Exploring factors influencing farmers' compensation request for combating soil erosion in a Mediterranean cropland area

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Abstract

Many studies highlight the key role that farmers play in combating soil erosion, and measure their willingness to adopt sustainable cultivation practices in front of a monetary compensation. However, only a few of them focus on factors affecting the magnitude of such compensations, despite this information is crucial in the design and implementation of public supported actions aimed at combating agricultural land desertification. We try to contribute to fill this empirical gap by reporting results of a research carried out to investigate what factors influencing farmers' compensation request for combating soil erosion in a significant Mediterranean cropland area. Using a discrete choice experiment, we measured cereal growers' marginal compensation for adopting soil conservation practices. Then, using a post-estimation analysis based on a Seeming Unrelated REgression (SURE) model, we identified and analysed which farm's and farmers characteristics significantly influenced the requested compensations. This post estimation analysis proved that farmers' motivations, opinions and currently undertaken cultivation practices matter.

Introduction

Soil erosion is one of the major environmental threat to the sustainability and productive capacity of agriculture, either in developing or developed countries (Blaikie, 2016; Panagos et al., 2018; Rodrigo-Comino, 2018; Wynants et al., 2019). Several studies highlight the key role that farmers play in combating soil erosion (Shelef et al., 2016; Panagos et al., 2017; Gebrekidan et al., 2019), and provide strong evidence that farmers also realize that soils are not as fertile as they once were (Boardman et al., 2017; Moges and Taye, 2017; Nigussie et al., 2017; Orchard et al., 2017). Especially in developed countries, empirical research shows that farmers recognize the importance of adopting sustainable cultivation practices, and welcome the opportunity of adopt Agri-Environmental Schemes (AES) locally proposed by policy makers to contrast soil erosion. Such schemes offer a monetary compensation to farmers who are engaged in the adoption of sustainable cultivation practices on their farmland (Buller et al., 2017).

Effective and efficient AES to combat soil degradation should not disregard in-depth analyses of farmers' preferences, and should be capable to consider differences in perceptions, motivations and opinions among farmers. Furthermore, AES should rely on knowledge of farmers' and farm's characteristics influencing the request of compensations for adopting defined sustainable cultivation practices. Despite several studies measured the compensation required by farmers to adopt on-farm conservation practices, only a few of them investigated what factors affecting the magnitude of such monetary compensations (Jack et al., 2009; Bamière et al., 2011; Ma et al., 2012; Krishna et al., 2013; Conner et al., 2016; Villanueva et al., 2017; Tienhaara et al., 2020).

In this study, we identify and analyse what factors influencing farmers' compensation request for combating soil erosion in a significant Mediterranean cropland area. To achieve this objective, we firstly measure the marginal compensation (Marginal Willingness to Accept, MWTA) requested by farmers for the adoption of soil friendly practices, and then explore farmers' preference heterogeneity for such practices. Determinants significantly explaining such heterogeneity are related to farmers' and farm's characteristics, farmers' beliefs and opinions, and currently adopted cultivation practices. In the analysis, we use a discrete-choice experiment approach (Louviere et al., 2000; Hensher et al., 2005) to measure MWTA, and a post estimation analysis based on a Seeming Unrelated REgression (SURE) model.

Results suggest that significant determinants vary among soil conservation practices, and are only in part related to farmers' and farm's characteristics. The compatibility of the prospected new soil conservation practices with the current production system seems to play a more relevant role. Estimates of MWTA are on average higher for practices that are judged by farmers are less easily integrated into the existing management practices. The case study related to cropland in Sicily (Italy), a Mediterranean region which is strongly vulnerable to soil erosion (Fantappiè et al. 2015).

Materials and method

Data used for this analysis were gathered through a discrete-choice experiment (DCE) designed to state farmers' preference for hypothetical AES, that were more binding than the current local regulatory framework. In a discrete-choice experiment, respondents are typically presented with a series of alternative hypothetical scenarios containing a number of variables, named "attributes", which present a defined number of variations, named "levels". Participants are asked to state their preferred choice between alternative scenarios, each one consisting in a combination of attributes and levels. In our application, each hypothetical AES scenario was based on four sustainable goals, which represent some of the most relevant agri-environmental goals defined by the European Common Policy for Rural Development. These goals were*i*) the protection of soil from water erosion, *ii*) the maintenance of soil organic matter, *iii)* the maintenance of landscape features, and *iv*) the agro-biodiversity conservation. In the prospected choice experiment, farmer who was willing to adopt more coercive agricultural practices received an additional monetary compensation, which represents the fifth attribute of the hypothetical AES scenario (see Table 1). Each respondent was asked to select his preferred choice among option A, option B and option C, the latter representing the status quo. The choice task was presented in an iterative manner for four times. An example of the choice task is illustrated in Figure 1. Interviews covered a random sample of 125 cereal farmers who grow crops in the Sicilian slope inland areas, with average gradients of farmland over 15%. Table 2 reports summary statistics of sample.

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To analyse DCE data we relied on Mixed logit (MXL) econometric model (Train, 2003). MXL is based on the random utility maximization (RUM) framework proposed by McFadden (2001). According the RUM, the$n$ -th farmer's utility for the j -th option in the$t$ -th choice occasion (U_{nit}) is composed by a deterministic part (V_{njt}) plus a stochastic part ($\epsilon_{\nu\vartheta\tau}$). The probability that the n -th farmer chooses the i -th alternative from the J choice set (with J = 1,..,3) in the t choice occasion (with t= 1,. . . 4) is:

$$P_{\text{nit}} = Prob\left(U_{\text{nit}} > U_{\text{njt}},\ \forall j \neq i\right) = Prob\left(V_{\text{nit}} + \varepsilon_{\text{nit}} > V_{\text{njt}} + \varepsilon_{\text{njt}}\ \forall j \neq i\right) = Prob\left(\varepsilon_{\text{njt}} - \varepsilon_{\text{nit}} < V_{\text{nit}} - V_{\text{njt}}\ \forall j \neq i\right)(1)$$

We assumed a linear and additive indirect utility function:

$$U_{\text{njt}} = \alpha\Omega\text{TA} + \beta_n^{'}\mathbf{x}_{\text{njt}} + \varepsilon_{\text{njt}}(2)$$

where WTA is the monetary attribute, $\mathbf{x}$represents the vector of non-monetary attributes, and α_n and $\boldsymbol{\beta}'_\nu$ are random parameters. For the random component, we hypothesized identically and independently Gumbel distributed errors. Assumptions imply that the conditional (on β_n) probability of observing a particular sequence of choices for each$n$ -th respondent ($y_n = y_{n1},\ y_{n2},\ y_{n3},\ y_{n4}$) is the product of standard logit formulas:

$L\left(y_{n1},\ y_{n2}, y_{n3},\ y_{n4}|\beta_{n}\right)=\prod_{t=1}^{4}\frac{e^{\beta_{n}^{'}\mathbf{x}_{\mathrm{njt}}}}{\sum_{j=1}^{3}e^{\beta_{n}^{'}\mathbf{x}_{\mathrm{njt}}}}(3)$

Unconditional probability was calculated as the integral of equation (3) weighted by g(.) function, which is the density function ofβ_{ν} (Revealt and Train, 1998):

$P_{n}\left(y_{\mathrm{nt}}\right)=\int L\left(y_{n}|\beta_{n}\right)g\left(\ \beta_{\mathbf{n}}|\,\mu,\mathbf{\Omega}\right)d\beta_{n}(4)$

This integral is approximated through simulation, in this case study by using 1,000 random draws, and the maximum simulated likelihood estimator is the value of unknown parameters that maximizes the unconditional probability. To obtain a posterior distribution of β_n for the sampled people, we followed the procedure described by Revelt and Train (2000). To estimate coefficients and posterior distribution of β_n for each assumed random attribute we used STATA 16.0, and employed respectively the packages *mixlogit*and *mixlbeta.* Individual MWTA estimates were assessed as the ratio between the coefficient estimate and the coefficient related to the monetary attribute. We assumed that all no-monetary attributes were random and normal distributed among individuals. Oppositely, the monetary attribute was assumed as fixed. This implies that MWTA distributions are consistent with the hypothesis of β_n distributions.

Factors influencing the farmers' willingness to accept for the adoption of soil conservation practices were identified through a post-estimation analysis based on a Seemingly Unrelated REgression (SURE) model (Greene, 2005). We specified three equations and assumed a contemporaneous cross-equation error correlation. The main advantage of SURE model over equation-by-equation OLS is the gain in efficiency that results from the incorporation of correlation in un-observables across equations for a given individual (Greene, 2012).

Dependent variables for the three equations were the MWTA for 1) turfing sloping surfaces, 2) reducing the distance of temporary furrows sinks, and 3) maintaining the soil organic matter. Individual MWTA for the n-*th* individual for m-*th* attribute was given by:

$\mathrm{MWTA}_{\mathrm{mn}}=\mathbf{x}_{\mathrm{mn}}{}^{*}\delta_{\mathrm{m}}+\boldsymbol{\varepsilon}_{\mathrm{mn}}$ (5)

where $\mathbf{x}_{\mathrm{mn}}$ is a matrix of explanatory variables assumed to be exogenous, δ_{m} is a parameter vector and $\boldsymbol{\varepsilon}_{\mathrm{mn}}$ is the error term, n = 1,. . . , 125 and m = 1, 2, 3.

Regressors included:

- cereal grower's and farm's characteristics,
- cereal grower's previous experience with AES,
- cultivation practices undertaken to maintain soil fertility and reduce the risk of water erosion in sloping surfaces, to breaking up and smoothing out the surface of the soil, and to control weeds, pests and pathogens;
- cereal growers' opinions on the importance of protect the environment, and control soil erosion and on motivations to justify the prevention of soil fertility.

The model was estimated through feasible generalized least square estimator (FGLS) (Zellner, 1962; Greene 2012) by using STATA 16.

1. **Results and Discussion**
2. **Farmers' attitudes and opinions, and currently undertaken cultivation practices**

Table 3 reports results about the stated farmers' opinions on the importance of preserve the environment and contrast soil erosion. The same table reports also statistics about motivations that should justify the adoption of proper cultivation techniques. We used a 5-points Likert scale ranging for 0 which represents the modality "not important" to 4 which represents the modality "high importance".

Respondents assigned a high importance both at protecting the environment (77%) and at controlling soil erosion in own cultivated lands (79%). Regarding the latter aspect, the 76% of respondents judged highly important adopting during the cultivation of own lands techniques aimed at maintaining soil fertility. Motivation to justify the prevention of soil organic matter was prevalently related to guarantee high yields. The

82% judged this motivation highly important. The protection of soil fertility to leave cultivated land productive for future generations was also be judged relevant. However, the rate of respondents who considered this item highly important was a bit lower (71%), and a minority of respondents assigned to this motivation a value of importance equal to 1 (2.34%) or 2 (9.38%).

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The 40% of respondents declared the adoption of temporary furrows sinks as main strategy to control water soil erosion in sloping surfaces. The 13%, otherwise, prefer the permanent turfing of sloping surfaces. To maintain soil fertility, the most adopted practices were the grazing stubble, straw and crop residues (75%) and the burying of crop residues (46%). The burning of crop residues indeed was the less adopted practice (18%).

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Table 4 reports the incidence in the adoption of other cultivation practices, such as fallow, harrowing and plowing, fertilization, weeds and pests and pathogens control. Only the 18% of respondents adopted the fallow procedure, whereas the 60% practiced a contemporary crop rotation regime. The plowing with a working depth greater than 15 meters was a frequent practice among Sicilian cereal growers (64%) as well as the soil harrowing (55%). Fertilization was prevalently mineral (68%), while weeds control was prevalently chemical (55%) and performed as a post-sow practice (58%). Cereal growers who use pesticide were the minority of respondents (4%).

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As it concerns the propensity to adopt AES, almost the totality of respondents known the current regulation (93%), and a relevant percentage of respondent (63%) declared his willingness to adopt new eco-conditional measures in the land cultivation if properly economically compensated. However, cereal growers who have experience with the current compensation framework aimed at reduce soil degradation were negligible. The 43% of the respondents in the past token land out of production to reduce crop surpluses adopting the famous EU set-aside regime, and the 30% of them adopted agricultural production methods compatible with the requirements of the protection of the environment and the maintenance of the countryside. As showed by Table 6, cereals growers who adopted measures aimed at increase afforestation, protect and improve the environment or environmentally-favourable extensification farming systems were negligible.

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3.2 MWTA estimates

Table 7 reports coefficient estimates of the MXL model. Variables representing practices aimed at controlling the risk of soil erosion, named *Turfing* and *Furrows sinks* , were both significant respectively with a significance level equal to $p<0.001$ and to $p<0.01$, and shown a positive sign. Turfing sloping surfaces was preferred to the realization of furrows-sinks because this practice assures a higher level of protection against water erosion. Coherently, in the hypothesis of furrows sinks, the realization of more closed sinks was preferred. The coefficient of *Soil_fertility* shown a lower significance level ($p<0.10$) and positive sign, meaning that the practice of grazing stubble and firebreaks was preferred to the creation of firebreaks and burying of crop residues, and that the creation of firebreaks and burying of crop residues is preferred to the burning of crop residues. The improvement in the degree of maintenance of the countryside features (*Landscape*) and the increase of the surface dedicated to crop local endangered varieties (*Agro-biodiversity*) were both statistically significant. Estimated sign was negative for both these latter attributes. The coefficient of *WTA* was highly significant ($p<0.001$) and its sign was positive, meaning that the farmer's utility increases with higher compensation. Finally, the constant term (β_0), which represents the Alternative Specific Constant (ASC) for the status quo alternative (option C), was negative and highly significant ($p<0.001$). The latter result was coherent with that obtained by similar studies, confirming the farmers' preference for the non-status quo alternative (Birol et al., 2006; Espinosa-Goded et al., 2010).

As it concerns parameter estimates related to standard deviations, results confirmed our hypothesis of heterogeneous farmers' preferences for agri-environmental practices. The better statistical performance is showed by the MXL model's specification which assumed for all the attributes' coefficients—except for the coefficient of *WTA* —a randomly normal distribution. The z value of standard deviation (Hensher et al., 2015; Mariel et al., 2013) refused the hypothesis that the parameter for *Landscape* variable was randomly distributed.

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Table 8 reports estimate of MWTA for all the practices on which the choice experiment was designed. Focusing our attention on those relative to soil erosion control and soil fertility preservation, cereals growers were willing to turfing sloping surface instead of realize temporary furrow sinks in front of a compensation that, on average, equals to ranging between \euro -440.68 and \euro 1,486.16.

Oppositely, to reduce the distance between temporary furrow sinks, respondents asked always a compensation, that on average equal to 7.64. The presence of strongly variable preferences among farmers was evident also in practices aimed at maintain soil organic matter. MWTA in on average equalled to \euro 125 and ranged between \euro -408 and

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3.3 Determinants of MWTA

Results of the SURE model shown that the MWTA for turfing sloping surfaces was positively and significantly affected by the magnitude of sloping surface and by the farmer's family size. In particular an increase of sloping surface equal to one hectare implied an increase of MWTA equal on average to \euro 1.98. Further, cereals growers asked an additional compensation equal to \euro 53.28 for each additional family component. The required MWTA for reducing the distance between temporary furrow sinks was otherwise lower if the farmer was enrolled in previous AES (familiarity) and if he assigned a high importance at containing soil erosion on his cultivated lands. Respectively, MWTA decreases on average of \euro 2.26 and \euro 2.68.

The MWTA for adopting practices aimed at maintain soil fertility matter was indeed affected by several determinants regarding farm's and farmers' characteristics and cultivation practices currently undertaken. In particular, it increases with the increase of the cultivated surface of a value equal to \euro 1.01 per ha. If a cereals grower's relative wants became a farmer the compensation increased on average of \euro 104.74. Further the undertaking of particular cultivation practices in some case caused an increase of the required compensation, such as the pre-sow weeds control (\euro 76.09), the plowing with a working depth greater than 15 meters (\euro 63.06) and the construction of temporary furrows sinks (\euro 104.75); in other cases, the MWTA decreases, such as for farmers who adopted the fallow (\euro -86) or the burning of crop residues (\euro-101.40).

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Conclusions

In this study we explored opinions and preferences of a representative sample of Sicilian cereal farmers about their willingness to adopt conservation practices specifically designed to control water erosion and to maintain soil organic matters.

Our study show that farmers generally assign a high importance at controlling soil erosion in own cultivated lands, judging imperative the adoption of techniques aimed at preserving soil fertility to guarantee high yields and, with a latter extent, to leave cultivated land productive for future generations. However, only a negligible number of farmers declares the currently construction of temporary furrows sinks to control water soil erosion in sloping surfaces. Farmers who permanently turf the sloping surfaces are minimal. Approximately the 40% of respondents do nothing for contrasting water soil erosion in sensible lands.

Oppositely, farmers are more rational in the adoption of practices aimed at preserving soil fertility: this objective is currently preserved by a relevant percentage of farmers through the adoption of efficient strategies, such as the grazing of stubble, straw and crop residues and/or the burying of crop residues.

Our discrete-choice experiment reveals that farmers positively welcome the opportunity of “doing more” in conservation practices in exchange of a monetary compensation. However, MWTA for some proposed practices are extremely variable at individual level, highlighting the existing of strongly heterogeneous preferences also in a group of farmers which is representative of a fairly homogeneous and spatially delimited cultivation context, such as the cereal growing in the Sicilian slope inland areas.

This heterogeneity indicates the existence of several determinants which might affect the individual value of MWTA also in a limited geographical area. Our post-estimation analysis suggests that significant determinants differ among practices, and are only in part related to farmers’ and farm’s characteristics. Variables such as the farmer’s age, his educational level and gender, which have been identified as traditional key factors in explaining farmers’ preferences for conservation practices (Prokopy et al., 2008) seems to be not relevant in this analysis. Oppositely, the compatibility of the prospected new practice with the current production system seems to play a more relevant role. These finding, which are consistent with those obtained by Conner et al. (2016), suggest that farmers are more willing to adopt more familiar and simpler practices that could be more easily integrated into existing management practices. Otherwise they ask higher compensations.

To conclude, our study suggest that future design of AES should capture the availability of farmers to more commit themselves to protect land and environmental resources, and that compensation should be modulated to reflect this increased awareness among farmers to protect soil resource.

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Sustainable aims	**Alternatives**		
	A	B	C (*Status quo*)
Protection of soil from water erosion	Construction of temporary furrows sinks at 20 m	Construction of temporary furrows sinks at 40 m	Construction of temporary furrows sinks at 80 m
Maintenance of soil organic matter	Grazing stubble, straw and crop residues	Creation of firebreaks and burying of crop residues	Burning of crop residues
Maintenance of landscape features	very good	good	Sufficient
Agro-biodiversity conservation (% of crop surface cultivated with local endangered species)	70%	70%	0%
Additional payment	1,000 €/ha	600 €/ha	0 €/ha
I prefer:	□	□	□