Application of statistical physics to agroecology: an adsorption-desorption model of plant intercopping

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The French Intensive Method involves cultivating plants in a smaller space and with higher yields than traditional gardening methods. Typically, diversified crops are planted as densely as possible. Models in computational agroecology may assist farmers in the maintenance of such farms. Various planting strategies are used including batch with regular spacing, synchronised or desynchronised. We propose a phenomenological model in which the plants are represented as disks with a growing radius. The plant volume or biomass can be estimated as a half-sphere of radius R(t). In the simplest model we consider the growth to be linear in time $R(t) = \alpha(t-t0)$ with $t0 \le t \le tb$, when the plant is planted at time t0 and harvested at time tb. In a more refined model the time-dependent radius is modeled as a sigmoidal function corresponding to slow growth in the initial and final stages. We consider a monoculture and a mixture of two vegetables, for example lettuces and cabbages, with different maximum radii and growth rates. In addition to regularly spaced planting, we explore an alternative strategy consisting of randomly selected the planting positions and times. These models take inspiration from random sequential adsorption and parking lot models with the additional constraint that a newly sown plant must be placed so that it does not overlap with others over the course of its growth. We describe different event-driven algorithms (1D and 2D) to simulate the dynamics of this system. At low planting rates the position of a new plant may be selected randomly, but at high plant coverage the method is inefficient so in 1D we employ a rejection free algorithm. The steady state of the field consists of disordered configurations of the plants. We study the evolution of the effective planting rate as a function of the nominal planting rate, the fraction and distribution of each species in the steady state. When both vegetables are planted with equal probability, simulations show that the proportion of big plants starts decreasing above a given threshold. This model and the algorithms may be extended to more species and other planting strategies to examine original farm designs and to help manage a complex rotation plan.