Designing eco-system service provisioning by agro-landscapes

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In many regions agriculture has given rise to recognizable land-use patterns that result from the interaction between natural factors and human action. Such patterns as perceived by humans are denoted here agro-landscapes. Agro-landscapes provide a larger number of ecosystem services than fields or individual farms. For example, surface water storage, erosion containment or biodiversity associated with agriculture such as pollinators or natural enemies of agricultural pests require spatial scales beyond the current farm sizes, and cultural identity of landscapes becomes apparent only at the scale of the landscape as a whole.
While in the past landscapes emerged as by-products of land use, increasingly policies are targeted at the regional scale and constrain the scope for manoeuvre at farm level. On the other hand, the window of opportunity for agriculture may also increase, for instance when farmers create arrangements to market labelled regional products, or reduce pest attack and GMO pollen fluxes by area-wide management schemes. The call for ecological intensification of production systems (IAASTD, 2009) will require mobilization of solutions at all spatial scales. These opportunities and demands suggest that agronomy should move beyond its classical singular focus on production maximization to a broader interpretation of efficiency and to inclusion of a broader suite of indicators for sustainable development.
Changes in landscapes are socially and technically complex, due to the high number of stakeholders and due to limited knowledge on cause-effect relations, often fragmented due to disciplinary divides. Agronomy has analytical and synthetic roles to play to support such land use planning processes. Analytically, understanding the effect of spatial-temporal land-use arrangements on ecosystem service provisioning presents a major challenge. Synthetically, approaches are needed that accommodate the evaluation of land use in a multi-objective and multi-scale fashion and are suitable for multi-stakeholder interaction. In this abstract we present recent progress in both domains based on work in our groups.

Methodology

Disease-suppressive landscapes. Potato late blight caused by *Phytophthora infestans*, is a major cause of potato yield loss and fungicide input. The pathogen has a major genetic capacity to overcome host resistance. To investigate opportunities for spatial design as a management option Skelsey et al. (2010) developed a multi-scale spatial-temporal simulation framework in which they combined quantitative information on epidemic progress, fungicide management, spore dispersal and spore survival, with a landscape generator. Invasion rate and extent by a resistance breaking *P. infestans* genotype were calculated for scenarios differing in (1) the proportion of potato in the landscape; (2) the fraction of resistant potato genotypes; (3) the size and orientation of fields; and (4) the degree of spatial clustering of potato fields. Two sets of scenarios were run, one in which each field was assigned a single cultivar and the other in which resistant and susceptible cultivars were mixed per field. Scenario results represented averages of 10 random landscapes and 10 years of observed weather. In each run, a random field was infected during the first infection opportunity.
Multifunctional landscapes. To support discussions on allocation of production and public goods oriented land use activities with an extent of 10 km^2 a static modelling framework was developed called Landscape IMAGES (Groot et al., 2007; 2010). The spatial units of interest consisted of fields which could be used by different types of agricultural land use activities, non-productive margins which might include grass strips, hedgerows etc., and remaining area such as infrastructure and buildings. For a given land use pattern, different spatial and non-spatial indicators were calculated, together describing the performance of the landscape. Populations of alternative land use patterns were generated, evaluated in terms of the indicators and 'evolved' to a next 'generation' according to the logic of evolutionary optimization. Evolution to a next generation was based on the Pareto-rank of patterns in the population, which allowed

to identify trade-offs between indicators without recourse to a priori weights as in most multi-criteria methods. We applied the approach to an area in the Netherlands where farmers and non-governmental landscape conservationists negotiate about restoration of hedgerow patterns. Four indicators representing farm gross margin, biodiversity, landscape value and nitrogen loss were formulated, in a later study extended with 7 indicators representing ecological quality, landscape character and implementation costs.

Results and discussions

Disease suppressive landscapes. Results indicated that landscapes can be designed to mitigate effects of virulent *P. infestans* invasions. In the scenarios, decreasing the area under potato and the fraction susceptible cultivars had major but non-linear effects. Arrangement of fields perpendicular to the dominant wind direction also showed promise, as opposed to field size and clustering of potato field. Within-field mixing of susceptible and resistant genotypes consistently contributed to less disease compared to monocultures, incidence of diseases fields being at least a factor 2 lower on average. *P. infestans'* dispersal capacity necessitated isolation distances of 16 km or more between fields with different cultivar resistances. The pathogen was found to disperse significantly between susceptible cultivars in regions as far as 32 km apart. Epidemics depended strongly on weather - landscape configuration interaction, underlining the importance of co-incidences to spark epidemics.

Multifunctional landscapes. Trade-offs between the 4 objectives (Fig. 1-left) showed that some pairs had narrowly defined relations, such as plant species number and gross margin, indicating competition among these objectives. In such cases, improvement in one objective comes at a cost to the other objective. For other pairs, improvement in one objective had no or limited effect on the other. Together, the trade-offs and the associated landscape patterns (e.g. Fig. 1-right) showed the room for manoeuvre in the discussion among landscape conservationists and farmers.

The illustrations showed an analytical and a synthetic approach to combine agronomy with landscape ecology, biomathematics, economics and communication sciences, to reveal consequences of spatial-temporal interactions among processes, indicators and objectives, and suggest new options in land use planning.

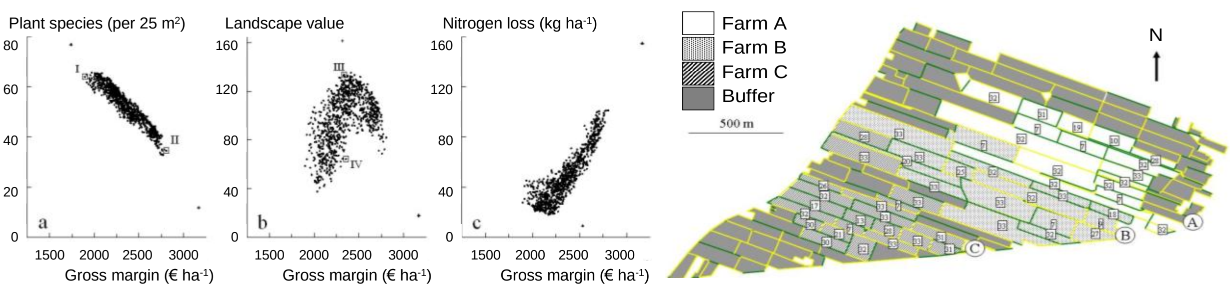

Fig. 1. Trade-offs among farm gross margin, biodiversity, landscape value and nitrogen loss (left) and an example landscape with 3 farms, fields and hedgerows (right).

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