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Farmland abandonment, public goods and the CAP in a marginal area of Italy

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ABSTRACT

Land abandonment is affecting several areas of Europe, and the issue has since some years become a policy objective. The consequences of land abandonment are however difficult to assess as both agriculture and land abandonment are linked to socio-environmental public goods, but the relationship between public good provision and land use, as well as their societal value, are unclear and debated. Policy such as the Common Agricultural Policy affects land abandonment and public good provision in different ways, by providing income support and targeting the provision of environmental public goods.The objective of the paper is to assess the land use, public good levels and welfare deriving from agricultural production and from the provision of three selected PGs, in three alternative scenarios. In a reference scenario land use allocation is driven by the maximization of agricultural income; we then compare these results with a scenario where land use decisions maximize the societal welfare, hence including the value generated by the three, and with a scenario that simulates Measure 13 of the Rural Development Programme (payment for Areas Facing natural or other specific Constraints). The method used is a land allocation model calibrated for the hill and mountain area of the province of Bologna (Italy), in which the public goods societal values are the results of a choice experiments taken in the Emilia-Romagna region. The main results is that the societal optimum is reached through a substantial change in land allocation (e.g. a strong reduction in land abandonment and an increase in forest areas) and in the composition of the welfare (from private agricultural income toward public good benefits) with respect to the private optimum. Moreover, generic income support reduces land abandonment but also total welfare as it has negative effects through the reduction of carbon sequestration and increase in soil erosion. More targeted policies, that more explicitly connect support to public good provision, have better welfare effects.

1. Introduction

The abandonment of agricultural land, defined as "the cessation of agricultural activities on a given surface of land and not taken by another activity (such as urbanisation or afforestation)" (Pointereau et al., 2008), is a longstanding and on-going process (Ramankutty and Foley, 1999), especially affecting developed countries. In Europe, an estimated 120 M ha of cropland has been abandoned since 1990 (Levers et al., 2018); however, large spatial variations characterize the extent of the phenomenon as e.g. in Italy and Spain around 10-14% of agricultural land has been abandoned and only 1% in e.g. Belgium or Denmark (Hart et al., 2012). Such a process is not expected to be reversed in the future as 11% of the European Utilized Agricultural Area (UAA) is estimated to be under risk of abandonment in the period 2015-2030 (Perpina Castillo et al., 2018). Land abandonment is a complex phenomenon that is characterized by a great heterogeneity in the local magnitude and in its causes (Hatna and Bakker, 2011). Different driving forces behind it have been identified: climate (Levers et al., 2018), the regional context (Rickebusch et al., 2007), the accessibility of the area (Corbelle-Rico and Crecente-Maseda, 2014), the low productivity of agriculture (Sluiter and de Jong, 2007).

The socio-environmental consequences of land abandonment are controversial and ambiguous (Queiroz et al., 2014), as they depend on: the location of the phenomenon; the agro-ecosystem context; the type of environmental aspects considered; and the time span of the analysis. Indeed, both agriculture and land abandonment are linked to a wide range of Public Goods (PGs) (and bads) and assessing the trade-offs among them is a complex task (van der Zanden et al., 2017).

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Agriculture, in addition to providing food and fibres, is strictly connected to the preservation of cultural heritage (Daugstad et al., 2006) and landscapes (Plieninger et al., 2014). Moreover, a large number of European species have adapted to - and are dependent on - agricultural landscapes, hence making their reduction a threat to biodiversity protection (Zakkak et al., 2015). In particular in Southern Europe, land abandonment is linked to increases in soil erosion and fire risks (García-Ruiz and Lana-Renault, 2011). On the other hand, land abandonment increases soil carbon sequestration, thus contributing to the mitigation of climate change (Novara et al., 2017); furthermore, the actual impact on both biodiversity and soil erosion could depend on post-agricultural management, and, in the long-run, land abandonment could lead to higher biodiversity (Navarro and Pereira, 2012) and lower soil erosion.

The problem of understanding these trade-offs is further exacerbated if we move from technical relationships to economic trade-offs, as most of the PGs under consideration are not priced by the market, and their evaluation is either implicit in the political/policy processes or relies on environmental valuation methods, such as Choice Experiments (CE). These methods are applied in few cases of policy decision-making and are at times questioned due to their approximations and dependency on the information and experience of respondents. Their results must be carefully employed as, for example, they are highly affected by survey design (Rakotonarivo et al., 2016), by the complexity of the problem presented (Hoyos, 2010), and by space dimension (Glenk et al., 2019).

In recent years, the problem of land abandonment and the related PG trade-offs has also entered the policy debate and is increasingly affecting policy objectives and design (Renwick et al., 2013). One aspect concerns the role of agricultural policies due to the effect on farmers' incentives to cultivate land (Raggi et al., 2013). However, in turn, complex policies, such as the Common Agricultural Policy (CAP) affect the phenomena in different ways. In particular, CAP first pillar payments and Measure 13 payments for Areas Facing natural or other specific Constraints (AFC), provide generic support to agriculture with unclear effects on the provision of PGs, as their main impacts are indirect and occur as a result of income support and some incentives to cultivate more land. On the other hand, second pillar measures may be directed explicitly to environmentally beneficial practices, such as agri-environmental measures (M10), organic farming (M11) or forestry (M8). The next reform of the CAP for the period 2021-2027 will offer an opportunity to address some of these issues, not only with new voluntary ecological measures in the First Pillar of the CAP, but also through more comprehensive planning processes covering all measures.

For policy makers, however, taking informed decisions on the issue remains difficult given the complexity of the problem. In principle, simulation models can be helpful to support evidence-based policies, but few models exist that analyse the problem (Renwick et al., 2013). For example, few partial or general equilibrium models take into account land abandonment (van Meijl et al., 2006), and it was only relatively recently that CAPRI was equipped to do so (Renwick et al., 2013). Some analyses assess land abandonment under different policy and economic environments, but the resulting PG levels are computed through environmental indicators and not in terms of societal welfare impact (Renwick et al., 2013; van der Zanden et al., 2017). The inclusion of feedbacks between the socio and ecological systems in the assessment of land abandonment is even more rare (Figueiredo and Pereira, 2011). None of the models assume a normative point-of view, where the *optimal* degree of land abandonment and cultivated land, considering the contribution of their related PGs levels on the societal welfare, is evaluated.

The objective of the paper is to assess the land use, PG levels and welfare deriving from agricultural production and from the provision of three selected PGs, in three alternative scenarios. In a reference scenario land use allocation is driven by the maximization of agricultural income; we then compare these results with a scenario where land use decisions maximize the societal welfare, hence including the value generated by the three PGs, and with a scenario that simulates the AFC (Measure 13) RDP scheme.

The methodology used is a mathematical programming model the main decision variable of which is the allocation of land among different uses (agriculture, land abandonment and forests). The model is calibrated for the hill and mountain area of the province of Bologna (Italy). The model simulates the impact of different scenarios on three selected PGs: carbon sequestration, soil erosion and rural vitality. Simulations are run under alternative market and policy scenarios. This makes it possible to highlight the economic trade-offs among the three agri-environmental PGs generated by different patterns of land allocation.

The main novelty of the paper is that we assess the trade-offs between agriculture and land abandonment with respect to three PGs, taking into account the societal Willingness To Pay (WTP) for the unpriced PG. Indeed, in most of the analyses that address the problem of land abandonment, socio-environmental indicators shedding light on the economic value of the environmental change are considered (Renwick et al., 2013; van der Zanden et al., 2017). Moreover, in most of the analyses that address the problem of land abandonment, land use decisions are driven by the maximization of private agricultural income (Renwick et al., 2013; van der Zanden et al., 2017), and socio-environmental indicators are simply a by-product output of such maximization. While this realistically imitates the processes that affect land use decisions, such an approach can only partially inform policy makers on the goals of public interventions. By introducing the WTP into the mathematical programming model we provide an estimate, albeit rough, of the potential societal optimal land use allocation among abandonment, forest and agricultural activities. The use of WTP for unpriced goods in simulation models is limited, to the best of our knowledge, to a few examples, that do not take into account land abandonment (Conrad and Yates, 2018; Uthes and Matzdorf, 2016).

The remainder of the paper is organised as follows. Section 2.1 provides a description of the methodology and Section 2.2 of the case study area. The results are illustrated in Section 3, while a discussion is provided in Section 4. Section 5 concludes and provides policy recommendations.

2. Method

2.1. Model description

There is extensive literature on mathematical models aimed at simulating the policy impact on environmental PGs indicators. This has been largely applied to the CAP. A stream of this literature uses farm-level models (Bartolini et al., 2007; Louhichi et al., 2017; Reidsma et al., 2018; Solazzo et al., 2016; Viaggi et al., 2013). Another stream uses regional partial equilibrium, agent-based or other territorial-based models (Bertoni et al., 2018; Blanke et al., 2017; Espinosa et al., 2016). In all of these cases, the environmental PGs are measured based on physical indicators. Some of these models use multi-criteria analysis to provide an optimization based on a combination of different public objectives (Tziolas et al., 2017). To some extent this implies attributing values to environmental performance. However, the direct use of the monetary values of PGs addressed that arise from from locally-based estimations is rarely used in studies modelling trade-offs among different PGs (Gómez-Limón et al., 2019).

We formulate a regional mathematical programming model in which the main decision variable is land allocation. We run different scenarios by changing the objective function. In the scenario Sce_Welfare the model maximizes the welfare of the area, taking into account both the private agricultural income, and the societal values of the PG taken into account. The main characteristics of the model are the following. First, the total welfare of the area is given by the sum of the agricultural income and of the utility derived from the three PGs. Second, the private component of the welfare, i.e. agricultural income, is differentiated by crop and slope of the land. Following the usual assumption, the costs of agricultural production marginally increase in the area allocated to crops, entailing marginally decreased productivity (Heckelei and Wolff, 2003). In other words, any additional unit of land allocated to a given crop entails a lower increase in profit than the previous one. Third, a relevant feature of our setting is the inclusion of a cost specific to the change in land allocation, namely from the current land use categories of land abandonment and forest toward the agriculturally productive land use activities (Peerlings and Polman, 2008).

Such a model is described by the following equations:

$$\max \Pi^{agr} + U^{pg} \tag{1}$$

s.t.

$$\Pi^{agr} = \sum_{i,l,s} a_{i,s} x_{i,l,s} - \sum_{i,s} b_{i,s} x_{i,l,s} \left(\sum_{l} x_{i,l,s} \right)^2 - \sum_{i,l,s} c_{i,l} x_{i,l,s} \tag{2}$$

$$U^{pg} = \sum_{g} u_g \left(\sum_{l,s} e_{g,i,s} x_{i,l,s} \right) \tag{3}$$

$$\sum_{i} x_{i,l,s} \leq \bar{X}_{l,s} \tag{4}$$

Where Π^{agr} indicates the income from agricultural production; U^{pg} denotes the utility derived from the three PGs g (rural vitality, soil erosion and carbon sequestration). $x_{i,l,s}$ is the decision variable, i.e. the allocation of land among land use activities i, in different parcels characterised by categories of current land use categories l (agricultural land, abandoned land, forest), and slope classes s. With the term *land use categories* we refer to the major categories of land uses that are currently in the area. The model can thus, in principle, allocate agricultural activities in land that are now characterised by land abandonment. The modelling of such a characteristic of the land parcels is introduced to associate costs related to land conversion, from one land use category to another one. The description of the parameters follows. $a_{i,s}$, is the agricultural revenues function parameters; $b_{i,s}$ is the cost parameter, differentiated per crop and land use activities; $c_{i,l}$ represents the cost of land use conversion, differentiated by land use activity and current land use category; u_g is the society WTP per unit of any given PG considered; $e_{g,i,s}$ is the parameter of the production function of the PG, differentiated by slope classes and land use activitie$\bar{X}_{l,s}$is the total available land use per slope classes and current land use categories.

In a second scenario, Sce_AgrRent, we assume that land allocation is only driven by the agricultural income. Such a scenario is then described by:

$$\max \Pi^{agr} \tag{5}$$

s.t. Equations (2) and (4).

In a third scenario we assess the impact of the AFC payment. To model such a scenario we keep the objective function described by equation (5), and we add a policy term p in equation (2) that incentivizes agricultural activities. Equation (2) then becomes:

$$\Pi^{agr} = p \sum_{i,l,s} x_{i,l,s} + \sum_{i,l,s} a_{i,s} x_{i,l,s} - \sum_{i,s} b_{i,s} x_{i,l,s} \left(\sum_{l} x_{i,l,s} \right)^2 - \sum_{i,l,s} c_{i,l} x_{i,l,s} \tag{6}$$

We assume that all land in the area is equally eligible for the AFC payment.

In a further set of scenarios, we assess all the possible combinations of PG values that can be considered in the objective functions. These scenarios are described by Equations (1) to (4), and are listed in Table 1.

We code the mathematical programming model in GAMS - Development Corporation. General Algebraic Modeling System (GAMS) Release 24.2.1. Washington, DC, USA, 2013.

Model implementation to case study area

Table 1
Objective function scenarios and PG considered in each scenario

Scenarios	Soil erosion	Carbon sequestration	Rural vitality
Sce_Welfare	x	X	x
Sce_AgrRent			
Sce_AFC			
Sce_eros	x		
Sce_carb		X	
Sce_ruvi			x
Sce_eros_carb	x	X	
Sce_eros_ruvi	x		x
Sce_carb_ruvi		X	x

Case study region and calibration of the agricultural activities model

The case study region is the hilly and mountain area of the Province of Bologna (now called "area metropolitana"). The size of the entire province is 3,703 km^2 of which 36% (1330 km^2) is hilly and 21% (790 km^2) is mountain areas. One millions (1 M) inhabitants live in the province, with an average density of 272,71 inhabitants/km^2. Agriculture is mainly characterised by arable crops (in 2017, 14775 ha), even though there is significant cultivation of permanent crops (in 2017, 4759 ha).[1] The area has experienced a substantial reduction in agricultural activities. In the period 2000-2010, the number of farms decreased by 45% (from 7948 to 4409), and the UAA by 22% (from 73745 ha to 57338).[2]

In terms of policy, the area has extensively benefited from the 2013-2020 RDP. The most important measure is 13.1.01, providing a payment for farms located in AFC, which distributed more than €6 M of funds to around 4,000 farms in the period 2015-2017 (Guglielmini, 2019; elaborations on data from the Agenzia Regionale per le Erogazioni in Agricoltura). The payment is set at €125 $ha^{-1}y^{-1}$ (Emilia-Romagna, 2018). Agri-environmental measures (support to organic production and Agro-climate-environmental payments) are important too, providing aggregate funds of almost 8M€ to around 200 farms in the period 2015-2017.

The process of PG selection, model building and analysis followed a participatory approach that was accompanied by a local network of stakeholders, involved through four workshops.[3] Stakeholders included different professions and came from a variety of institutions, including agricultural advisors, the regional administration, land reclamation boards, farmers' organisations, researchers and food industry. Around 4 to 10 stakeholders participated in each workshop. Over the course of the first three workshops the PGs most relevant for the area were identified and defined; the three most important for the modelling exercise were subsequently selected, which are: 1) soil erosion, 2) rural vitality and, 3) carbon sequestration. The 4th workshop was devoted to the presentation and discussion of the modelling results as well as of the policy implications.

For the calibration of the agricultural sector part of the model, we consider the following productive land use activities (i): grape, fruit, arable, forestry, and grassland; and the following non-productive ones (i): abandoned land and forest.[4] Land uses were derived from the CORINE land cover database for the year 2011. The income for the productive land uses is differentiated by crop and land slope classes (see

[1] Data from the statistical service of the Emilia-Romagna regional administration: http://statistica.regione.emilia-romagna.it/servizi-online/statistica-self-service/agricoltura/agricoltura-e-zootecnia.

[2] Data from the statistical service of the Emilia-Romagna regional administration: http://statistica.regione.emilia-romagna.it/servizi-online/statistica-self-service/agricoltura

[3] The four workshops were held respectively on February 22nd, 2016; June 20th, 2016; March 16th, April 12th; 2017.

[4] The distinction between forestry and forest is that the former has a commercial use, whereas the latter has no commercial use.

Table 2
Values (€) per land use activities and slope classes of parameter $a_{i,s}$ - revenues

		Slope classes (*s*)										
		< 5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	> 50
Land use activities (*i*)	**grape**	2614	2397	1832	1402	1086	855	635	424	224	136	33
	fruit	2636	1918	1421	1113	893	755	613	466	337	187	51
	arable	1019	957	862	762	654	535	399	268	156	79	17
	forestry	422	388	361	337	370	417	427	336	214	176	46
	grassland	355	395	399	381	345	291	226	156	99	49	11
	abandoned	0	0	0	0	0	0	0	0	0	0	0
	forest	0	0	0	0	0	0	0	0	0	0	0

Table 3
Values (€) per land use activities and slope classes of parameter $b_{,s}$ - costs

		Slope classes (*s*)										
		< 5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	> 50
Land use activities (*i*)	**grape**	8.14	3.22	1.80	1.30	1.19	1.40	1.87	2.61	3.75	5.38	2.00
	fruit	4.88	1.93	1.08	0.78	0.71	0.84	1.12	1.56	2.25	3.23	1.20
	arable	0.35	0.14	0.08	0.06	0.05	0.06	0.08	0.11	0.16	0.23	0.09
	forestry	22.21	8.78	4.91	3.55	3.25	3.83	5.09	7.11	10.24	14.68	5.45
	grassland	0.35	0.14	0.08	0.06	0.05	0.06	0.08	0.11	0.16	0.23	0.08
	abandoned	0	0	0	0	0	0	0	0	0	0	0
	forest	0	0	0	0	0	0	0	0	0	0	0

Equation (2)). "Income", given the land allocation problem at hand, has been approximated through land rent. The use of land rent as a plausible proxy for the decision-making criterion is consistent with the fact that land allocation is the main decision-making variable at hand. It corresponds to maximising the total income of a farm with extra-profit equal to zero and paying at market price all other factors. Both parameters $a_{i,s}$ and $b_{i,s}$ for land rent have been estimated using the locally available estimates of land values by type of land use activity and sub area in the territory considered. These are called Valori Agricoli Medi (VAM - Agricultural Average Values -) and are updated year by year by a local Commission, based on land market trends. The average rent per hectare of each type of crop has been derived by multiplying the related value by a coefficient equal to 3%. The parameters $a_{i,s}$ (Table 2) and $b_{i,s}$ (Table 3) have been further estimated assuming that the income value derived from the VAM represents the average rent of that land use type, while the marginal value is zero. Hence, parameter $a_{i,s}$ represents the intercept of the marginal rent function, while $b_{i,s}$ represents the coefficient of the quadratic term in the rent function (coefficient attached to marginal reduction of rentability by increasing land allocated to the same crop). The calibration of the model assumes a Ricardian framework coupled with the observation that UAA is lower than Total Agricultural Area (the case study region is characterised by land abandonment) which implies that the land allocation observed entails a marginal productivity of land that is null: $a_{i,s} - b_{i,s}x_{i,s}^{obs}$. The calibration results are also used to classify land into the three current land use activities (set l). We assume that changes in the land use categories are costly. For example, the conversion of abandoned land to agriculture requires operations to prepare the land for cultivation. This information is used to account for the potential costs that a change in fundamental land uses involves. Such a parameter, $c_{i,l}$, represents a linear annualization of the costs related to the required operations to prepare the conversion of land from e.g. abandonment to agricultural uses (Table 4).

Table 4
Cost (€/ha) of land conversion per current land use categories and and land use activities

		Current land use categories (*l*)		
		Agricultural land	Abandoned land	Forest land
Land use activities (*i*)	**grape**	0	70	500
	fruit	0	70	500
	arable	0	70	500
	forestry	0	70	500
	grassland	0	70	500
	abandoned	0	70	500
	forest	300	150	0

Public goods: societal Willingness To Pay and technical relationship between provision and land use

In the model we introduce the societal value, i.e. the society WTP of the three PGs (parameter u_g). The WTPs are the results of a Discrete Choice Experiment (DCE) that was part of an on-line survey that was carried out by a professional agency in December 2016 on a panel of respondents who are representative of the Emilia-Romagna region population. A Logit model is applied to assess the valuation of the WTP for the three PGs considered, with a final number of 1007 of valid respondents. We refer to Appendix A in order to further illustrate the DCE that has been carried out.

Table 5 shows the most relevant socio-demographic characteristics observed on the respondents' sample. Among the variables that identify the characteristics of the respondents that are more unique in the estimation of the WTP, it is worth noting that almost 18% and 20% of respondents in the "area metropolitana" and the other Provinces of Emilia-Romagna, respectively, are residents in the hilly and mountain areas. The WTPs resulting from the Logit model are then:

- for soil erosion: €16.54 per family, per year, per millions of tonnes of non-eroded soil;
- for carbon sequestration: €92.09 per family, per year, per millions of tonnes of sequestrated CO_2;
- for rural vitality: €0.47 per family per year per a single farm that does not exit from the market.

Eleven (11%) per cent of respondents have always selected the status quo – they choose not to pay for the provision of the PGs under consideration. The reasons for this behaviour in the DCE exercise should be further investigated in order to attribute them to one of the

Table 5
Descriptive statistics of the respondents' sample.

Sample characteristics	Values
Samples dimension	1,007
Share of respondents for the province (%)	
Bologna	28.80
Ferrara	6.75
Forli'-Cesena	7.15
Modena	13.51
Piacenza	5.86
Parma	9.43
Ravenna	10.13
Reggio Emilia	9.33
Rimini	9.04
Age (min-median-max)	41.77 (18-41-99)
Male (%)	50.74
Average household size	2.91
Average number of minor	0.69
Average number of elderly	0.30
Households with at least one farmer member (%)	12.41
Share of unemployed (%)	35.25
Households with at least one member with university degree (%)	38.04
Level of education (%)	
1 – primary school	0.60
2 – secondary school	9.73
3 – higher school	52.02
4 – BA degree	14.02
5 – MA degree	22.54
6 – other postgraduate	1.09
Monthly household income (min-median-max)**	2,808 (1,000-3,000-8,000)
Annual payment for Land Reclamation Authority**	129.11 (0-30-10,000)
Annual payment for food basket**	2,706 (10-2,000-10,000)
Residence in hilly and mountain areas (%)	19.36

two main causes of it (either the intention to not pay for the PG under analysis or the intention to not express a preference in the card scheme of the DCE itself). In absence of a more detailed interpretation, in this paper we assume that this 11% of the respondents in the sample would not pay for the PG provision. Demographic data reports that there are 2,001,717 families in Emilia-Romagna. Accounting for those respondents who always choose the status quo, families in Emilia-Romagna that are supposedly willing to pay for agricultural PGs are 1,781,528. Considering these values, WTPs are introduced in the model in the following way. For soil erosion, we consider €16.54 • 1,781,528 families and we divide by 1,000,000 to reach a value of €29.5/tonne. We introduce the WTP as a societal cost for the amount of erosion generated by agriculture. For carbon sequestration, we apply the same procedure to reach a value of €164.0/ton. The WTP is introduced as the societal benefit linked to the provision of carbon sequestration from the different land uses. For rural vitality, the same procedures lead to an estimate of €887,318/per farm that keeps running. This figure, given the characteristic of the mathematical programming model we are using, is to be reported in terms of land allocation. Considering the location of the UAA across altitude classes, and considering 101,646 + 250,147 = 351,793 ha of hilly and mountain areas, we compute 887,318 / 351,793 = €2.38/ha in order to have a figure for the WTP that can be attributed to the land. This assumes a direct link between farm and UAA.

The technical relationship between land use and PG production are the results of the model INVEST for both carbon sequestration and soil erosion (Tallis et al., 2011). Carbon sequestration is assumed to be only produced by non-productive land uses. Land abandoned sequesters 0.95 t/ha of carbon, while forests sequester 2.30 t/ha of carbon. The production of soil erosion is differentiated per crop and slope of the land according to Table 6. The table shows the complexity of the issue at stake. While forest unambiguously provides the lowest soil erosion levels, some agricultural activities (fruit production) are more damaging than abandoned land, whereas the allocation of abandoned land to arable would reduce erosion. Rural vitality is assumed to be simply a linear function of the agricultural land.

3. Results

3.1. Comparison of agricultural rent, AFC and optimal welfare results

Table 7 presents the economic results in the whole set of scenarios. The scenario Sce_AgrRent is used as a reference benchmark for the analysis of the other scenarios. Note that even though the land allocation is only driven by the maximization of the agricultural rents, a substantial share of the welfare (45%) is due to the production of the PGs considered. The Sce_welfare scenario, where land allocation is the one that maximizes the sum of both the private rent and the whole set of benefits from the PG is, by definition, the one with the highest total welfare. With respect to Sce_AgrRent, the optimal welfare entails an increase in the societal value of the PG (+36%) and a parallel reduction in the private agricultural rent (-13%). Altogether, however, the scenario Sce_Welfare entails an increase in the welfare of only 4% with respect to the scenario AgrRent, indicating that the current situation is not far, in economic terms, from the *optimum*, given the rather strong assumptions of the model. In the AFC scenario, both the private rents, net to the AFC payments, and the societal values of PG are reduced with respect to the Sce_AgrRent, as the payment pushes agricultural land above the privately optimal level. Further, it is worth noting that the Sce_Ruvi scenario does not yield a result different from the Sce_AgrRent, hinting at the fact that the WTP for rural vitality is not high enough to affect land allocation.

To further interpret the results, Table 8 shows the land use for the different scenarios. Despite the fact that changes in total welfare are minimal, the optimal land allocation is substantially different from the one in the Sce_AgrRent scenario. The Sce_welfare is scenario characterised by a noteworthy reduction in agricultural land (-18%), but an even sharper reduction in abandoned land (-87%), and by a parallel expansion of forest. The AFC scheme also drives a decrease in abandoned lands (-54%); this decrease is covered by the expansion of agriculture (+6%), and not by forests.

The additional scenarios are useful to disentangle the effect of the PG values on the land use allocations. First, as mentioned earlier, the WTP for rural vitality is not high enough to cover the conversion costs, and land allocation is locked-in into the one driven by the agricultural rent (the same in the Sce_AgrRent scenario). Second, the societal cost of soil erosion, in the Sce_Eros scenario, results in the enlargement of agricultural production on the abandoned land, as some of the agricultural activities, such as grassland and forestry, are better in terms of erosion than abandoned land. Third, carbon sequestration alone would, however, have the opposite result, since it would increase both forest and land abandonment at the expense of agricultural production.

In Table 9 we list the results with respect to the levels of PG provision in the different scenarios. Such levels mirror the previous findings. The scenario Sce_Welfare increases carbon sequestration and reduces soil erosion, but at the same time reduces the rural vitality, with respect to the Sce_AgrRent. Furthermore it should be noted that the reduction in soil erosion has to some extent synergies with both carbon sequestration and rural vitality. The Sce_Carb scenario, that maximizes the total welfare by only taking into account the value of carbon sequestration and agricultural rent, entails an obvious increase in carbon sequestration, but also a reduction in soil erosion, with respect to the Sce_AgrRent. A similar pattern can be observed in the Sce_Eros scenario, where the PG value of soil erosion, coupled with the agricultural rents, drives not only a reduction in erosion, but also an increase in rural vitality.

Table 6
Parameter of erosion (t/ha) per crop and slope classes

Land use activities	Slope classes										
	< 5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	> 50
grape	0.68	2.40	5.13	8.31	10.74	13.03	16.24	18.40	19.23	23.08	27.95
fruit	0.46	1.98	4.54	7.44	10.32	12.94	14.97	16.58	18.96	21.22	23.88
arable	0.28	0.90	1.75	2.79	3.85	5.25	7.19	8.38	9.70	13.96	13.59
forestry	0.11	0.40	0.71	1.15	1.71	2.22	2.45	2.61	2.99	2.92	5.86
grassland	0.08	0.33	0.77	1.26	1.66	2.03	2.23	2.47	2.85	2.88	3.33
abandoned	0.27	1.29	3.07	5.17	6.82	7.75	8.41	8.65	8.85	9.93	11.28
forest	0.01	0.04	0.10	0.16	0.22	0.26	0.30	0.34	0.40	0.45	0.64

Table 7
Private rent, societal value of PGs provision and welfare in the different scenarios

Scenarios	private rent (€)	societal value of PG (€)	welfare (€)
Sce_AgrRent	36,811,170	30,296,370	67,107,540
Sce_Welfare	31,858,250	38,085,510	69,943,770
Sce_AFC	36,493,685	30,043,903	66,537,589
Sce_Erosion	36,045,960	32,389,740	68,435,700
Sce_Carb	35,171,350	33,502,970	68,674,320
Sce_Ruvi	36,811,170	30,296,370	67,107,540
Sce_Eros_Carb	31,800,540	38,143,070	69,943,610
Sce_Eros_Ruvi	36,044,000	32,388,130	68,432,130
Sce_Carb_Ruvi	35,192,640	33,492,230	68,684,870

3.2. Sensitivity analysis

3.2.1. Sensitivity on agricultural price levels

Fig. 1 shows the main results of the sensitivity analysis on the price levels. First, it is worth noting (Fig. 1A) that an increase in the price levels tends to reduce the differences in the land allocation between, on one hand, the optimal one represented in the Sce_Welfare scenario and, on the other hand, the scenarios driven by agricultural rent, Sce_AgrRent and Sce_AFC. Price increases entail a relatively higher priority for agriculture with respect to the societal values of the PG, and thus a convergence among the scenarios, as the optimal societal welfare is closer and closer to the private agricultural rent.

Furthermore, note that increases with respect to current price levels entail slower changes in land allocation if compared with a decrease in the same levels. Conversion costs slow down the expansion of agricultural land into abandoned areas, and further enlargement would be in forest areas for which the conversion would face much higher costs. Interpreting from a different angle, land abandonment is a process that can be easily and rapidly ignited, but reversing it would require greater monetary efforts. This also hints at the importance of carefully assessing the trade-offs between land abandonment and agriculture, including the related PG trade-offs, and to cautiously weigh policies in marginal areas.

Fig. 1B shows how the changes in land allocation result in PG provision levels. The results further highlight how the relative values of soil erosion and, especially, carbon sequestration are the main drivers of the divergence in the optimal land allocation and the one driven by the agricultural rent. Carbon sequestration decreases in all the scenarios, as price levels increase. Soil erosion exhibits the most peculiar pattern, as its level, despite being much lower, increases in the Sce_Welfare, but decreases in both Sce_AgrRent and the Sce_AFC. An unintended consequence of the expansion of agricultural land occurs through crops, which are less prone to erosion than abandoned land.

3.2.2. Sensitivity on public goods Willingness To Pay levels

In Fig. 2 we depict the main results of the sensitivity analysis on the WTP level of carbon sequestration. The sensitivity analysis is carried out by multiplying the original WTP by a coefficient of between 0.1 and 2, i.e. at one the WTP is the original one. Not surprisingly, increases in the WTP cause a large increase in forested areas, which expand mostly in previously agricultural ones (Fig. 2A). Abandonment also decreases and at an increase of 40% in the current WTP levels, it is completely substituted by forest. It should also be noted that changes in land allocation only occur when the WTP level is around 50% of the estimated one, as the conversion cost toward forests and its opportunity costs (agricultural rent) are also too high with respect to the WTP levels to affect land allocation., The resulting PG levels are depicted in Fig. 2B. The patterns mirror the one described for land allocation. Rural vitality decreases as land allocation to agriculture is also reduced. The graph also shows the strong synergies between carbon sequestration and erosion. Indeed, forests also greatly reduce soil erosion, and while the results are mostly driven by the value of carbon sequestration, soil erosion is also reduced.

The results on the soil erosion WTP are depicted in Fig. 3. With respect to changes in the carbon sequestration WTP, variations in the soil erosion WTP have a lower effect on land allocation (Fig. 3A). While doubling the carbon sequestration, actual WTP causes a reduction of 40% of agricultural land, and doubling soil erosion WTP entails a reduction of 10% of the land allocated to agriculture. At low levels an increase in the soil erosion WTP actually entails an increase in agricultural land. Changes in PG levels and synergies are also less marked than in the carbon sequestration WTP sensitivity analysis. Doubling the soil erosion WTP from the current level entails an increase in carbon sequestration of 4%, whereas doubling carbon sequestration WTP causes a reduction in soil erosion of 32%.

For rural vitality, changes are even less pronounced than in the previous case (Fig. 4). Much greater increases in its WTP are necessary to have a substantial effect on land allocation, and hence on PG levels.

Table 8
Land use categories and agricultural activities in the different scenarios (ha)

Land use	Sce_AgrRent	Sce_Welfare	Sce_AFC	Sce_eros	Sce_ruvi	Sce_carb	Sce_Eros_Carb	Sce_Eros_ruvi	Sce_Carb_Ruvi
abandonded land	6,126	767	2,847	2,277	6,126	9,337	780	2,255	9,201
forest land	97,011	112,866	97,011	100,717	97,011	103,137	112,983	100,717	103,137
agricultural land	55,802	45,306	59,081	55,944	55,802	46,465	45,176	55,967	46,601
grape	2,642	2,180	2,708	2,372	2,642	2,450	2,178	2,372	2,452
permanent	3,760	2,990	3,869	3,332	3,760	3,431	2,985	3,332	3,435
arable	32,606	26,896	34,137	31,601	32,606	28,209	26,837	31,611	28,273
forestry	313	254	338	338	313	242	253	338	243
grassland	16,480	12,985	18,029	18,302	16,480	12,134	12,922	18,313	12,197

Table 9
Level of PG provision in the different scenarios

PG	Sce_AgrRent	Sce_Welfare	Sce_AFC	Sce_carb	Sce_carb_ruvi	Sce_eros	Sce_eros_carb	Sce_eros_ruvi	Sce_ruvi
Carbon sequestration (t)	228,944	260,320	225,829	246,085	245,955	233,812	260,601	233,790	228,944
Soil erosion (t)	262,413	174,864	253,801	249,488	249,140	219,275	174,486	219,210	262,413
Rural vitality (ha)	55,811	45,317	59,091	46,475	46,611	55,954	45,187	55,977	55,811

3.2.3. Sensitivity on AFC payment level

Fig. 5 shows the results of the sensitivity analysis on the Sce_AFC scenario payment levels. On the left, in Fig. 5A, we depict the changes in the land allocated to agricultural activities and abandonment. Land allocated to forestland is not depicted as the payment levels taken into account do not modify it. Not surprisingly, the increase in the payment levels drive the expansion of agricultural land into abandoned land. The expansion occurs mostly through arable land and grasslands, while permanent crops and grapes increase at a much slower rate. This is explained by the fact that marginal rent for the latter crops, while in general higher, is also steeper. The substitution of abandoned land with mostly grassland and arable land also entails a reduction in soil erosion (Fig. 5B), since these two activities tend to generate less soil erosion than abandoned land (see Table 6 for a comparison).

4. Discussion

The results of the analysis are to be interpreted in light of the assumptions and data that structure the modelling framework. The main ones are repeated here for clarity. The model maximizes the sum of agricultural rent and of the values generated by a bundle of the three selected PGs. Land uses have different impacts on those: for example, carbon sequestration is assumed to be delivered only by forests, rural vitality is only linked to agricultural areas, and soil erosion depends on both land use and the slope of the land. Among the PGs, the societal value of carbon sequestration is the highest. Moreover, we include in the model costs associated with major land use change, namely from land abandonment and forest to agriculture. Finally, in the scenario Sce_AFC, the AFC payment is assumed to be only linked to agricultural activities, without any environmental requirements.

Having in mind these characteristics, the main results of the model indicate that the maximization of the societal benefits, including the value provided by the three PGs considered and the agricultural rent, would only slightly improve the welfare of the area. Improvement would require a substantial change in the composition of the welfare (from the private agricultural rent to the societal values of the PGs) and in the allocation of land (from agriculture and abandonment toward forests). The impact of the AFC payment is also not substantial since its impact on the conversion of land abandonment into agriculture is limited by the presence of the conversion costs.

Given the high simplifications that modelling inherently entails, and the uncertainty regarding PG provision processes and values, we investigate several scenarios differentiated by the mix of PGs in the maximization and we run sensitivity analyses on all the main parameters. The results of these exercises shed further light on the main results and the related interpretations. The main driver of the optimal land allocation is carbon sequestration that causes a large expansion of forests. Rural vitality by itself has no impact in the land allocation and hence on the welfare, as its low value is insufficient to cover the costs associated with the conversion. The control of soil erosion has the highest synergies with the other PGs and among land use activities. Forests are strongly linked to both carbon sequestration and the reduction in soil erosion and some agricultural activities reduce soil erosion with respect to land abandonment. The results are interesting if considered in the framework of ongoing trends in ecosystems. Climate change has become the number one environmental concern, so the societal value of carbon sequestration has the potential to increase further, even sharply, compared to the current perceptions by citizens. On the other hand, soil health is more and more considered to be the key to future agro-ecosystem preservation. Accordingly, its value may be expected to increase. Altogether these considerations may lead one to think that future trends can actually emphasise further the directions taken by the results of this paper.

Moreover, the sensitivity analysis on agricultural price levels shows that their reduction rapidly causes the expansion of land abandonment. On the contrary, an increase in the price levels has a limited and slow impact on the conversion of land abandonment toward agriculture, as the conversion costs almost lock the area into its presiding situation. Given the limitations of the modelling exercise, such findings call for cautious policy implications that will be highlighted in the next section.

This work has several limitations. First, the model used assumes that farmers and decision-makers take decisions aimed at maximizing their income, which is by itself a rather strong, albeit widely accepted, assumption. The objective of farmers' decision-making can be both extremely heterogenous and various, as it can include environmental, social, and risk-minimizing objectives. Moreover, the assumption of an income maximising mathematical model in comparative equilibrium, due to its simplification of the decision-making process, cannot take into account the complexity of the abandonment processes. In this respect, the results should be weighed against other factors slowing down the process of adaptation to new favourable conditions (e.g. structural factors in farm adaptation to new market opportunities) or further strengthening the abandonment process (e.g. ageing).

Moreover, the methodology that we use is a classic land allocation

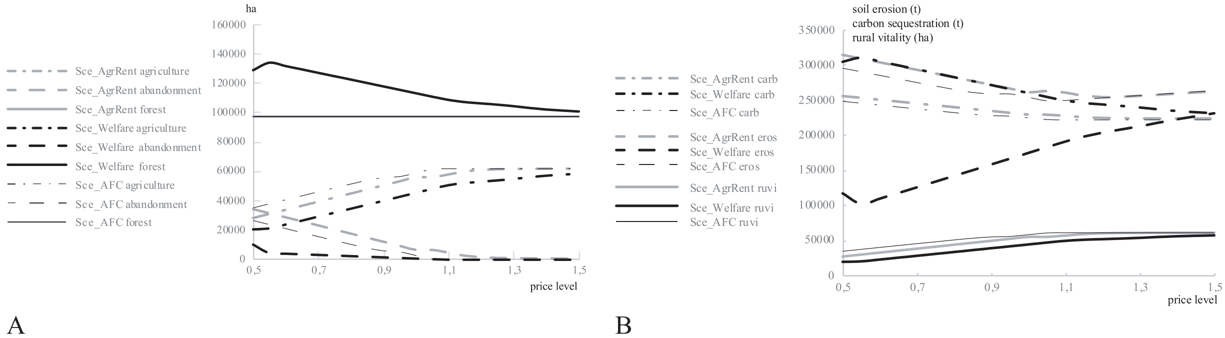

Fig. 1. Results on the sensitivity analysis on agricultural price levels (share of current ones). A) land use categories in the scenarios Sce_AgrRent, Sce_Welfare, Sce_AFC. B) Provision levels of PGs in the scenarios Sce_AgrRent, Sce_Welfare, Sce_AFC.

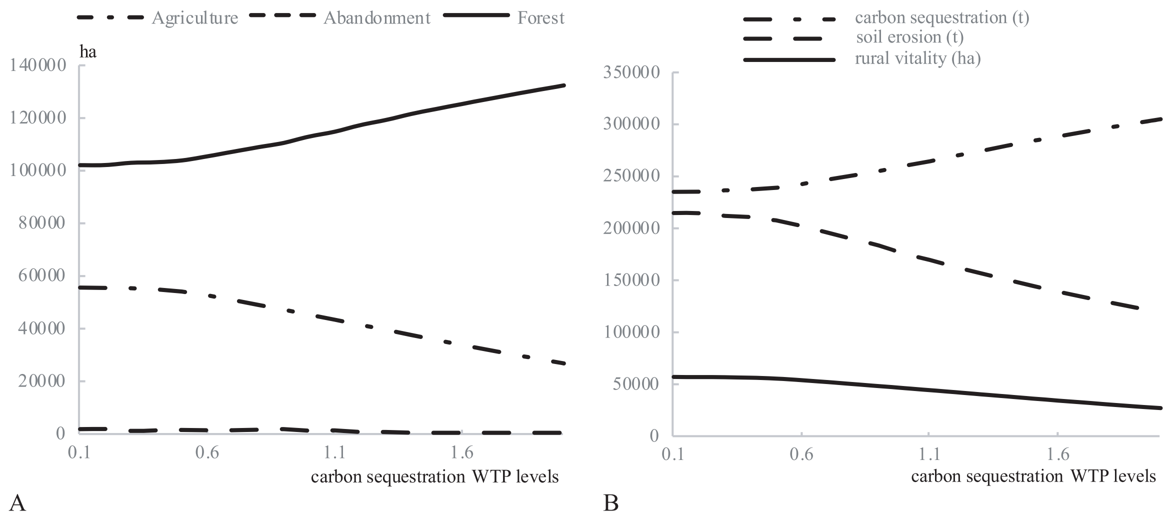

Fig. 2. Land allocation (A) and PG provision levels (B) in the scenario Sce_Welfare for different level of carbon sequestration WTP.

model set in a Ricardian framework. The availability of data, in particular the small number of observed farms in mountainous areas of the Farm Accounting Data Network (the most used and comprehensive database on farm level in the EU), coupled with the high variety of land characteristics, constrained the choice of the methodology and prevented, for example, the estimation of cost function parameters through a positive mathematical programming model (Heckelei et al., 2012).

In addition, the WTP values that we used in the model are specifically derived for the area, so are at the highest level of accuracy allowed by these instruments. However, the methods used to estimate the WTP for unpriced goods, through a DCE in this case, have their own limitations that affect the validity of the results of the simulation models. Moreover, we introduce the WTP values as averages, implying a linear benefit function for the PGs that may lead to extreme results. An advancement in the analysis would be the use of a marginally decreasing WTP.

Third, while we make progress compared to most of the available literature, by taking into account the value of a bundle of PG, we do not comprehensively assess the whole potential provision of PG from the areas. Biodiversity is the most crucial one that is lacking, as it is an important feature of both land abandonment and agriculture.

The lack of explicit consideration of time and dynamics is an additional limitation common to all of the aspects mentioned above. The method cannot account for the complexity of societal and ecological relationships over time, which can also bring opposite effects depending on the time frame of analysis and may include unexpected or unintended effects.

In order to corroborate, qualify and discuss the outcome of the exercise and to derive policy implications, the models' results were presented at a local stakeholder workshop. The stakeholders showed a marked interest in the value of PG introduced in the model aimed at assessing the policy instrument, showing that indeed better economic data to inform policy making is appreciated. They clearly recognised the potential impact that these values have on the model results and hence the potential policy implications for an acceptance of (managed) re-forestation of abandoned land. Yet they expressed surprise over the relative low value for erosion with respect to carbon sequestration and apparently the disinterest of Emilia-Romagna citizens with respect to rural vitality. This was, however, recognised as an important message. The stakeholders interpreted this result as citizens have little interest in agriculture *per se,* and they may even find the income support policies as unfair and unmotivated, while they value very highly the PGs connected to land management. Moreover, they commented in general on the issue of land abandonment in mountain areas in the region. Some stakeholders commented that the current land abandonment process is somewhat the outcome of the interruption of years of coupled support that in turn had artificially supported the "unnatural" expansion of agriculture in marginal lands. As for soil erosion, the outcome of both

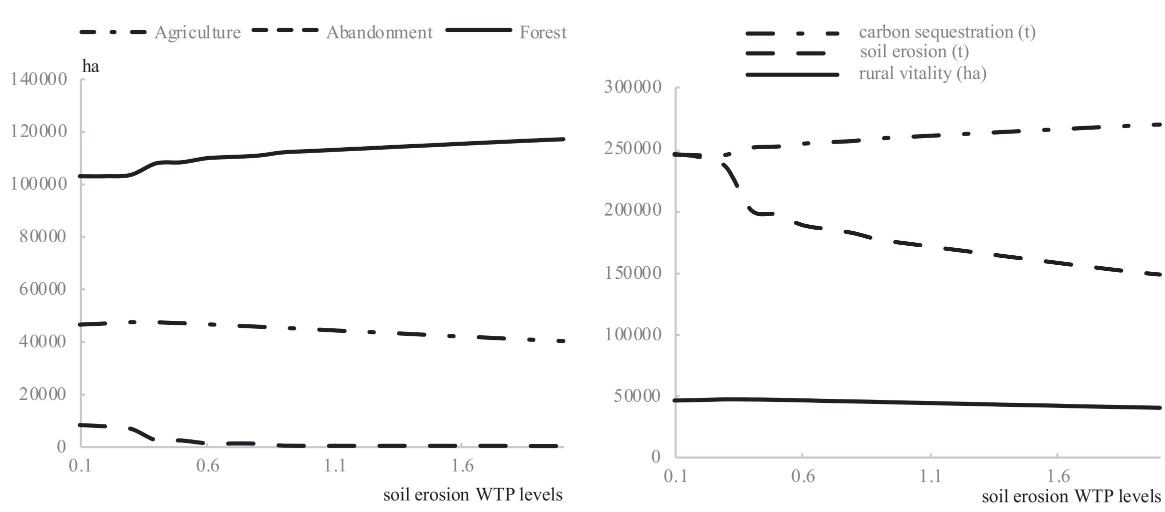

Fig. 3. Land allocation (A) and PG provision levels (B) in the scenario Sce_Welfare for different level of soil erosion WTP.

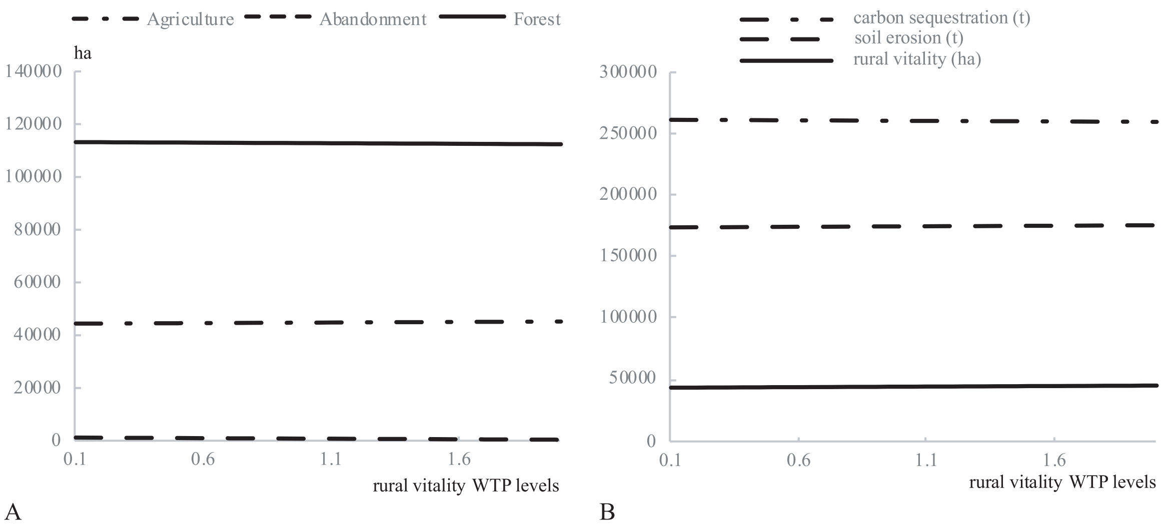

Fig. 4. Land allocation (A) and PG provision levels (B) in the scenario Sce_Welfare for different level of rural vitality WTP.

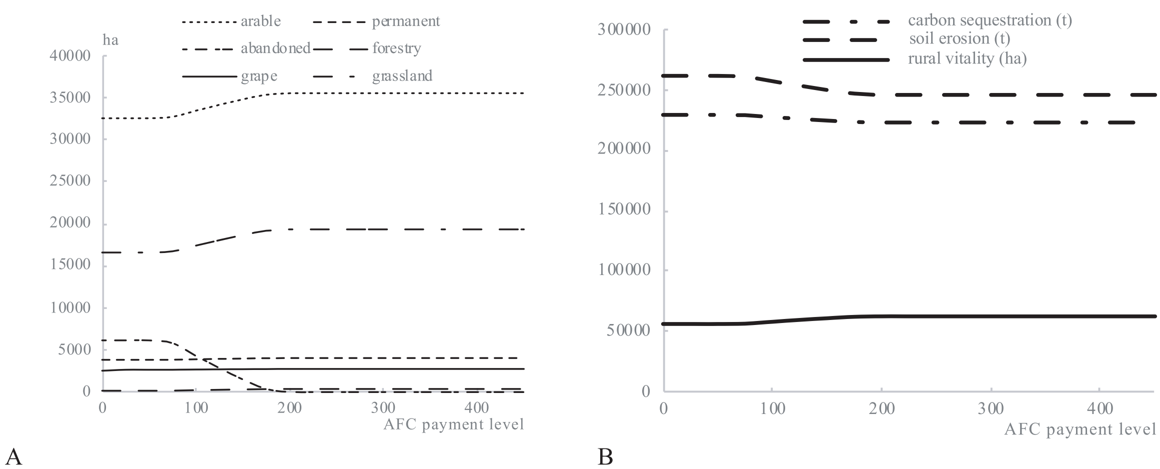

Fig. 5. Land allocation among agricultural activities and land abandonment (A) and PG provision levels (B) in the scenario Sce_AFC for different level of the AFC payment.

modelling and stakeholder feedback highlight the need to distinguish more clearly in the discussion the distinction between erosion on cultivated soil surface (increase by agriculture to different degrees depending on crop and intercropping practices) and interventions to recover damages related to water flows that are more likely positively connected to human presence, but not directly considered in the model, as not directly connected to the area used.

More specifically regarding the model results, while stakeholders appreciated the effort, they observe how the modelling of the policy could be improved to come closer to the actual policy measures that are present in the regional RDP. More specifically, they observe how in reality abandoned land cannot be eligible for the financial scheme here analysed, and thus the results on the conversion of these lands back to agriculture should be taken cautiously as it would only be possible after a change in policy. In addition, it was highlighted that we did not consider potential new measures concerning soil erosion on cultivated land that could have contributed to smooth trade-offs, achieving results that are better in terms of societal welfare than any of those simulated above.

5. Conclusions and policy implications

In recent years, the abandonment of agricultural land has become an increasingly important issue in certain areas of Europe, and the subject of an increasing number of policies. However, despite the large number of studies on the topic, surprisingly little has been said about the economic consequences and the trade-offs in terms of PGs among land abandonment, agriculture, and forests. In this paper we provide a first step in this direction, using a mathematical programming model fed by WTP estimates for public goods provision and stakeholder co-design and feed-back. We compare the optimal land allocation that maximizes the private agricultural rent and societal values of three different PGs: carbon sequestration, soil erosion and rural vitality. We then compare the outcome of such a model with the land allocation patterns driven by the maximization of agricultural rents, with and without policy support.

The results of the analysis show that the maximisation of total welfare in the area would require an increase in forested land at the expense of both agriculture and land abandonment. Such an allocation would change the composition of the societal welfare, increasing the share of value due to PGs, and reducing the share represented by private agricultural rents. However, the resulting welfare only increases by 4% with respect to an agricultural rent-driven land allocation. The driving force behind such a result is mostly the relatively high value of carbon sequestration, the synergies between carbon sequestration and soil erosion in forest areas, and the relatively low values of agricultural rents and rural vitality. Moreover, the welfare results generated by the implementation of payment for AFC show that there are strong trade-offs between rural vitality and the other PGs when generic income support is used. This instrument reduces land abandonment but also total welfare as it has negative effects through the reduction of carbon sequestration and increases in soil erosion.

These results confirm that land abandonment is indeed problematic, being less productive than forests in terms of the public goods considered and, obviously, less profitable than agriculture. A first policy implication of such finding is that land abandonment should be the target of policy intervention but that such an intervention should promote the afforestation and/or reforestation of these areas, or, at least, some PG-oriented management, rather than generic agricultural production. However, given the high uncertainty on parameter levels, for example on the relationship between land use and PG provision and on their values, these policy implications should be taken cautiously.

Moreover, the results also show that land abandonment can be easily triggered by a reduction in prices, but that its re-conversion to agriculture, when and if prices increase, is more difficult given the presence of conversion costs. Note that these conversion costs are even higher for forested areas. This hints at the idea that policy should still to some extent address land abandonment by agriculture. Hence, a prudent policy change could be to better focus agricultural policies, explicitly connecting economic support to agricultural practices specifically delivering PG benefits, or, in perspective, with results in terms of the delivery of ecosystem services. For example, more clear conditionality constraints on soil erosion could be envisaged to justify (even higher) support for AFC, but also preferential access to AES encouraging soil management. While further analysis is required, such policies would partially maintain a land allocation pattern more flexible than afforestation, and at the same time improve the provision of the relevant PGs.

Some more detailed policy recommendations may emerge from the current study. Since, despite its reversible character, land use changes (especially from forest/abandoned to agricultural land) entail costs, agri-environmental policy should have a longer time horizon and build on a comprehensive assessment of the PG provision they aim to achieve. In particular, incentives towards e.g. afforestation might assume an option value approach. This should also take into account the volatile societal preferences for PG and the limitations that any WTP valuation assessment involves, but also the strong trends in increasing value attributed to some PGs, in particular carbon sequestration and the reduction of soil degradation.

Clearly, attention to the possibility of farms managing non-agricultural land, while ignored in this paper, is key to managing the trade-off and would require specific policy measures in the future. Connection between agriculture and forestry measures in mountain areas should also be considered, with a focus on land having recently exited from cultivation. In light of the development of the bioeconomy, productive uses of non-cultivated land could also be promoted for biomass production, whilst keeping in mind the impact on carbon balance.

As it is not expected to cease in the near future, research should delve deeper into the economic consequences of agricultural land abandonment, especially with respect to the trade-offs and the synergies that different land uses have on the delivery of public goods. More precisely, from a policy-wise perspective, one of the priorities would be a comprehensive assessment of societal WTP for the PGs that are delivered in marginal areas. This is not limited to have an estimate for the whole range of PGs, but also to to refine and disentangle the WTP for agriculture itself, i.e. rural vitality, with respect to the PG that some agricultural practices can deliver. Moreover, as the PG benefits can be at different scales, e.g. global scale for carbon sequestration or biodiversity, local scale for soil erosion, the spatial distribution of the WTP, and thus the demand for PGs, matters and should be better addressed. The inclusion of this data in simulation models would not only result in a more precise assessment of the optimal mix of land uses, but it would also highlight how the welfare generated by the PG would be distributed. Both types of information would provide important insights for policy-makers with an eye to better targeting the practices to be financed in RDP measures, and to potentially develop Payment or Ecosystem Service schemes. In this prospect, simulation models can be a powerful tool to inform policy-makers, but their development should further pursue the integration of PG values and stakeholder participation.

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Appendix A

The questionnaire related to the Discrete Choice Experiment (DCE) is structured upon 7 Sections, namely:

- Section 1 – Knowledge and perception of the hilly and mountain areas
- Section 2 – Economic valuation
- Section 3 – Cards selection
- Section 4 – Further considerations on the choices done
- Section 5 – The Common Agricultural Policy and the Public Goods
- Section 6 – Personal information
- Section 7 – Comments on the questionnaire

Section 1 concerns a general inspection of the behaviour and knowledge of the respondent of the hilly and mountain areas of Emilia-Romagna (e.g. whether the respondent is resident in the area, has a second home there, has relatives living there, usually goes there for leisure, for work, etc.). The respondent is also asked to state the frequency (expressed in a scale from 1 = "More than two times per week" up to 5 = "Never", with "Do not know" and "Not answering" possibilities included) with which he/she does some peculiar activities in such areas (e.g. biking, trekking, fishing, hunting, harvesting, etc.). Finally, the respondent is asked to declare how much important are some peculiar issues in the hilly and mountain areas (e.g. landslides, floods, viability, etc.) expressed in a scale from 1 = "Very important" up to 5 = "Not important", with "Do not know" answer included.

In Section 2 the respondent is informed about the three PGs under analysis, namely:

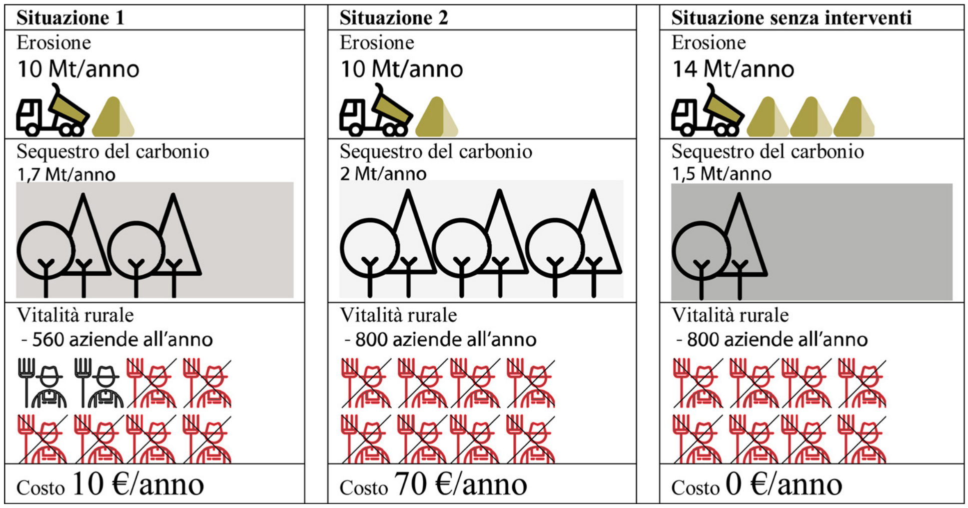

Fig. A1. Example of choice card.

1) The PG is defined in the most general way
2) The PG is defined with respect to the potential effects it can produce
3) It is defined how the PG is measured
4) The information on the actual level of the PG provision is given

For the sake of clarity, we report for each PG the previous structure as it is faced by the respondent:

Soil erosion

1. *"Soil erosion, in the hilly and mountain areas, is conceived as the phenomenon of removal of the foundational material of the local area"*
2. *"The effects of soil erosion in the hilly and mountain areas are the reduction of agricultural land fertility and the increasing of the slopes instability. Eroded soil is then transported down to the valley where it contributes to decrease the efficiency and the flow rate of rivers and canals with the consequent increasing of floods risk"*
3. *"Soil erosion is measured in terms of the quantity of soil that is annually lost in the hilly and mountain areas that are defined as stable, i.e. the areas that are not interested by landslides"*
4. *"In hilly and mountain areas of Emilia-Romagna, every year, there is a loss of around 14 million tons of soil, corresponding to around 21.4 tons per hectare of stable land in the hilly and mountain areas"*

Carbon sequestration

1. *"Carbon sequestration, in the hilly and mountain areas, is conceived as the amount of carbon dioxide (CO2) sequestered in terms of wood and vegetation by the forestry"*
2. *"The carbon sequestered from the atmosphere contributes to mitigate the climate change"*
3. *"Carbon sequestration is measured in terms of the quantity of carbon dioxide that is annually sequestered as wood and/or vegetation by forestry"*
4. *"In the hilly and mountain areas of Emilia-Romagna, every year, 1.5 million tons of carbon are sequestered, corresponding to around 2.3 tons per hectare of forestry"*

Rural vitality

1. *"Rural vitality, in the hilly and mountain areas, is conceived as the preservation capacity of the people living in the rural areas whose one of the main aspects is represented by the production network of the agricultural holdings"*
2. *"The preservation of the population in the rural areas contributes to guaranteeing the maintenance and the surveillance of the territory. This is particularly relevant in the marginal mountain areas"*
3. *"We restrain the measurement of such a Public Good only to the aspects linked to the presence of the agricultural holdings. The vitality of the rural area is then measured in terms of the number of farms that are located in the hilly and mountain areas which, every year, definitively end their activity"*
4. *"In hilly and mountain areas of Emilia-Romagna, every year, around 800 agricultural holdings end their activity"*

In Section 3, four different scenarios for the choice of the cards are proposed to the respondent. Fig. A1 depicts an example of choice card:

Sections 4 to 7 complete the questionnaire, asking further information related to the choices done and some considerations on the current CAP structure, profiling the respondent in terms of socio-demographic characteristics and with respect to the perception of the whole survey.

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