How much can a virtual territory help us to understand the resilience of the heroic viticulture? A case study in Trentino (IT)

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Abstract
In Trentino (IT) two types of vineyard landscape coexist in dynamic equilibrium: the valley is mechanized and plots have a great extent, on the steep slopes a terraced viticulture developes with small size plots and little mechanization is possible.
In this work we assume that the emergence of two different contexts - steep slopes and the valleys - result from the complexity of the processes that underlie the development of a territory, and the different factors in play should be studied in their intrinsic diversity because none of them should be considered as the main cause of the emergence of the landscape structure.
With some simple (but not simplistic) assumptions on the landscape structure the authors developed a parsimonious agent-based model for the simulation of these dynamics. The results obtained were compared with the historical evolution of the landscape documented in historical archives and with the current state of the territory.
The goal is to determine the plausibility of such a simplified model that can describe the evolution of the landscape to the current configurations. We will show, finally, the representations of the model and the dynamics of two viticultural landscapes of the Trentino region (IT).

Keywords
Viticulture, agent based modeling, landscape dynamic

Introduction
The traditional vine growing terraced landscapes retain a strong local identity: for example the Douro Valley (PT), Lavaux (CH) and the Cinque Terre (IT) are so worldwide known that some of them were enrolled in the UNESCO World Heritage List. But these are only few famous examples among less known landscapes pulverized across the entire world: for the prohibitive working conditions are often recognized as heroic viticulture and CERVIM (the Center for Research, Environmental Sustainability and Advancement of Mountain Viticulture) has compiled a list of these areas in Europe.
Some years ago the authors developed an automatic methodology to identify the terraces of the vineyards in *Val di Cembra* and *Banyuls sur Mer* to be applied to the description of the heterogeneity of the different traditional terraced landscapes (Delay and Zottele 2012a) knowing that the terraces are the symbol used to create a strong link between the wine and the consumer (Delay and Zottele 2012b). The strong identity of these two viticultures do not protect the vine growers form the dynamics of global market that dictates lower prices for the same quality: the higher costs of managements of the vineyards on the steep slopes than the mechanizable ones on the bottom of the valleys push the mountain wines out of the market. However, in a warmer climate, the terraced vineyards with their excursion of altitudes are becoming interesting for the wine producers because the grapes can reach those quality standards that are more and more difficult to attain at lower altitudes (Caffarra and Eccel 2011). At the time of this writing, some wine producers pay more for white grapes cultivated at higher elevation than 400 m, paying even more when a low environmental impact protocol is set in production.
In the "Valsugana Trentina" region (Trentino, IT) we have examples of the two co-existent and adjacent agricultural landscapes: a flat, bottom-of-the-valley mechanized orchards and a traditional terraced viticulture that climbs the slopes made up of small plots that have successfully resisted the abandonment and reforestation. With this work we want to show a model to investigate the emergence of this dynamic equilibrium as the interaction of different factors and to exploit the attitude of the vine growers to maintain the production in an area that would appear at first sight disadvantaged (Figure 1). The model has been published by Zottele and Delay, 2015

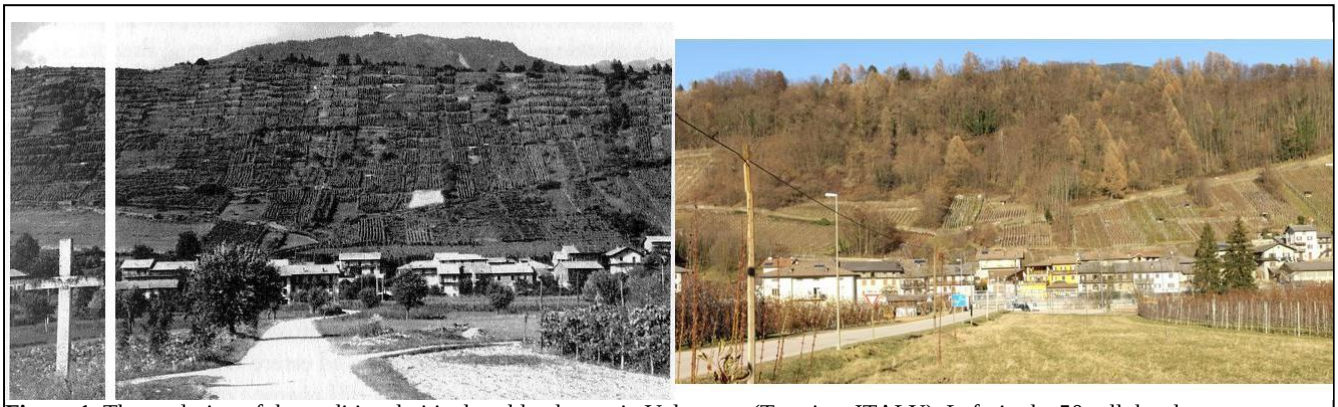

Figure 1. The evolution of the traditional viticultural landscape in Valsugana (Trentino, ITALY). Left: in the 50s all the slopes are cultivated (Marchesoni, 2010, Sartori's archive). Right: 2013: the upper part of the hill and its terraces are completely abandoned, while the actual plots maintain the traditional landscape matrix.

Materials and methods

We will describe shortly the developed model of landscape dynamic describing emerging pattern based on the choice of the vine growers to maintain or abandon their activities depending to the benefits of each owned plots. In the bottom of the valley, the management costs are lower (mechanization benefit) than on the steep slopes where the production can benefit higher remunerations (climatic benefit). A synthetic landscape has been used: the computation matrix is 200^2 cells, a quarter of the landscape is flat, the other cells have a slope of 45° simulating the steep-slope viticulture (Figure 2). The mutual interaction between the landscape and the vine growers has been codified with an Agent Based model (ABM) that mimics a *complex system* of human behaviors and spatial patterns (Batty 2012).

To describe the system we use a *variable of state* that computes the expected benefit of the vine grower to continue to operate on each plot. The *reason* to continue to operate, to expand the activity or to abandon is described with a *utility function* that changes in space and time and that is proportional to the benefits (number and position of the plots).

$$f_{u,j}(t) = \alpha(T_{g,i} - T_{c,i}) + \beta T_{r,j} \quad \text{(Equation 1)}$$

T_c represents the mean costs for all the plot (of the i-th vine grower that could own fields on the slopes and in the valley), T_g is the mean profit and Tr is the climatic benefit. We used the work of Lang et al. (2004) for the different management costs in the bottom of the valley and on the slopes. The climatic benefit has been modeled to have a maximum benefits at higher altitudes and no benefit for the plots at the bottom of the valley. For a complete description of the individual terms of (Eq. 1) see Zottele and Delay (2015). The α and β parameters measure the mechanization benefit and the climatic benefit respectively. We then introduce a utility threshold F_u, so that, when the value of (Eq. 1) is lower than the threshold the vine grower has less benefits than charges and will abandon one of the plots (the one minimum value of climatic benefit$_j$).Otherwise, the vine grower expand occupying one the neighboring cells (at a distance < R_p, the *radius of interest*) of his plots and choosing the one with the maximum climatic benefit. In our synthetic experiment we place 100 vine growers randomly on the matrix each with 25 random plots (Fig 2.).

The authors ran 23100 simulations to explore the spatial pattern emerging by all the combination (behavior space) –with different discretization steps, replicated 10 times - of the parameters α, R_p, F_u.

Results and Discussion

Some spatial pattern emerged conditioned to some ranges of values set in the behavior space. One of the most notable result is linked to R_p: the resilience of the traditional terraced landscape, in terms of active vine growers is enhanced by the possibility for them to access distant plots (Figure 3). Then, the ratio between the mechanization benefits and the climatic benefits must be less than 0.3 (Figure 4): with this value both viticulture (on the bottom of the valley and on the steep slope) coexist and expand. Even with high values of F_u (expected utility) the traditional viticulture survives but with few active growers that owns plots both on the bottom of the valley and on the slopes. For a deeper analysis of the results see Zottele and Delay (2015).

The importance of Rp shows that a healthy traditional viticulture could survive if it is ensured farmers' mobility. A well maintained system of roads should be fundamental for the landscape resilience. In a similar way, the benefit of mechanization depress the viticulture of the mountain: a good policy of remuneration for the vine growers that works on the steep slope is also fundamental. In the work of Zottele and Delay (2015) is discussed how a superficial consideration of the importance of the ratio between mechanization and climatic benefit could lead to a possible destruction and trivialization of the traditional landscape.

Conclusion

The authors hope to improve this parsimonious and simple (but not simplistic) model introducing a refined parametrization of the benefits used to define the utility function. This implies a even more multidisciplinary approach to the ABM

modelization of the landscape, that is still at its first steps regarding the agricultural landscape.The authors would also include the possibility for an wine grower to destroy all the terraces in a plot to benefit the mechanization even on the steep slope: this action - the erosion of the traditional landscape – could have strong collective consequences weakening the quality peception of the wine by the consumer as studied by Tempesta et al. (2010).

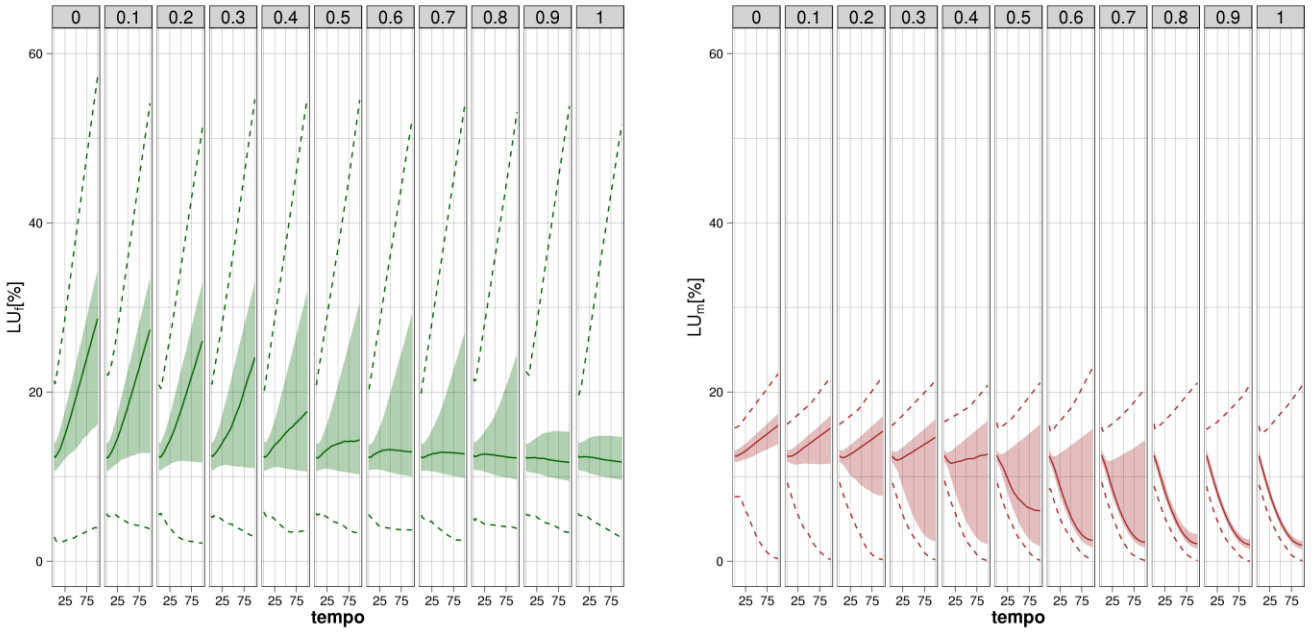

Figure 3. Land use (%) evolution for different ratio between the mechanization and climatic benefit. In green the land use for the bottom of the valley, in red for the steep-slope traditional landscape. The solid lines shows the median values, the colored area shows the 25th and 75th percentile respectively. The dashed lines show the minima and the maxima respectively.

Figure 2. Two initialization of the model. The big circle are the position of the vine growers, at each vine grower 25 plots are assigned. The black cells are the bottom of the valley, the elevation is represented in shades of gray

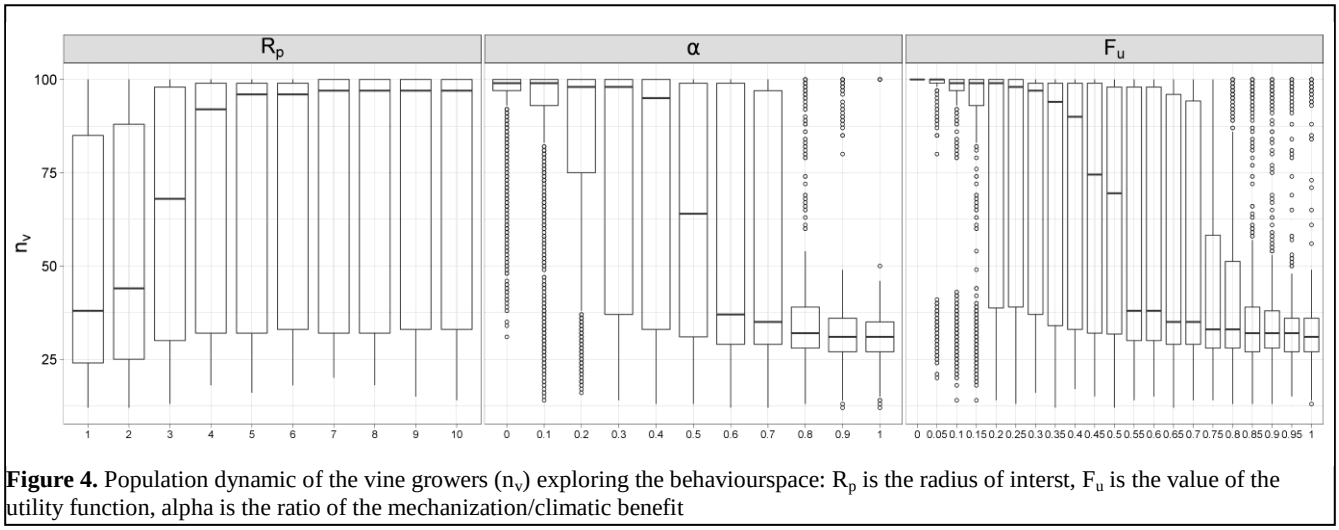

Figure 4. Population dynamic of the vine growers (n_v) exploring the behaviourspace: R_p is the radius of interst, F_u is the value of the utility function, alpha is the ratio of the mechanization/climatic benefit

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