Spatial pattern of plant community influences productivity and diversity effects: an Individual Based Model approach

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Various spatial patterns (regular, random or clumped) result in different intensities of neighbourhood interactions. Also density of individuals and (a)symmetry of competition change ecosystem processes (Wiener *et al.* (2001)). To study these effects, we designed an Individual Based Model (IBM) of plant community with an asymmetric competition for light. We ask how is the productivity affected by the spatial pattern, density of individuals and diversity. To quantify answers we use transgressive overyielding and net effect of Loreau & Hector (2001).

Model & Methods

Our model modifies Berger & Hildenbrandt (2000) IBM for trees

- a field of neighbourhood (FON) approach is used, but instead of dbh, plant biomass b grows with growth rate r to maximum biomass b^{max}

$$\frac{\Delta b}{\Delta t} = br(1 - b/b^{max})C(F^A)$$

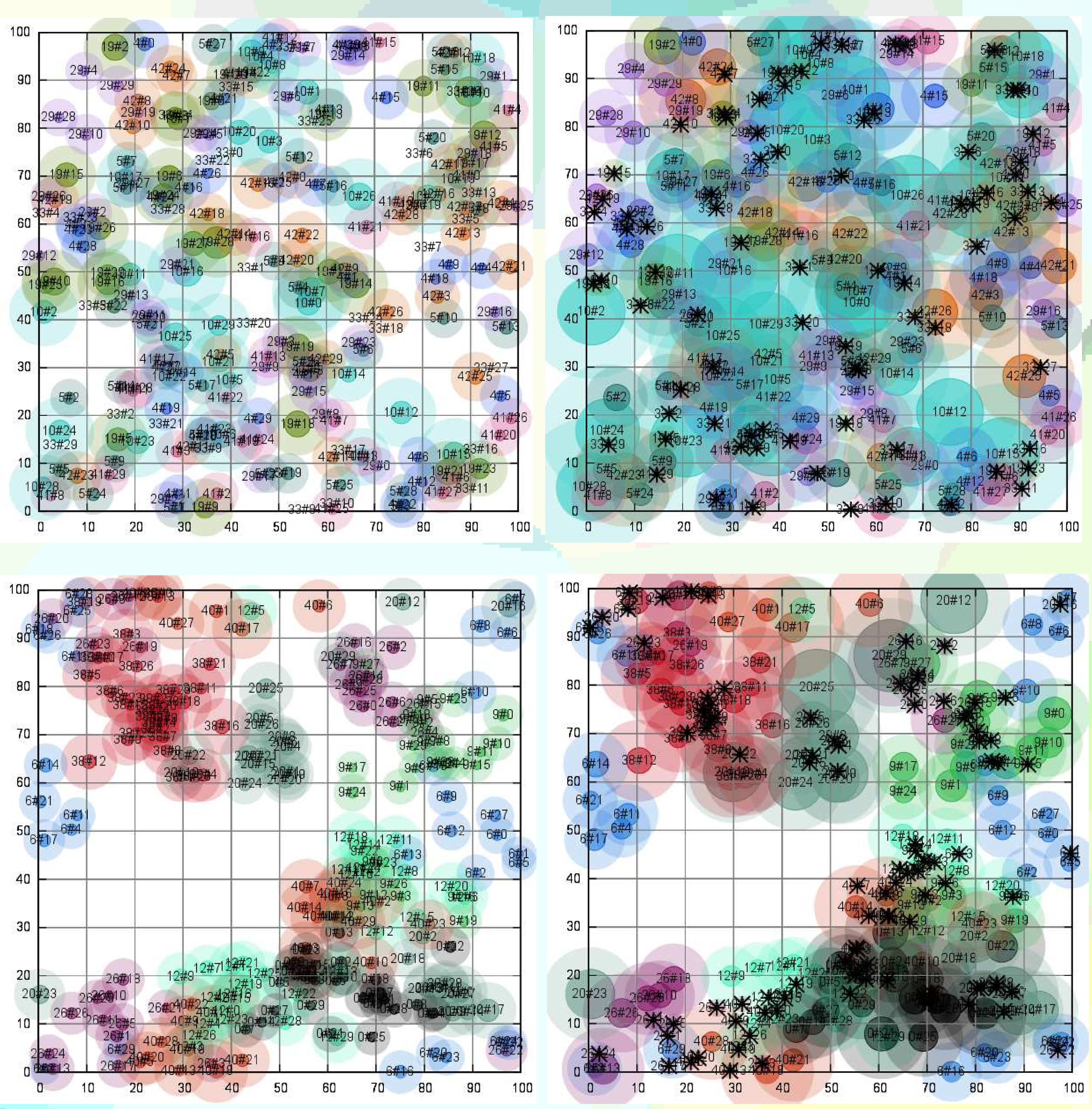
- plant is designed as a cone with volume corresponding to its biomass
- around plant biomass is an area called zone of influence (ZOI) where plant competes for resources if there is overlap with other plants
- an asymmetric competition of plant k for the light limits grow of biomass and changes shape of cone (height/width investments)

$$C_k(F^A) = max\{0, 1 - \frac{1}{Ast_k} \sum_{n \neq k} h_{kn} \int_{A'} FON_n\}$$

- FON_n denotes a scalar field over ZOI of plant n that states a distance-dependent intensity of neighbour, A and A' are k's and n's ZOI areas, st_k is shade tolerance and h_{kn} scales competition according difference of plants heights

A pool of 50 species is generated with log-normal distribution of parameters, then parameters of plants are generated with log-normal distribution of values with means given by randomly chosen species. Variability between plants is much smaller than between species. Field is assumed as a torus, so there is no edge effect. We use factorial design, with 20 densities, 4 number of species (2, 4, 8, 16) and 5 spatial patterns

- random pattern: positions of plants are randomly generated
- regular pattern: positions are randomly chosen from regular grid
- clumped patterns: consists of 16 clump centres (positions) and their "standard deviations" that together express decreasing probability of plant occurrence with increasing distance from a centre. We define three inter-species relationship of clumps: clumped+ (each clump belongs to one species), clumped- (each clump consists all species) and clumped0 (plants are randomly placed to clumps).



Fields with 8 species (colours differ species) each with 30 plants in random (first row) and clumped+ pattern (second row) at the time 1 (first column) and time 100 (second column). Crosses denotes dead plants.

All results are based on simulations with 9 repetitions.

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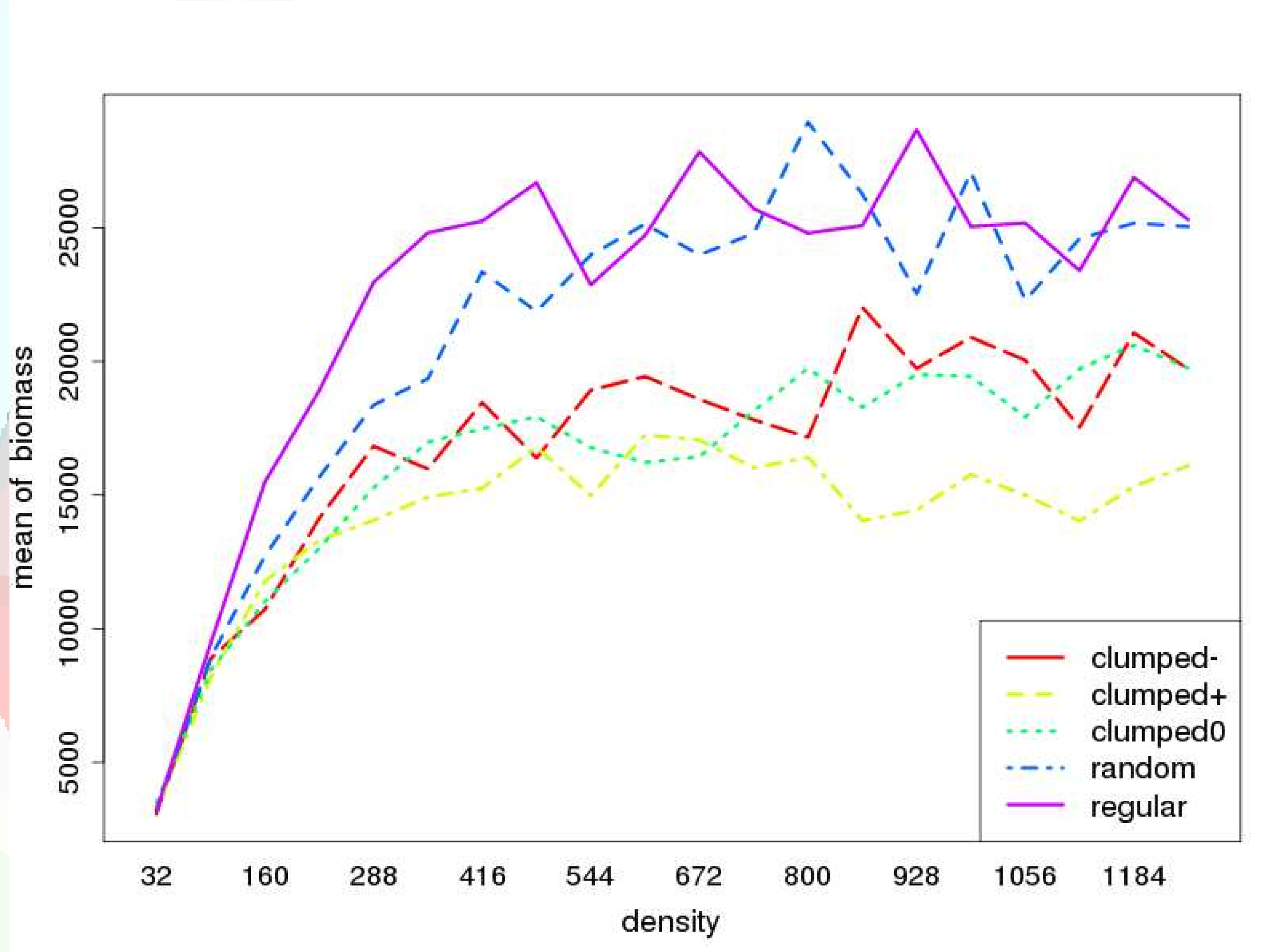
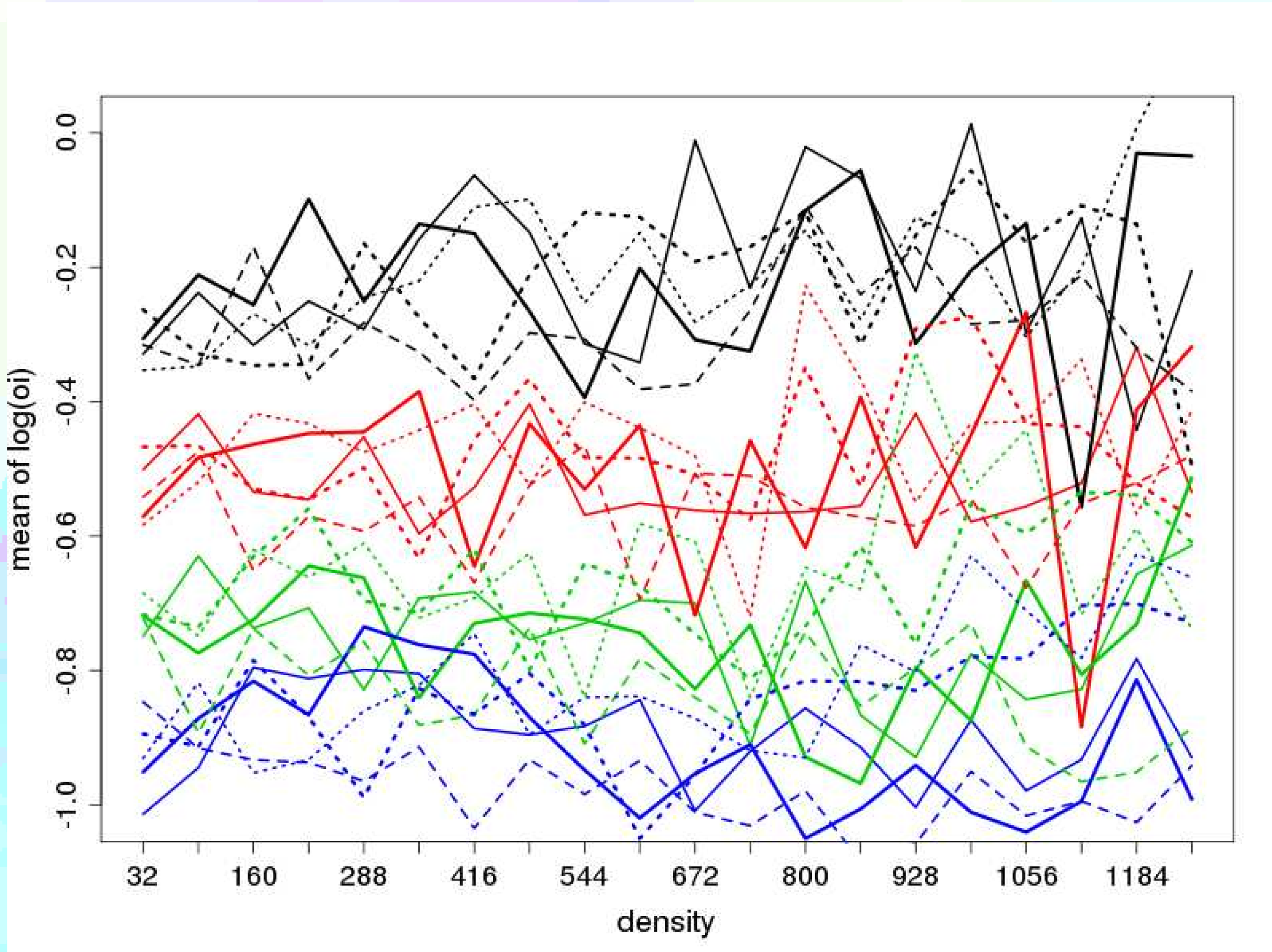
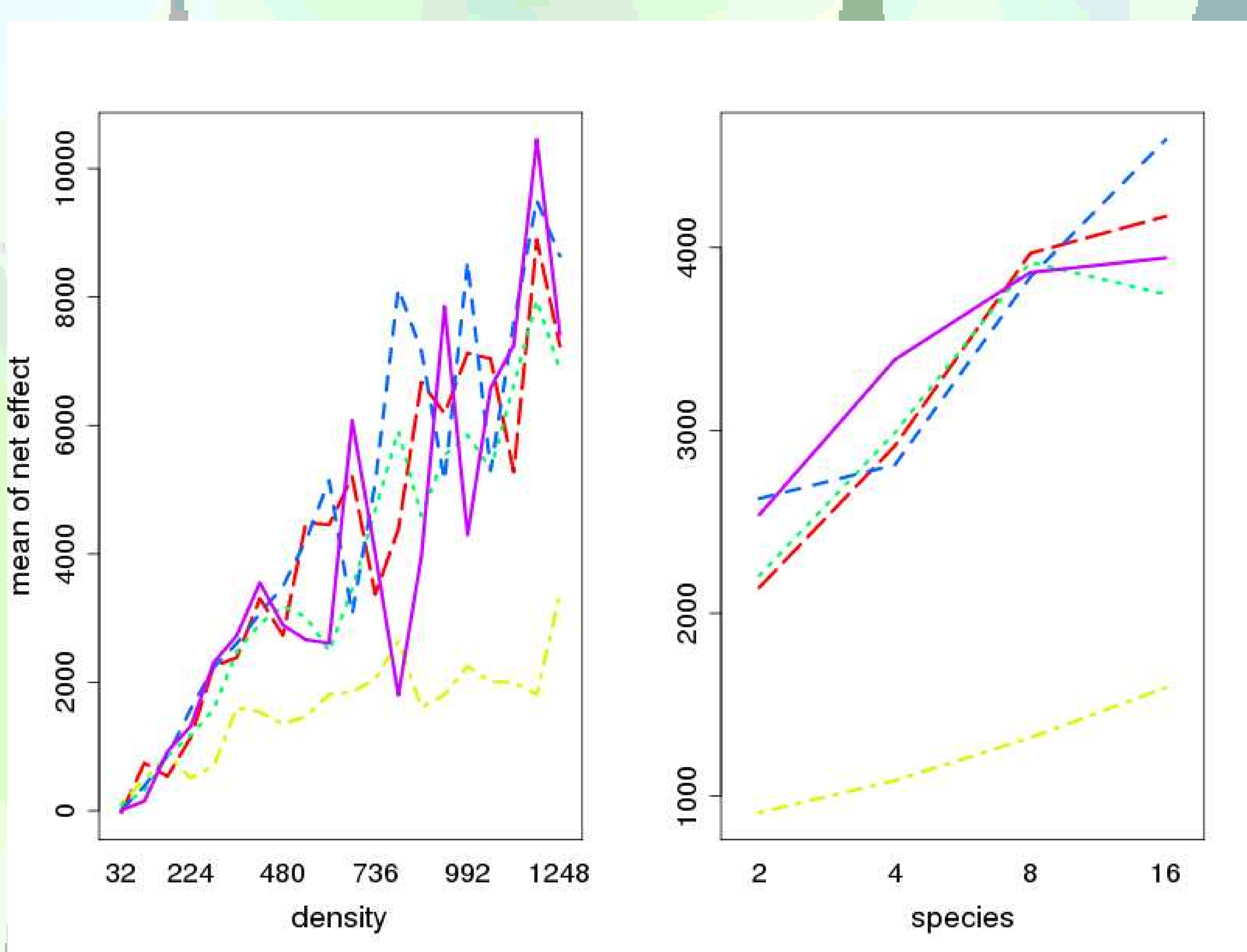
Results



Total biomass increases with density with saturation around the density of 400 plants. The regular spatial pattern is saturated by the lower, and clumped by higher density than random pattern. Clumped patterns have lower biomass. Averaged over all the species richness values used.



Transgressive overyielding (mixture yield over maximum yield monoculture) decreases with the number of species (2 species with black lines, 4 with red, 8 with green, 16 with blue), but does not show a consistent trend neither along the density gradient nor with the spatial patterns (random with solid line, regular with bolder solid, clumped+ with dashed, clumped- with dotted, clumped0 with bolder dotted).



Net effect (yield observed minus yield expected) depends on all, the spatial pattern, total plant density and number of species (for legend see above). Clumped+ has the lowest net effect.

References

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Loreau, M. & Hector, A. (2001) Partitioning selection and complementarity in biodiversity experiments. *Nature* 412: 72-76 & 413: 548.