as possible. The distances between points on the ordination are measures of their degree of floristic similarity.

• Like numerical classification, ordination is a data reduction method that summarizes information in a simpler, more space-efficient, more visual means than a table.

• Often a major objective is to relate the ordination to environmental gradients.
Two basic types of ordination

**Direct ordination** examines vegetation changes along known environmental gradients (e.g. a moisture gradient or elevation gradient.

**Indirect ordination** examines the environmental causes of vegetation patterns by first arranging the stands or species according to their floristic similarity and then through correlation of the ordination axes with environmental variables.
Approaches to ordination
Direct gradient analysis

- **Definition:** A highly intuitive way to portray variation along a single or multiple environmental gradients. The plots display species or community abundance in response to a known environmental gradient (often this is a complex environmental gradient).

- **Basis of approach:**
  - There are key factors in the development of soils and vegetation, including climate, parent material, topography, other organisms, and time.
  - Direct gradient analysis is an examination of the response of individual species or vegetation types to gradients of these factors.
**Some basic definitions**

*Complex environmental gradient:* An environmental gradient that is composed of multiple, often correlated factors. Almost all physical gradients are complex environmental gradients (e.g. soil moisture gradient is also usually a gradient of soil pH, soil organic matter, soil aeration, etc.).

*Coenocline:* A gradient in plant community composition.

*Ecocline:* The simultaneous gradient in species composition and environmental variation.

*Normal distribution:* (= Gaussian distribution), a mathematical distribution defined with a mean and variance. Graphically, a normal distribution looks like a bell-shaped curve. With respect to vegetation, patterns of species along environmental gradients often resemble normal distributions. Gause (1930) first described such distributions in ecology in his studies of orthoptera.

*Mesotopographic gradient:* An ecocline along a small to medium-sized hill slope. Coined by Billings (1973) for alpine areas to portray the variation in communities along hill-slope gradients mainly as a response to varying soil moisture and snow conditions.

*Catena:* The soil science term for change along a hill slope, often with specific reference to the hill crest, shoulder, backslope, footslope, and toeslope.

*State factors:* The set of variables that control another variable. With respect to vegetation they are the factors that control development of vegetation. A mathematical equation describes vegetation as a function of a set of primary state factors: \( \text{Vegetation} = f(Cl, O, R, P, T) \), where \( Cl \) is the climate, \( O \) is the organisms, \( R \) is the relief (topography), \( P \) is the parent material, and \( T \) is time. Jenny (1941) first wrote this equation with respect to the state factors controlling soil development. He considered the soil to be a function of same five independent factors. Major (1951) later used the same variables as controls on the vegetation. Even more broadly, the same variables determine ecosystem structure and function.
A simple one-dimensional direct ordination of species along a topographic gradient in Ireland
2D Ordination of Irish moor grasslands

Nardus stricta

Molinia caerulea
Grassland species along a moisture gradient in Nelson County, North Dakota

Graminoids

Forbs

Ubiquitous species

Dix and Simiens (1967)
Another example from Whittaker (1956)

2-D ordination of stands along soil pH and calcium gradients at Prudhoe Bay, AK

Figure 55. Soil pH vs calcium concentration. Distinct clusters represent the major study sites.

Figure 56. Regressions of calcium concentration vs soil pH for the acidic and alkaline tundra areas. The highest calcium levels are in soils with pHs near 7.

From Walker 1980
Ordination of flora elements and life forms along an elevation gradient in Arizona
3-D distribution of salt-water organisms
Whittaker diagram: 2-D ordination showing location of major plant communities along moisture and elevation gradients in the Smokey Mountains

- x-axis: moisture/topography gradient
- y-axis: major elevation gradient
- Isolines show positions of broad plant formations.

Whittaker diagrams for two different substrates:

• x-axis: moisture/topography gradient.
• y-axis: major elevation gradient.
• Separate ordinations for serpentine and diorite soils.
• Isolines show positions of broad plant formation. Dashed lines are plant associations.

Species distribution plotted on background ordination space

- 4 species from Whittaker’s Smokey Mountain study.
- Background shows the distribution of plant communities in the ordination space.
- Small numbers show cover values for the given species in stands.
- Red lines are isolines of showing areas of equal cover classes for each species.

Species distributions:
- Fraser fir: Limited to high-elevation, Fraser fir forests.
- Striped maple: coves, ravines, sheltered slopes at all elevations.
- Red maple: broad range of slope positions and elevations, but focused at lower elevations.
- Sugar maples: sheltered coves and ravines at most elevations.

Whittaker 1956
4 more species

- Chestnut dead stems: mid- to higher elevation, oak forests.
- Yellow wood: lower elevation, cove forests.
- Mountain paperbush: mid-elevation oak forests.
- Flowering dogwood: lower elevation cove and oak forests.
Pine species

- Focused in the drier rocks and ridges and open slopes.
What are the habitats of these four species?

Sassfras albidum

Sorbus americana

Tilia heterophylla

Tsuga canadensis
Complex environmental gradients: complex soil moisture gradient
Toposequences or catenas

One of the most common direct gradient analyses is the portrayal of vegetation and soils along moderate-sized hill slope gradients that do not involve major elevation transitions. In soils, such gradients are often called catenas (L. chain; referring to series or closely connected series, especially a series of excerpts from the works of the Fathers of the Church). These are especially instructional because they portray the variation in species in response to complex soil and moisture gradients typical of most landscapes.

Example
Graphs of species, soil, and diversity information along a toposequence at Innavaite Creek, Alaska.

a. Schematic of the toposequence showing transitions in vegetation and soils.

b. Soil physical and chemical properties along the toposequence.

c. Distributions of common growth forms and species.

d. Diversity along the gradient.
West-facing slope at Imnavaig Creek, AK
Idealized toposequence: Imnavait Creek Alaska
Fig. 4.5. Vegetation of the R4D region. Dashed and solid lines indicate watershed boundary and intensive research site, respectively.
Fig. 4.2. Surficial geology of the R4D region. Dashed line indicates Innavaït Creek watershed boundary. Solid line indicates intensive research site of Fig. 4.1.
- Hill crest
- Snow bed
- Mid slope
- Lower slope
- Toe slope
- Valley
Terrain and Vegetation of the Innavaite Creek Watershed

### Vegetation, Innavaite Creek Intensive Study Area

<table>
<thead>
<tr>
<th>Community Type (GIS codes)</th>
<th>Ha</th>
<th>% of Map</th>
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<tr>
<td>Cetonia miphocerus-Rhizocorpus geographicum (07)</td>
<td>0.15</td>
<td>0.22</td>
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<tr>
<td>Hieracium alpinus-Arcturus alpinus, subtype Arcutus alpinus (01)</td>
<td>0.89</td>
<td>1.29</td>
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<tr>
<td>Hieracium alpinus-Arcturus alpinus, subtype Salix phyllephylla (02)</td>
<td>0.06</td>
<td>0.09</td>
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<tr>
<td>Hieracium alpinus-Arcturus alpinus, subtype Vaccinium vitis idaei (03, 04)</td>
<td>0.82</td>
<td>1.18</td>
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<td>Hieracium alpinus-Betula nana (06)</td>
<td>1.52</td>
<td>2.21</td>
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<tr>
<td>Dryas octopetala-Cassiope tetragona, subtype Calamagrostis inaeparvi (05)</td>
<td>3.54</td>
<td>4.85</td>
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<td>Dryas octopetala-Cassiope tetragona, subtype Nupharum argenticum (09)</td>
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<td>Sparganium relleum-Eriophorum vaginatum, subtype Salix planifolia ssp. baldinii (subalkaline facies) (16, 17)</td>
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<td>7.20</td>
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<td>Eriophorum angustifolium-Salix planifolia ssp. baldinii (20)</td>
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<td>0.48</td>
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<tr>
<td>Salix chamaecytis-Cassia aquatica (25, 19)</td>
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<td>0.34</td>
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<td>Eriophorum angustifolium-Cassia aquatica (21, 22)</td>
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<td>0.12</td>
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<td>Sparganium lanceolata-Salix francisci (23, 24)</td>
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<td>Sparganium orientale-Eriophorum schweickerti (20, 28)</td>
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<td>1.22</td>
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<tr>
<td>Hippuris vulgaris-Spergularia hyperborea (29)</td>
<td>0.05</td>
<td>0.08</td>
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<td>Barren and miscellaneous vegetation types (08, 18, 30, 33, 34)</td>
<td>0.23</td>
<td>0.34</td>
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<tr>
<td>Water (31)</td>
<td>0.05</td>
<td>0.03</td>
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<tr>
<td><strong>Totals</strong></td>
<td>68.92</td>
<td>100.00</td>
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</table>

Fig. 4.6. Vegetation of the Innavaite Creek intensive research site
Fig. 4.3. Surficial geomorphology of the R4D intensive research site shown in Fig. 4.1
Trends in major growth forms and species along two toposequences

- Rubus chamaemorus
- Eriophorum vaginatum
- Cassiope tetragona
- Salix reticulata
Trends in soil physical and chemical properties