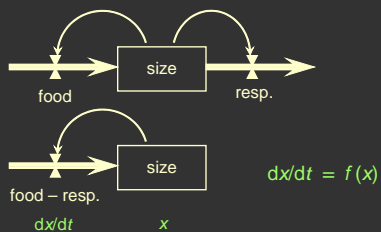


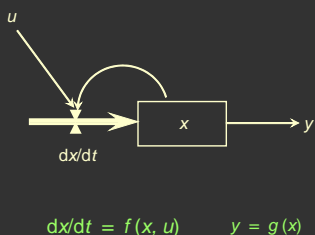
System Dynamics

Jay W. Forrester (1961) "Industrial Dynamics"



Graphical representation and computer simulation of dynamical systems. E.g., Vensim, Stella.
Stocks and flows, or states and rates. Equivalent to difference or differential equations.

System Dynamics



With inputs (u) and outputs (y).

Distance-dependent (spatial)

Individual trees:

- Free-growing. Increment depends on current size:

$$\Delta z_i = f(z_i)$$

"size" z might be a scalar such as D , or a vector such as (D, H)

- With competition, growth depends also of size and position of neighbours:

$$\Delta z_i = f(z_i, p_{i1}, z_{i2}, p_{i2}, \dots)$$

"Individual-tree distance-dependent" models, or "single-tree spatial", or "spatially explicit", or ...
 dx/dt may be used instead of Δz .

Competition indices

Effect of neighbours usually expressed through a *competition index* or growing space measure:

$$\Delta z_i = f(z_i, p_{i1}, z_{i2}, p_{i2}, \dots)$$

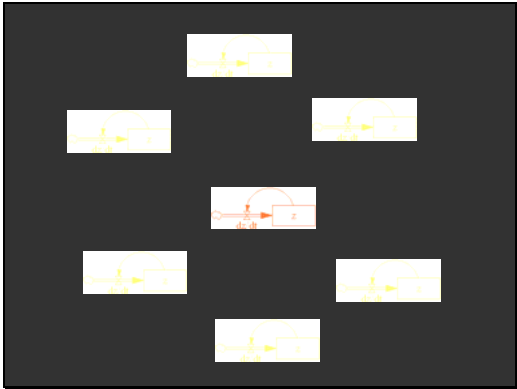
$$\Delta z_i = f(z_i, c_i)$$

$$c_i = g(z_{i1}, p_{i1}, z_{i2}, p_{i2}, \dots)$$

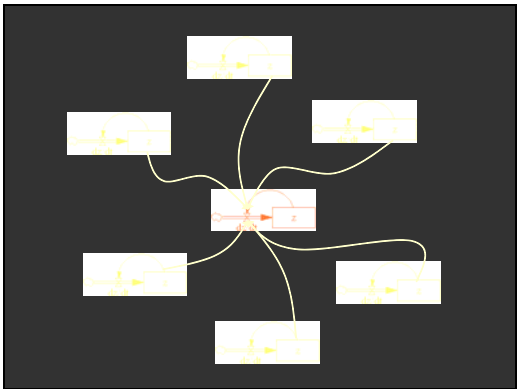
Example:

$$z_i = D_i \quad c_i = \sum \frac{D_j / D_i}{r_{ij}} \quad (\text{Hegyvi, 1974})$$

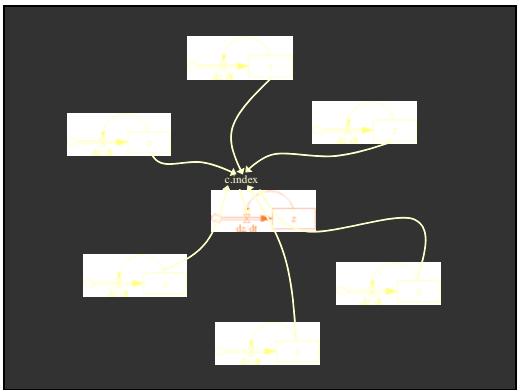
Split problem into two by introducing a competition index.



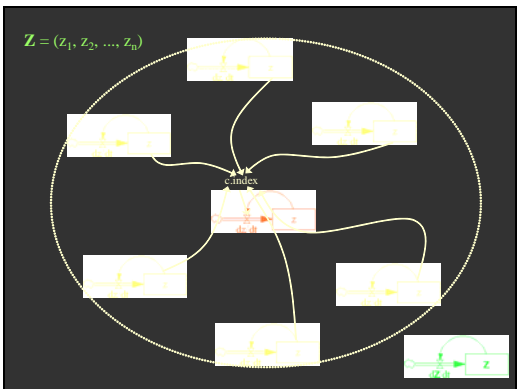
In pictures:
Free-growing, non-interacting trees.



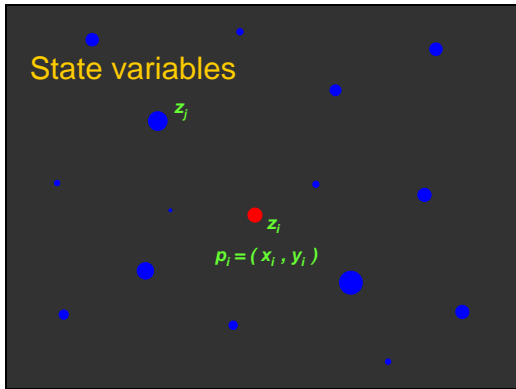
Competing.



Competition index.



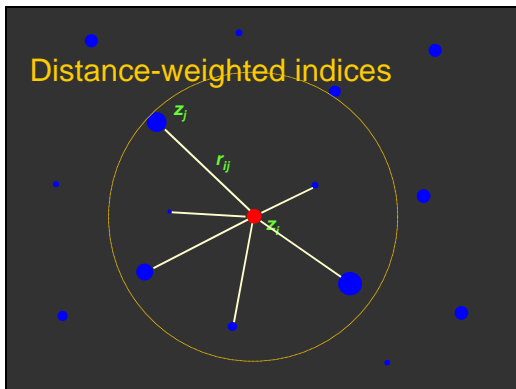
System and sub-systems.



Trees described by “size” z (possibly a vector), and position p .

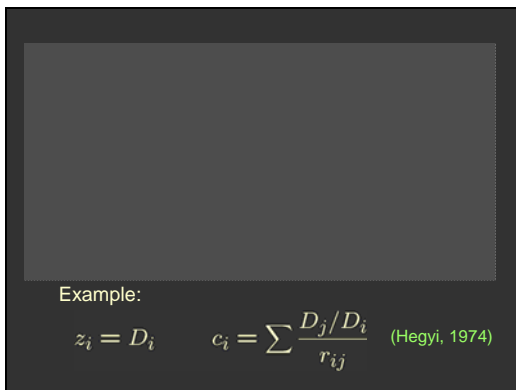
Competition index types may be grouped as:

- Distance-weighted
- Zone of influence
- Area potentially available (APA)
- Others

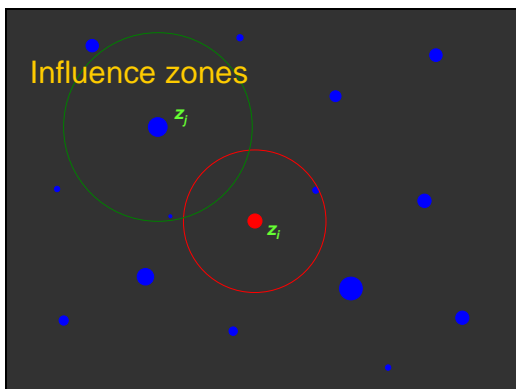


Competing neighbourhood defined in various ways: closest n trees, trees within a given distance (possibly dependent on subject tree size), trees counted in a basal area sweep, etc. Here simply a fixed radius circle, as in Hegyi’s index.

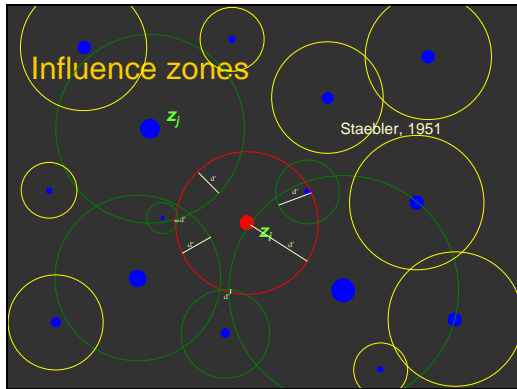
Competitors weighted by some function of size and distance, and added together.



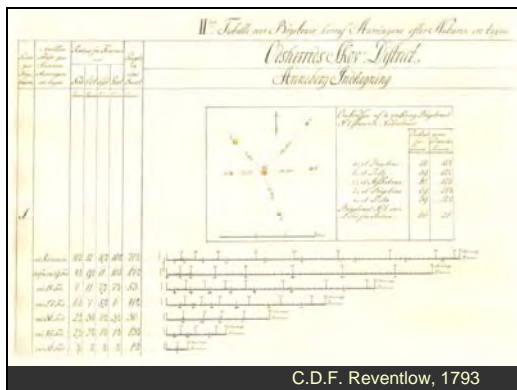
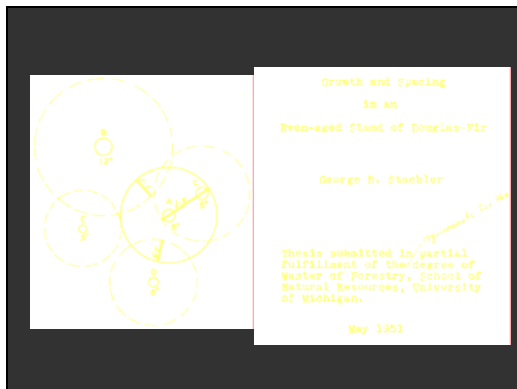
Hegyi’s is one of the simplest examples of distance-weighted competition index.



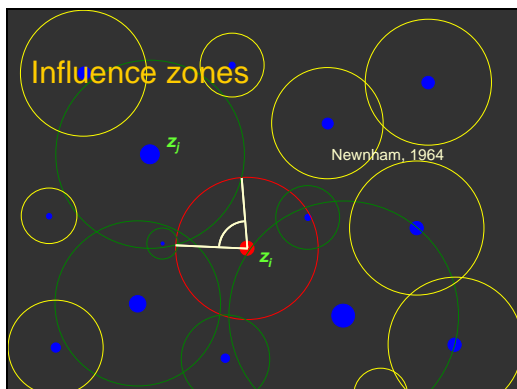
Zone of influence is a function of size. E.g., radius proportional to dbh, to crown diameter of open-grown trees with the same dbh, or related to tree height.



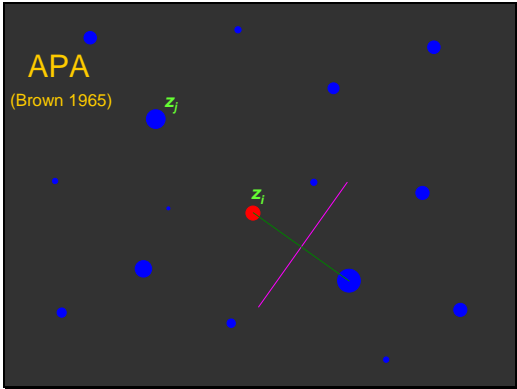
Tree i competes with green-circle trees.
 Competition index based on the overlaps, somehow.
 The first (?), in Staebler's 1951 MSc thesis, used the overlap width, d .



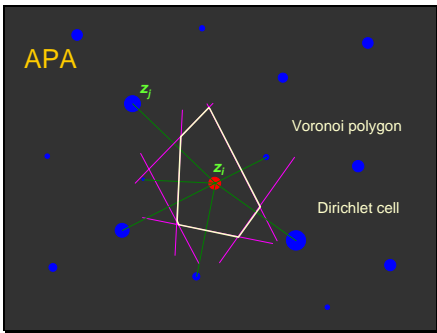
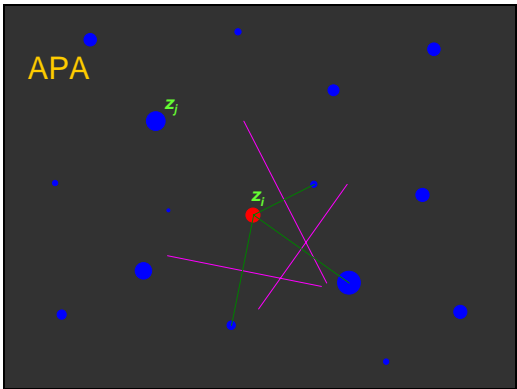
J.P. Skovsgaard (2004) "Forest Measurements", p.550-566 of the *Encyclopedia of Forest Sciences*, Volume 2.



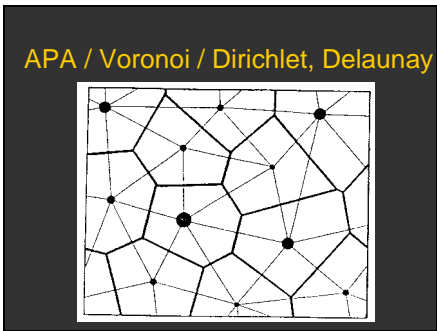
Newham's index (1964 UBC PhD thesis) is the sum of the angles subtended by the overlaps



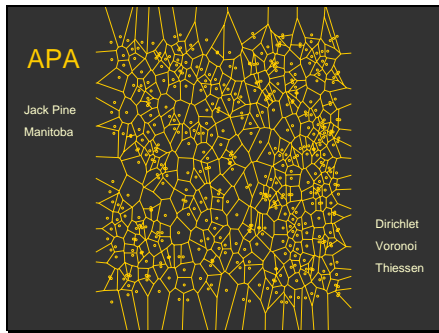
Looking at ground points instead of trees.
Points assigned to the closest tree.



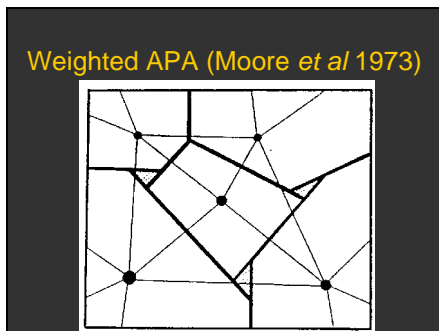
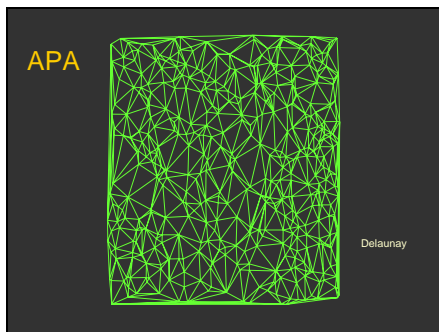
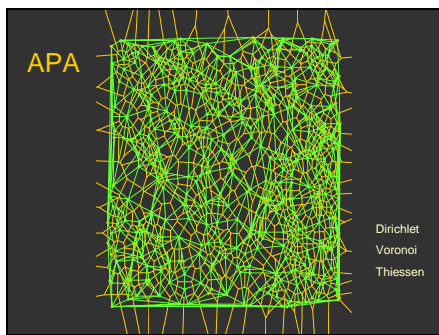
Area Potentially Available (G.S. Brown, NZ
For.Res.Notes 38, 1965).
The index is some function of the area.



Tesselation: partition into Dirichlet cells.
Delaunay triangulation: partition into competing-tree triangles.

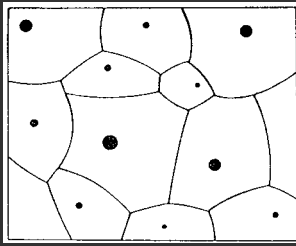


Can. J. For. Res. **36**(11): 2983-2993, 2006.



Partitions located on the connecting lines in proportion to the diameters of the two trees.
Unassigned “gaps”.

Johnson-Mehl



Curved polygons, from using a distance measure weighted by tree size.

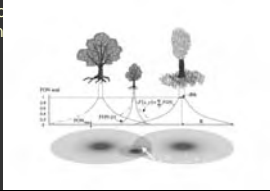
No known forestry applications (model originated in Physical Chemistry)

It might also make sense to limit APA to the intersection of the Dirichlet cell and an influence zone circle

Other

- "Ecological field theory" models (EFT), "Field of Influence" (FON)

Resource weighting function



EFT: *Ecological Modelling* **29**: 215-243, 1985.

FON: *Ecological Modelling* **198**: 115-126, 2006.

Other

- TASS
 - BC MoF model. (Much) more on that later
- Light tracing
 - E.g. SORTIE. More on that later

Comparison

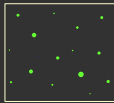
- APA: ground spot taken over by one tree; "hard", all-or-none competition
- EFT/FON, Distance-weighted: spot shared by all trees, in proportions depending of tree size and distance; "soft"
- Influence zone: combination

Comparison

- "Soft" vs "Hard"
 - Above ground, crown competition for light, approx. "hard"
 - Below ground, root competition for water and nutrients, approx. "soft"

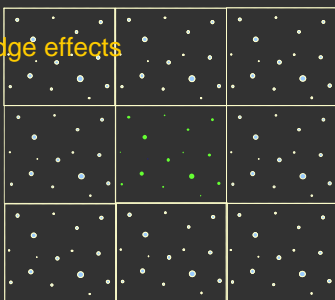
Also, note that distance weighted and zone-of-influence models would give the same value if all trees were concentrated on one side of the subject tree (not so in APA).

Edge effects



Competition indices and increments calculated for all trees within a (real or hypothetical) sample plot.

Edge effects



Usually assumed that the pattern repeats itself outside the plot, to avoid high predicted increments near edges.

Can also be seen as joining opposite edges together, forming a toroidal surface.

Spatial model structure

- competition index
 $c_i = g(z_i, p_1, z_2, p_2, \dots)$
- increment
 $\Delta z_i = f(z_i, c_i)$
- mortality
 $\text{Prob}\{\text{tree } i \text{ dies}\} = h(z_i, c_i)$
or dies if Δz_i becomes negative (or small)

Summarizing...

The models include also a mortality sub-model. For mixed stands, different parameters for each species may be used.