Agricultural policies and the emergence of voluntary landscape enhancement efforts: an exploratory analysis of rural tourism using an agent-based model

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Conservation and enhancement of ecosystem services have become a priority of rural policies. Feedback loops from rural policies on ecosystem service supply have often been highlighted in the literature, but only vaguely investigated. In this paper, we model feedback loops from rural policies through an agent-based model, and we analyse whether feedback loops can indirectly create a system in which voluntarily landscape enhancement emerges from the interactions between farmers and rural tourists. The results suggest that, in certain conditions, feedback loops from policies can be a relevant element to take into account, but that greater attention to the ecosystem service demand is required.

Keywords: agent-based model; rural tourism; agri-environmental payment

1. Introduction

While agricultural and rural landscapes are able, in certain conditions, to provide a wide range of ecosystem services (ES), their optimal provision is generally considered a challenge in human-managed ecosystems (Tilman et al. 2001; Zhang et al. 2007). The under-provision of ES with no market (e.g. regulating services) is deemed to be driven by the ‘externality’ character of the benefit the agricultural sector would provide, since farmers would face provision costs for goods from which society as a whole benefits without any compensation being paid to farmers (Gullstrand, De Blander, and Waldo 2014).

For this reason, a number of measures to change private incentives to conserve or to enhance ES, and the landscape characteristics that provide them, have been introduced by way of rural policies (Engel, Pagiola, and Wunder 2008). For instance, the EU Common Agricultural Policy (CAP) began focusing on the protection of landscape elements through the agri-environmental measures introduced in 1992 until the most recent reform (Regulation (EU) of the European Parliament 1305, 1306 and 1307/2013). The CAP agri-environmental payments (AEPs) embed the concept of positive externalities, as they provide incentives for environmental goods that are considered to be under-supplied based on market incentives. However, payment levels are justified by the private costs that farmers incur to comply with environmental prescriptions, making it unlikely that payment levels result in optimal supply (Bartolini et al. 2012; Hanley et al. 2012). These payments are expected to continue in the next programming period (2014–2020) with an
even stronger emphasis on landscapes (Regulation (EU) of the European Parliament 1305/2013).

The management of ES provision in rural landscapes is further complicated by the fact that the benefits of some ES accrue to the agricultural sector itself. This notion has received less, but nonetheless increasing, attention. For instance, Zhang et al. (2007) list the ES that improve agricultural productivity, advocating for a better understanding of the determinants of those ES, and of the potential trade-offs with the dis-service to agriculture. Van Zanten et al. (2014) develop a conceptual framework to address the complex relationships that lay behind the provision of ES from rural landscapes, explicitly including the possibility that ES benefits return to the agricultural sector.

This makes the problem different from the ‘simple’ externality characterisation of the ES provision, since the private optimum may be expected to be closer to the social optimum compared with pure public goods. However, the literature shows that the existence of some private benefits does not ensure the optimal management of resources. Notably, the literature has begun highlighting the “tragedy of ecosystem service” provision (Lant, Ruhl, and Kraft 2008, 969), or the coordination issues related, for instance, to pest management (Heal et al. 2004) and crop pollination (Cong et al. 2014). Moreover, uncertainty on ecological processes and on the actual values of ES might also explain the under-provision of rural ES (Cong et al. 2014). When coordination issues are solved, for instance, in some cases in which recreational values and rural tourism are involved, since these processes are dependent on actions at the landscape scale, ES can bring substantial benefits to rural economies (Brunori and Rossi 2000).

The indirect role of agricultural policies in such processes is, to the best knowledge of the authors, largely unexplored. Since ES supply can affect the rural economy through markets for private goods, policies aimed at compensating for externalities (public-good-type ES) could indirectly influence the agricultural sector’s production of private goods. This influence can trigger positive or negative feedback loops into decisions concerning the production of public-good-type ES. This is not the case if the causal effects from the policy incentives, through rural landscape management, imply that agriculture unidirectionally pours ES benefits into other sectors of society.

Feedback loops are not a new issue in environmental policy. The so-called ‘rebound effects’ indicate unintended negative feedbacks that counteract the intended positive economic effects of a given policy, typically due to profits for the polluting sector generated by the policy itself (Maestre et al. 2012). Instead, the term ‘second-order effects’ is thought of as a representation of the positive feedback loops generated by conservation measures (Cooper, Hart, and Baldock 2009; van Zanten et al. 2014). The term thus considers the possibility that a conservation payment could enhance landscapes in such a way as to provide benefits to landscape users and, as a result, farmers would find opportunities for novel, profitable activities above and beyond the policy payments (van Zanten et al. 2014). This is the case, for instance, of rural tourism, a relatively new phenomenon involving recreational services provided by a rural landscape. The mechanism here is that through policies, improved landscapes attract new tourists who in turn increase demand for private goods produced by farmers (Daniel et al. 2012; Cooper, Hart, and Baldock 2009).

These aspects have only been vaguely addressed by the literature (Cooper, Hart, and Baldock 2009; van Zanten et al. 2014), even though they could become crucial at times of increased attention to economic competitiveness in the field of resource and environmental management, and also when budgets earmarked for environmental protection face fierce competition from other policy objectives (Hodge 2012). From a
policy standpoint, knowledge of feedbacks could be explicitly included in policy design to exploit such features.

The objective of this paper is twofold. First, we provide an exploratory modelling framework to address the fact that rural ES benefits accrue to the rural sector, through rural tourism, and that this depends on interactions at a larger scale than the single farms. The model structure reproduces in an agent-based model (ABM) the conceptual framework developed by van Zanten et al. (2014). Second, we use the model to analyse whether, or to what extent, the feedbacks could lead farmers to voluntarily engage in landscape enhancement efforts. More specifically, we focus on the interactions between farmer decisions, landscape characteristics, rural tourism and the sequencing of AEP. We observe whether the landscape initially improved by the farmers’ participation in agri-environmental schemes triggers the development of a tourism sector that sufficiently rewards farmers so that feedback loops in the decisions lead them to voluntarily apply landscape enhancement measures. The ABM is applied to the structural conditions (the spatial distribution of farming productivity, the presence of a conservation area, the perception and behaviour of tourists concerning landscape elements) of a rural case study area (Po Delta, Emilia-Romagna, Italy).

Similar to Cong et al. (2014), we analyse those ES produced by and benefiting the agricultural sector; whereas Cong et al. focus on the coordination of farmers’ decisions, we concentrate on the evolution of the system and its relationship with public policy. Moreover, recreational services require a complex model set-up, which includes a group of users beyond the farmers whose characteristics are crucial for the valorisation of the service. As outlined by Randelli, Romei, and Tortora (2014), the evolution of a rural area from conventional agriculture to a basin of attraction for tourism is determined by interdependent factors at different scales. In our model, we consider a policy formulation (an external factor – global scale), the characteristics of the basin of tourists (meso scale) and the landscape elements, such as conventional farm productivity and landscape quality (local scale).

The paper is structured as follows: Section 2 describes the model structure and its application, including the data from the case study area and Section 3 presents the main results, which are then discussed in Section 4. Finally, in Section 5, we provide our conclusions.

2. Methods

2.1. Modelling approach

Increasingly, ABMs are used to investigate the relationships between rural economy, land-use change and agricultural policies (An 2012; Filatova et al. 2013). ABMs are especially designed for modelling feedback loops in agent decisions (Weisbuch and Boudjema 1999; Weisbuch 2000; Janssen et al. 2000; Manson 2006; Gotts and Polhill 2009; Huber et al. 2013; Polhill, Gimona, and Gotts 2013); however, in the analysis of rural policies, this potential is still largely unexploited (Le, Seidl, and Scholz 2012).

We build the ABM from the framework structure depicted in Figure 1. Our model is based on the conceptual framework developed by van Zanten et al. (2014), which considers the causal connections between policies, the management of agricultural landscapes and ES. Figure 1 shows a simplified version of the framework, in which it is possible to distinguish ES demand and supply as the determinants of ES values, and how these benefits re-enter in the rural sector (Targetti et al. 2014; Schaller et al. 2014).
The model is structured in subsequent periods of decisions and actions, where the aggregated outcomes of individual decisions taken in one period re-enter as information in the decisional process of the next period. In each period, farmers must decide between practising either conventional farming or green farming. The latter case refers to the application of generic landscape enhancement practices, which in reality can be thought of as organic farming, the conservation of hedgerows and buffer strips, or ecological focus areas. Green farming results in costs but it is rewarded by an AEP (link 1). The adoption of green farming increases the landscape quality of the relevant farm, as well as that of neighbouring farms (link 2). The consideration of the latter effect makes it possible to capture positive environmental externalities. Tourists are attracted by the landscape quality (link 5), and have the possibility of rewarding farms that attract them, thus contributing to their gross margins (links 6 and 7). Since green farming is costly, in the absence of policy payments the landscape would not be enhanced, and the tourism sector would not develop. Farmers observe: (a) whether neighbours decide to apply green farming and what is their resulting landscape quality; and (b) how the flow of tourists (and benefits) is related to landscape quality at the landscape scale. In the model structure we introduce feedback loops in farmers’ decisions: information on (a) and (b) shape expectations with regard to the private value of rural tourism, and thus affect decisions in the subsequent period.

The question is then whether by removing the policy incentives (link 1), the cycle represented by links 2, 3 and 4 on one side, and 5 and 6 on the other side, is such that link 7 creates sufficient incentives for farmers to maintain link 2 voluntarily. In this prospect, the indirect role of environmental policies, such as AEP, is to enable the coverage of the cost of the extensification of farming activities, while farmers learn the actual value of a novel activity such as rural tourism. The overall logic of the analysis is somewhat similar to the application of subsidies for the adoption of ‘experience goods’, which can be properly assessed only by experiencing them (e.g. Dupas 2014). In such a case, the financial support is functional to the initial adoption of the technology/goods; once it is adopted, agents learn the actual value of the product and the subsidy can be removed. The rationale is then applied to the adoption of a new production technology of sorts.

2.2. Model formulation

In the following, we provide the mathematical description of the model. At the beginning of each period of time \( t \), farms (set \( f \)) maximise the expected gross margins. The expected gross margins \( \bar{GM}_{tf} = f(\Pi_{tf}, \bar{S}_{tf}) \) are a function of the reward of the farming
activities ($\Pi_{t,f}$), and of the expected on-farm sales ($\bar{S}_{t,f}$). $\Pi_{t,f}$ is a function of the activity chosen, which is denoted by $G_{t,f}$, a binary variable indicating whether green farming ($G_{t,f} = 1$) or conventional farming ($G_{t,f} = 0$) is chosen: $\Pi_{t,f} = f(G_{t,f})$. For each farm, the expected on-farm sales depend on the expected landscape quality ($\bar{Q}_{t,f}$) and on the expected number of tourists ($\bar{C}_{t,f}$): $\bar{S}_{t,f} = f(\bar{Q}_{t,f}, \bar{C}_{t,f})$, $\bar{C}_{t,f}$, in turn, is a function of the expected landscape quality and of a parameter describing the tourists’ sensitiveness to landscape quality ($h_c$): $\bar{C}_{t,f} = f(\bar{Q}_{t,f}, h_c)$, whereas the expected landscape quality depends on both the activity chosen by farm and by the expected choices of the neighbouring farms ($\bar{Q}_{t,a\in A}$): $\bar{Q}_{t,f} = f(G_{t,f}, \bar{Q}_{t,a\in A})$. More details follow.

The benefits accruing from conventional farming are $\pi^c_{t,f}$, given by the productivity of the farm ($y_f$), and those from green farming are $\pi^g_{t,f}$, which depends on the cost of applying the environmental measure, defined in terms of the reduction in the productivity ($k$), and on the AEP (AEP$_t$). The on-farm sales depend on the expected amount of tourists that purchase local products for a value $s$:

$$\max_{GM_{t,f}} \Pi_{t,f} = \Pi_{t,f} + \bar{S}_{t,f}$$ (1)

$$\Pi_{t,f} = \pi^g_{t,f} + \pi^c_{t,f} = G_{t,f}[(1-k)y_f + \text{AEP}_t] + (1-G_{t,f})y_f$$ (2)

$$\bar{S}_{t,f} = s\bar{C}_{t,f}$$ (3)

Equation (2) is deterministically known. We now turn to how farmers build expectations with regard to on-farm sales, which depends on the expected landscape quality, and on the associated expected tourists.

The expected landscape quality for each farm depends on three components. First, the farm can augment its own landscape quality by applying green farming (by $q_f$). Second, it depends on the contribution of the neighbouring farms applying green farming ($q_{a\in A}$). The expected behaviour of the neighbouring farms is assumed to be the average over a period of time ($P$) of their decisions. Third, we give a landscape quality premium ($z_{f\in W}$) in case the farm is located within the conservation area (set of farms $W$):

$$\bar{Q}_{t,f} = q_f G_{t,f} + \frac{1}{P} \sum_{p=1}^{P} \sum_{a\in A} q_{a} G_{t-p,a} + z_{f\in W}$$ (4)

Observe that Equation (4) implies that even in the case that farm $f$ does not apply green farming ($G_{t,f} = 0$), can still have a positive landscape quality, due to its neighbours’ choices. Landscape quality can take values from 0 to 1, to be consistent with the tourist behavioural rule (see below).

Farmers build expectations on the number of tourists by observing the extent to which previous levels of tourists attracted by the landscape is related to the environmental quality of the farms. First, all of the farms in the landscape are classified into homogeneous classes of environmental quality ($v \in V$), where the population of the farms in each class in a given previous time span is $N_v$. Consider that the given Equation (4), the classification of a farm in a given class, holding expectations with regard to the neighbours choices as constant, depends on the activity chosen: $f \in v \mid G_{t,f}$. For these
classes, the average number of tourists over time is assessed:

$$C_{t,v} = \frac{1}{P} \frac{1}{N_v} \left( \sum_{p=1}^{P} \sum_{f \in v} C_{t-p,f} \right)$$

(5)

These estimates are associated with the different activities and they contribute to the ultimate assessment of their profitability of those:

$$C_{t,f} = C_{t,v} | f \in v$$

(6)

Finally, we describe the link between the landscape quality and tourists. After farms have chosen the activity, and consequently the actual landscape quality is determined, tourist can reward farmers if the landscape quality meets their level of satisfactions, according to:

$$Q_{t,f} \geq 1 - h_c$$

(7)

where, $$h_c \in [0,1] \forall c \in C$$ is an index that captures the sensitiveness towards landscape quality of each tourist ($c$) belonging to the total population of tourists ($C$), which is constant over time. Equation (7) means that, ceteris paribus, the higher the landscape quality, and the landscape sensitiveness, the higher the probability that the tourists will reward the farm. From another angle, a tourist with low landscape sensitiveness needs an exceptionally high landscape quality to reward farmers. Equation (7) implies that $C$ subdivides into two groups: $$\sum_f C_{t,f}$$ is the sum of the tourists found in the farms, for which then Equation (7) holds; and $B_t$ represents the tourists for which there is not any farm, for which Equation (7) holds: $C = \sum_f C_{t,f} + B_t$.

Farmers thus apply the environmental measure if the AEP plus the expected on-farm sales are higher than the costs of the application of the measure, plus the on-farm sales due to the tourists being attracted by the environmental quality generated by the surrounding farms.

At the end of each period of time, after the farms have decided upon their activity, the actual environmental quality of each farm is computed, and each tourist rewards one of the farms (if it exists) that meet the requirement of Equation (7). This ultimately makes it possible to compute the actual on-farm sales and thus the gross margins.

In this general set-up, we try to observe whether the feedback loops are such that farmers continue to apply environmental measures even without external support. To observe the effects of the dynamics of the system, we set a positive AEP in the first period ($t \leq 20$), whereas in the second period, the AEP is set to 0 ($20 < t < 50$). For further details regarding the sequence of actions, please see the ODD (Overview, Design concepts, and Details) description (see Appendix in the online supplement).

2.3. Data and specifications of simulations

We apply the model to the rural landscape of nine municipalities in the Province of Ferrara, in Emilia-Romagna, Italy. More than 50% of the case study area is under agricultural management, with 49% of the Utilised Agricultural Area (UAA) devoted to cereals (including rice), 17% to industrial crops and 17% to vegetables. Agriculture has traditionally played a significant role in the local economy, whereas the tourism sector
has been developing gradually in recent decades, attracted by the seaside, the Po Delta and the city of Ferrara.

A simplified version of the map of the area is employed in the model software (Figure 2). The map includes information on the location of the different municipalities, and of the conservation area (Po River Delta conservation area). The pixels (225) are the farms, and we assume that each of them represents a homogenous group of farms characterised by the same productivity. Data regarding farm productivity were collected from the Sixth Agriculture Census (2010), and data resolution is at the municipality level. Farm productivity is normalised by relativising values with respect to the highest productivity found in the study area ($y_p$); economic results are then consistently presented in terms of normalised gross margins). Since the data available do not provide information on the actual location of farms, productivity values are randomly assigned to the farms. We assume productivity is distributed according to a gamma distribution, the parameters of which are differentiated per municipality (Figure 2 shows the distribution of productivity across the landscape). The gamma distribution, contrary to more conventional forms, such as normal distribution, is chosen because it does not give negative values, which would be meaningless in the model set-up.

Tourists’ sensitiveness towards the landscape is obtained from a survey carried out from July to September 2013 in nine municipalities in the Po Delta area. The survey was distributed on three different occasions to people on the beach in the case study municipalities, distributed at the visitor centre of the Po Delta Park and in all agri-tourism structures located in the area. Three-hundred and eighty tourists filled out the questionnaire. Tourists assessed the influence of the local landscape elements on their choice of holiday location (e.g. water bodies, local fauna and flora, rural elements, etc.). A relative index (from 0 to 1) summarises the sensitiveness regarding the landscape, summing up the positive answers associated with the influence of landscape elements on the choice. The mean value of the index is 0.16 and the variance is 0.05. Since we want to explore the role of the size of the population of tourists, a gamma distribution with these features is introduced in the model to randomly assign the landscape sensitiveness parameter ($h_c$) to the population of tourists. Gamma distribution has been chosen in order to obtain positive values, which are then consistent with the index range.

Given the number of assumptions and the uncertainty attached to the real values of several parameters in the model, we parameterised the model to observe how model results depend on key parameters, which may yield insights into the role of different background factors and, at the same time, the robustness of the results.
contribute to the understanding of the relationships between input and output variables derived from a rather complex set of behavioural rules and from their interaction. The first parameterisation of the model accounts for different populations of tourists \((C)\), taking values from the tourist population in coastal areas adjacent to the case study area, in the municipalities of Comacchio \((C = 2,425)\), Ravenna \((C = 3,200)\) and Cervia \((C = 6,390)\) (Regione Emilia-Romagna Servizio Commercio, Turismo e Qualità Aree Turistiche 2012). Moreover, we vary the AEP from 0% to 12% of the highest gross margins found in the case study area; the range of values is in line with actual AEP, and was chosen after preliminary simulations showed that model results were independent on greater levels. Finally, we explore the full range of the mean landscape sensitiveness of the tourists (from 0 to 1).

Further assumptions concern landscape quality. We assume \(q_f = 0.2\), and \(q_a = 0.1\), implying that one-fifth of the landscape quality depends on the farmers’ choices, and the remaining score depends on the choices of their neighbours. Consistently, since the landscape quality can take values from 0 to 1 with 0.1 steps, we introduce 11 classes of environmental quality \((v = 0, 0.1, \ldots, 1)\) that reflect all of the potential levels of the variable.

Since two elements are randomly introduced in the model (farming productivity and tourist sensitiveness), we run the ABM 500 times and all of the results presented are the mean values across model runs.

All parameter values can be found in the Appendix in the online supplement (Table 1.1). The model is formulated in NetLogo (http://ccl.northwestern.edu/netlogo/).

3. Results

We first present the results of the model parameterised with the parameter levels that better resemble the levels actually found in the case study area: we hold the tourist landscape sensitiveness index to the level found in the case study area \((\bar{h}_c = 0.16)\), the AEP at 6% (which represents a middle value within the range selected), and vary the population of tourists \((C = 2,425; C = 3,200; C = 6,390)\). Sections 3.4 and 3.5 provide the results of a parameterisation on the landscape sensitiveness index (holding constant the AEP) and on the AEP level (holding constant \(\bar{h}_c = 0.16\) ), respectively.

3.1. Trends in green farm participation

Figure 3 shows how the number of green farms, in percentage terms, varies over time. As long as the AEP is positive \((t \leq 20)\), the percentage of green farms remains stable between 20% and 30%, depending on the tourist population. When the AEP drops to 0% \((t > 20)\), in all cases, the percentage of green farms is drastically reduced, but in the case of \(C = 6,390\), the tourists’ landscape quality demand is such that there is still around 10% of the farms that apply green farming. Hence, in such a case, the feedback loops are such that voluntary landscape enhancement efforts emerge as the result of interactions between: (1) the initial AEP that creates a landscape able to attract tourists; (2) a sufficient demand for landscape quality from tourists (thus only at a relatively high \(C\)); and (3) farmers’ expectations of tourist behaviour and of the aggregated decisions of other farmers.

3.2. Moran’s index and spatial distribution of green farms

The drop in the AEP also has an effect on the clusterisation of the green farming activities. Figure 4 depicts the trends over time of the Moran’s index \((I)\) measure of the
spatial autocorrelation of the choices of farming activities (green and conventional agriculture). $I$ is similar across the three tourist population parameterisations, ($I$ around 0.3), while the AEP is positive. The effect of the drop in the AEP is twofold. First, it causes a sharp increase in $I$ for any level of tourist population. Green farming is now only rewarded by tourist demand for landscape quality at the farm level, which in turn is

Figure 3. Evolution over time of the number of green farms (%) for different levels of tourist population and AEP. The vertical dotted line at $t = 20$ marks the passage from a positive AEP to a null AEP.

Figure 4. Moran’s index of farming activities (green and conventional farming). The vertical dotted line at $t = 20$ marks the passage from a positive AEP to a null AEP.
highly dependent on the presence of clusters of green farms. The isolated green farms tend to disappear with the drop in AEP. Second, it differentiates the clusterisation, showing that the higher the tourist population, the lower the I level. Increasing the population while maintaining constant the sensitiveness distribution implies that for any class of environmental quality, the expected consumers and thus the expected sales, are higher, so that there are relatively more incentives to maintain conventional farming and free-ride on the application of green farming by neighbours.

Figure 5 shows the spatial distribution of green (black coloured) and conventional farms (grey coloured) in the landscape, for selected periods of time (columns) and three levels of populations (rows).

3.3. Gross margins

The trends in the gross margins of green farms reflect the patterns we previously observed Figure 6. During the period of public support, gross margins remain relatively stable, at a level dependent on the tourist population. With the drop in AEP, gross margins in the case of $C = 2,425$, and $C = 3,200$ tend to decrease sharply, whereas in the case of $C = 6,390$, gross margins increase until they stabilise at around 100. The latter case is the
result of both the reduction in green farms, and the maintenance of relatively high landscape quality that still attracts tourists and results in them being concentrated on the remaining green farms. Conventional gross margins (not shown in the graph) remain stable over time at a sensibly lower level than the green farm gross margins.

3.4. Parameterisation of tourist sensitiveness index

Figure 7 represents the result of a sensitivity analysis on the mean value of the tourist sensitiveness index and its effect on the adoption of green farming. The lines represent

Figure 6. Mean of normalised gross margins of green farms.

Figure 7. Relationship between mean tourist landscape sensitiveness and the mean of green farms for $t > 30$. 
the mean number over the last 20 periods of the green farms. The figure shows that green farms increase with the mean value of the index up to 0.6, 0.7 and 0.8, respectively, for tourist populations of \( C = 6,390 \), \( C = 3,200 \) and \( C = 2,425 \). For greater values, the relationship becomes negative. This saturation affect is due to the specification of Equation (7), which models the rule that determines the relationship between landscape quality and tourist rewards. With relatively high tourist sensitiveness, a relatively lower level of landscape quality is needed to attract them; therefore, relatively more farms can rely on the landscape quality they “absorb” from their neighbours (Equation 4).

### 3.5. Parameterisation of AEP

We further analyse the interactions between AEPs and the characteristics of the basin of the tourist population for the establishment of green farms.

Figure 8 depicts the mean number of green farms in the last 20 periods (when the AEP is set at 0) as a function of the AEP level. The figure shows how the policy incentive levels interact with the population level in determining the number of green farms in the area. For \( C = 3,200 \) and \( C = 6,390 \), there appears to be a threshold in the AEP level that leads to the necessary critical mass of green farms that, in turn, enables self-sustained environmental protection. Further increases in the payment level are unnecessary since the landscape has already reached the saturation level, given the characteristics of the tourist population.

### 4. Discussion

In our case study, the use of ABM represents a useful experiment for the testing of model assumptions and relations in ‘laboratory’ conditions. In this sense, this experience confirms that ABM seems to be the proper tool to reproduce the complex interactions that work across those agents that affect and are affected by rural landscapes, as suggested by van Zanten *et al.* (2014). Indeed, the use of these analytical tools should likely be further explored in this direction. Moreover, in the experience carried out in this paper, the

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Figure 8. Relationship between AEP and the mean number of green farms (%) over the period for \( t > 30 \).
model highlights the implications of these interactions in determining choices, and emphasises the aggregated effects of these, including feedback loops, which were the main focus of our analysis.

Yet, the level of abstraction of the model requires a careful approach towards results, the interpretation of which should more realistically focus on a qualitative rather than a strictly quantitative assessment. The main limitation of ABM is generally the difficulty in validating the model. This is even more difficult in the current example, given the highly stylised nature of the model structure and the lack of real examples. The model seeks to numerically assess whether certain systems of agents and AEP could move towards a self-sustained cycle of actions. Limitations with respect to data make it necessary to greatly simplify behavioural rules and decision-making processes. Moreover, the features of the modelled AEP (its removal) and the time span (50 years) introduced in the model to observe changes in the systems are such that it is not possible to meaningfully compare model outcomes with actual or real patterns. However, when it was possible, mechanisms and parameter values reflected as much as possible actual observations (gross margins, interests on rural areas of actual tourists). Moreover, we introduced behavioural rules in the model after discussions with experts on local agriculture, as in the case of the assumption regarding cross-farm effects on the landscape quality variable. Local stakeholders anecdotally reported how small groups of adjacent farms spontaneously enhance the attractive potential of the area by coordinating themselves, including in their participation in policy schemes.

Keeping in mind the qualifications listed above, the results suggest that the interactions between farmer choices, agri-environmental measures and the characteristics of tourists lead, in certain conditions, to self-sustained landscape enhancement. If demand is sufficient, feedback loops in farmers’ decision-making foster ES evaluation and landscape enhancement efforts even in the absence of policy support. The AEP in this set-up works as a trigger that initiates a process that valorises the rural landscape. Moreover, the model depicts clear spatial patterns. The results indicate that the shifts from conventional to green agriculture (and the related benefits associated with tourism) occur in the area with the lowest agricultural productivity. The same pattern is suggested by Randelli, Romei, and Tortora (2014) for the evolution of rural Tuscany in which an initial weakness in terms of “standard” productivity becomes a strength in terms of environmental potential. At the same time, the lack of AEP leads to a sharp increase in the clusterisation of green farms, with areas characterised by high landscape quality and other areas left to conventional production.

The model structure presented here is affected by limitations on three main grounds. First, simplifications were necessary to treat the issue at stake in such model. Second, various data limitations, in particular in terms of details of farms information and tourist behaviour, did not allow for a fine-tuning of the model with a complete set of real-life information. Finally, the results are subject to a number of caveats that depend on the assumptions of the model. In order to elaborate in greater detail on this point, four main areas need to be discussed. First, the landscape quality of an individual farm is dependent on the choices of neighbouring farms, since in our set-up, individual choice accounts for only one-fifth of the maximum landscape quality of the farms. Different ratios affect the level of clusterisation of the green farms and their attractiveness potential for tourists. Second, we assume that farmers observe past choices for a limited period of time; a change in such an assumption would also change the evolution of the system (e.g. a longer period of observations would stabilise the choices). In addition, in practice, expectations about prices and payments may be more relevant than past observations, particularly in the
case of policy breaks. Moreover, farmers are only differentiated in terms of farm productivity, whereas the literature highlights their high heterogeneity and the number of varied factors affecting the adoption of agri-environmental measures, ranging from structural to personal variables (Barreiro-Hurlé, Espinosa-Goded, and Dupraz 2010; Defrancesco et al. 2008; Jongeneel, Polman, and Slangen 2008). Furthermore, the assumptions with respect to profit maximisation behaviours are certainly a limitation that, despite being well grounded in the literature, do not capture the full range of possible decision goals. Third, in the model, tourists’ attraction is dependent on the landscape quality of a single farm, while most likely tourist behaviour is affected by broader features inherent in the landscape. Finally, in the model, the behavioural rules of the population of tourists do not change over time; in particular, the landscape sensitiveness parameter is fixed throughout the entire set of model runs. As a result, learning/changes in landscape sensitiveness as a result of past behaviour are not taken into account by our simulations, while they are undoubtedly a relevant feature of real-life behaviour.

5. Conclusions

Despite its simplicity, the model captures some of the effects that could emerge from the complex relationships between the agents that shape rural landscapes. The ABM results theoretically depict how an AEP potentially creates an attractive landscape that triggers the development of rural tourism, which in turn valorises landscapes and creates an ES whose benefits return to the agricultural sector. In case the demand of these ES is sufficiently high, it might create enough incentives for some voluntarily landscape enhancement efforts.

The results seem to indicate three main implications for policy with regard to the conservation of natural elements in a rural landscape. First, in certain conditions, an approach that considers the potential existence of feedback loops from AEP could be explored and introduced in landscape planning. In cases where demand for ES is sufficiently strong, payments could be more explicitly considered as a temporary catalyst for the adoption of green technologies aimed at launching activities that will later be self-sustainable in the market.

Second, the coordination of farmers’ efforts seems to be crucial in order for the adoption of environmental measures and green technologies to be robust over time, and creates clusters of areas characterised by high landscape quality. This is in line with the increased attention being paid by the CAP agri-environmental measures to targeting and agri-environmental agreements, which are still, however, poorly applied in practice. This work emphasises the need to target areas with better potential for self-sustained exploitation of green conversion and the need to consider not only the ecological spill over potential from clustering, but also the potential economic synergies and spill overs.

Third, interactions with tourists (i.e. territorial marketing, environmental education, etc.) are a key issue for the valorisation of landscapes and related choices by farmers. The results of this paper highlight that this can be a substitute for, or a complement to, direct payments to farmers and hence tourist-targeted measures should be designed together and consistently with payments aimed at the adoption of green farm practices.

While this paper took a mainly explorative approach, further research could be carried out to address the analysis of the full range of effects that agriculture and environmental policies have on landscapes and on the ES they provide, so as to better tune the formulation of the policy itself. Moreover, the specific weaknesses highlighted in the previous section and, in particular, the need for a more realistic calibration of the model should be further investigated. More broadly, to ensure advances on the issue addressed
by this paper, further research is required to structurally analyse the factors that have led rural regions in the world (e.g. Tuscany, Champagne (Daniel et al. 2012)) to create strong regional brands, to determine whether these factors can be replicated, and whether these findings can be structurally introduced in the formulation of rural policies. At the same time, a key issue is the analysis of the potential for the formulation of institutional designs aimed at promoting a landscape-coordinated approach for the conservation of natural elements of landscapes and the enhancement of non-natural ones, in order to promote a better delivery of societal welfare as the result of landscape management.

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Supplemental data
Supplemental data for this article can be accessed here.

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