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Factors affecting purchasing process of digestate: evidence from an economic experiment on Sicilian farmers' willingness to pay

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Abstract

In this study, we evaluate from the perspective of the theory of commitment costs if the level of farmer understanding about digestate attributes could influence the willingness to pay (WTP) for it. For this purpose, we carried out a research on a sample of 223 Sicilian farmers to correlate their WTP for digestate with a set of eight attributes which usually characterise organic soil conditioners. An experimental design was set up so that participants were given different waiting times to decide on their WTP and different levels of information on the attributes of organic soil conditioners. The results highlight a positive WTP, but farmers are strongly influenced by how much information is available on digestate. Without it, farmers' WTP decreases drastically probably due to phenomena correlated to what economic theory calls commitment costs.

Keywords: Willingness to pay, Digestate, Experimental auction, Commitment costs

Background

Digestate is an organic soil conditioner obtained after anaerobic digestion, a biochemical energy conversion process without oxygen. Anaerobic fermentation consists of using microorganisms to break down the organic complexes (fats, proteins, carbohydrates) of plant and animal by-products. Digestate is an optimum organic soil conditioner, rich in nitrogen, phosphorous and potassium. It is more homogeneous compared to the biomass introduced in the anaerobic digesters on which its chemical composition depends (Tambone et al. 2013; Nkoa 2014).

International research (Risberg et al. 2017; Bezzi and Ragazzoni 2014) has shown positive effects from digestate on soil quality. Furthermore, positive effects on soil fertility have been highlighted due to its promptly available nutritional contribution to crops. Digestate also has a long-term effect on soil fertility due to the interaction of its organic fraction with the biochemical dynamics of the soil (Saveyn and Eder 2014). After anaerobic digestion, digestate frequently undergoes separation into a solid fraction used as a manure substitute and a clarified fraction containing nitrogen as ammonia, a fast-acting nutrient for crops (Adubaker et al. 2012).

Currently, digestate is mainly used in those geographic areas where anaerobic digesters are widespread. In other areas like the Mediterranean basin, despite the high biomass potential available, the number of anaerobic digesters is very low, and the use of digestate as soil conditioner is even more limited (Appel et al. 2016; Manetto et al. 2016; Chinnici et al. 2018). However, increasing the number of anaerobic digestion plants does not seem sufficient to promote the use of digestate as soil conditioner since its chemical/physical properties are yet little known among farmers (Fabbri et al. 2010; Dahlin et al. 2017).

An important condition for widening the digestate market is informing potential users about its chemical/physical properties and its benefits for soil improvement (Dahlin et al. 2015). A lack of data on digestate characteristics could create significant uncertainty among farmers on those benefits. Such uncertainty could also have negative repercussions on the use of digestate as a conditioner and consequently on the willingness to pay (WTP) for digestate notwithstanding the market potential. So, where digestate is little or completely unknown, informing farmers on its benefits might influence their WTP.

In conditions of uncertainty about the value of an asset, the estimate of the WTP as well as the identification of factors that influence the WTP could be affected by the possibility for potential consumers to delay the purchase to acquire future information on the same asset. An interesting approach that economic theory suggests for estimating the WTP of a good little known among potential users is the theory of commitment costs (Zhao and Kling 2000, 2001, 2004).

In such conditions, economic theory suggests that WTP for a good does not solely depend on its intrinsic characteristics but also on other factors such as a good's uncertainty level, the time available to make a purchase decision or the level of withdrawal from a purchase. Zhao and Kling (2000, 2001 and 2004) have deduced that there is a commitment cost associated with a decision to purchase today which forgoes any future option to acquire additional information about a good. Consequently, commitment costs may have significant effects in estimating WTP and its consequent implications.

Despite numerous studies having highlighted the existence of commitment costs (e.g. Johannesson et al. 1999; Lusk 2003; Corrigan 2005; Corrigan et al. 2008; Kling et al. 2013; Bazzani et al. 2017), and their influence on the WTP, a little explored idea regarding identifying the intrinsic characteristics or attributes of an asset which may influence WTP when there are commitment costs or which may contribute to arising them. Knowing little about an assets attributes may give rise to consumer uncertainty on the real value of an asset and consequent delay while further information is sought prior to purchase. In the case of digestate, knowing little about its chemical/physical properties could create farmer uncertainty about its use with consequent repercussions for the WTP (Jones et al. 2010) because of commitment costs.

So, on these premises, the aim of this study is to evaluate from the perspective of the theory of commitment costs if the level of farmer understanding about digestate attributes could influence the WTP. Thus, research was carried out in Sicily (Italy) on a sample of 223 Sicilian farmers to correlate their WTP for digestate with a set of eight attributes which usually characterise organic soil conditioners. An experimental design was set up so that participants were given different waiting times to decide on their WTP and different levels of information on the attributes of organic soil conditioners. In this way, it was possible to determine which digestate attributes influenced their WTP by varying waiting times and information levels.

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Below, there is some brief data on the potential for biogas and digestate in Sicily where our research was conducted.

Background information

Digestate is part of the biogas chain, an optimum example of circular economy which is a closed-cycle system in which all the products are resources and none are waste (Ammenberg and Roozbeh 2017). Fundamental to closing the cycle is the correct agronomic use of digestate which plays a key role in improving the environmental compatibility of anaerobic digestion with the surrounding environment both in terms of reducing costs and farmers' dependence on industrial fertilisers (Chinnici et al. 2015; Selvaggi et al. 2017; Valenti et al. 2017a). Inspired by 'biofuels done right' (Dale et al. 2010) which refers to integrating anaerobic digestion within the farm without reducing food or fertiliser production, 'biogas done right' term has been coined (Dale et al. 2016).

Due to the 'biogas done right' principle, soils can be employed all year round, crop rotation can be diversified, industrial fertiliser consumption can be reduced by using digestate and renewable energy can be used for the needs of the farm (Cerruto et al. 2016; Valenti et al. 2017b). In Sicily, where this survey has been conducted, the principle of 'biogas done right' has considerable potential to be applied efficiently. In particular, in Sicily, anaerobic digestion can make use of at least three macro-categories of biomass: (1) waste and agricultural and agro-industrial by-products (e.g. olive residues, citrus pulp, whey) which are often treated as wastes; (2) silage from traditional Mediterranean crops in rotation or the second harvest of the main crops chosen according to irrigation availability; (3) silage or plant cuttings from typically Mediterranean bushy crops (e.g. Prickly pear, *Opuntia spp)* grown on marginal land (Selvaggi et al. 2018a; Valenti et al. 2017c).

Methods

From April to June 2017, 223 Sicilian farmers (owners or managers) were interviewed, all of whom are involved in decision making regarding farm machinery purchase. They were recruited with the help of local agricultural unions and some Sicilian agricultural cooperatives. Farmers participated in a non-hypothetical experimental auction (Lusk and Shogren 2007; Pappalardo et al. 2016; Wongprawmas et al. 2016; Selvaggi et al. 2018b, 2018c). This type of experiment offers the advantage of providing an incentive for participants to truly reveal their preferences. A second price experimental auction mechanism was designed to elicit WTP for the digestate, and we couple these data with answers from a set of Best–Worst (BW) scaling questions that provide a score of the relative importance of various attributes of soil conditioners. By combining the two approaches, we are able to provide an estimate of attributes that can affect WTP for digestate.

In the first step of the study, we recruited farmers for the experimental auction, and at the same time, farmers were asked questions on knowledge of soil conditioners, digestate and demographic information. When the farmers were asked about their willingness to participate in the survey, the interviewers asked some screening questions: 1) Were they owners or managers of the farm? 2) Were they responsible for acquiring farm machinery? 3) Did they use soil conditioners on the farm or would they be interested in doing so? If all the answers were affirmative, those farmers were invited to take part in the survey by meeting up 1 day at a predetermined time to be interviewed using

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the experimental auction method. If even in this case they answered affirmatively, the farmers were invited to fill out a questionnaire asking for some socio-demographic data. In addition, the questionnaire contained questions, formulated with the BW method, on the relative importance of a set of soil conditioners' attributes.

In the second step of the study, the farmers' WTP for digestate was evaluated by a second price experimental auction (Vickrey auction) (Vickrey 1961). Prior to the actual survey, a preliminary survey was carried out on a group of farmers with the double aim of testing the experimental auction protocol and working out the minimum sample size of farmers to interview. The interviews took place in Sicily, in various rural areas, such as to involve farms with varying crops. To incentivise their participation in the survey, each participant was given €10 of food products.

Because there was no specific literature data on the WTP for digestate in this location, a preliminary study was conducted to help determine sample size, i.e. the number of farmers to include in each experiment treatment. As will be described momentarily, we utilised four experiment treatments. A pre-test was carried out on a sample of 60 Sicilian farmers in four different sessions corresponding to our main treatment effects. Using these data, we found a standard deviation of 5.12, and using a critical effect size of 1.34 (based on differences in means across sessions), we calculated the need of sample size of 56 subjects per treatment to attain 80% power.

Below, more detail on BW scaling and the second price auction are provided.

Best-worst scaling

To identify the relative importance of different attributes in the soil conditioner purchasing decision, we used the BW scaling approach, which was originally introduced by Finn and Louviere (1992) and was further developed by Marley and Louviere (2005). Respondents were shown a set of items and were asked to indicate which was the best and which was the worst (or, in this case, which was most and least important). Respondents made several repeated choices where the set of items varies across questions.

In our survey, the items used in BW questions were eight soil conditioners' attributes selected by main literature on the topic (e.g. Pappalardo and Lusk 2016; Dahlin et al. 2017; Hou et al. 2017). The eight attributes and the definition of each are reported in Table 1.

To determine which combination of attributes to present to respondents, we utilised a balanced incomplete block design (BIBD). The eight items (eight attributes) were assigned in groups of five to eight different BW questions (i.e. there were eight BW questions, each containing five of the attributes). To analyse the data obtained from the BW questions, we counted the number of times that a respondent chose an attribute as the most important and subtracted the number of times that the same respondent chose the same attribute as least important across the eight questions. Because each attribute appeared five times, the highest possible score is + 5, and the lowest is − 5.

The experimental auction protocol

The farmers in the experimental auction were each assigned a personal ID number and given a bag of bidding tickets so as to be able to bid anonymously during the auction experiment. Once the farmers were all seated, the coordinator explained that the experimental auction consisted of various rounds (depending on the treatment) and that

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Table 1 Organic soil conditioners' attributes

Organic origin	Organic soil conditioners are different from chemical fertilisers
Soil fertility	Organic soil conditioners have positive effects on soil fertility
Environmental sustainability	Organic soil conditioners production has no environmental impact
Local production	Organic soil conditioners are sourced locally
Safety	Organic soil conditioners are safe to use because they are not chemical products
Price	Organic soil conditioners costs
Natural product	Organic soil conditioners are natural products which contribute to producing healthier foods
Microbial activity	Organic soil conditioners improve microbial activity in the soil because they are rich in organic substances

each participant would make various bids to acquire digestate. With all the rounds over, one round would randomly be selected to reveal the auction winner and the second highest bid which would represent the market price (Vickrey auction) (Vickrey 1961). The number of rounds depended on the experiment treatment the farmer had been allocated to but in never treatment, after each round, data on the highest bid and the second highest bid which determined the sale price were provided.

Prior to the experimental auction with the digestate, five test rounds were carried out with an anonymous test product (a 500 g packet of spaghetti). This auction was only to familiarise the bidders on the protocol. In the real auction, the bidding was for a ton of digestate and consequently the auction winner really bought a ton of digestate paying the second highest price. The auction winner received a coupon for a ton of solid digestate at market price from a known producer. The farmers' bids did not include transport costs from the producer to the auction winner's farm.

Experiment treatments

The survey was designed to evaluate whether waiting for additional future information on digestate would influence their WTP for it. So, the experiment was designed with four treatments subdividing the farmer sample into four subgroups to which bidders were randomly assigned.

In the first treatment, 'Treatment 1' (T1, 56 members), the experimental auction had only one round, and its members were only provided with basic information on digestate, e.g. where it was produced and how it worked on the soil. Members were also shown a sample of digestate in a container which they could touch and smell. No information on the attributes described above was provided to the participants.

In the second treatment, 'Treatment 2' (T2, 55 members), the experimental auction had five rounds, and bidders were given the same basic information on digestate as in the previous group and shown the same sample of digestate. No information on the attributes described above was provided to the participants.

In the third treatment, 'Treatment 3' (T3, 56 members), the experimental auction had ten rounds, and the bidders were given the same basic information as in the two previous groups as well as the same sample of digestate.

In the final fourth treatment, 'Treatment 4' (T4, 56 members), the experimental auction had ten rounds, but bidders were told that after the first five rounds they would receive additional information on digestate regarding the attributes described above

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(organic origin, soil fertility, etc.). So, the bidders made their first five bids on the basic information received in the three previous treatments. Subsequently, bidders made five more bids having received the additional digestate information.

To avoid any issues of bias or affiliation (Corrigan et al. 2011), in none of the treatments was the winning bid revealed at the end of each round nor the second highest bid representing the market price. Table 2 shows the treatment characteristics.

Results

Summary statistics

Table 3 shows the main socio-demographic characteristics of the farmer samples interviewed in the four experiment treatments. The values of Fisher's exact test show that the samples in the four treatments show no differences in terms of gender, age, qualifications, farm income or crop type. In other words, the sample data set is compatible with the null hypothesis (H0) of equal means such that the original populations of the four experiment treatments have the same structure and that any observed differences with the sample data is due to chance.

In particular, for the four interviewed groups, men predominate and the prevalent mean ages are between 18–39 and 40–49. The prevalent educational rate is middle school diploma, and the prevalent income of farms run by the interviewees was more than € 50,000 per year. The main farm crops were seed crops and field horticulture.

Table 4 shows the descriptive statistics for WTP in the four treatments. Comparing them, the statistics seem to favour the commitment costs theory and the delay effect to acquire future information. The average bid was highest for T1 (auction with only one round) at €15.82; whereas, the lowest average bid was for T3 (auction with ten rounds) at €5.77. This result might signify that despite not knowing exactly what might be explained in subsequent rounds, the fact that the farmers had the opportunity to learn through more bids, may have been sufficient to lower their WTP in treatment T3 compared to T1 and T2.

Moreover, T4, the average bid in the first five rounds (T4a) was much lower than in the final five rounds (T4b) having received the additional information on digestate.

Results of the BW analysis applied to attributes of soil conditioners are shown in Table 5. Soil fertility is on average the most important attribute across the four treatments, while environmental sustainability and natural product were the next most important attributes on average. The other attributes with positive scores were microbial activity and organic origin. On the contrary, the least important attributes for farmers are local production, safety and, quite surprisingly, price.

The exact values of the Fischer's test show that the farmer samples in the four treatments show no point differences relative to the importance of the soil conditioners

Table 2 Treatment characteristics

	(T1)	(T2)	(T3)	(T4)
Auction protocol	Yes	Yes	Yes	Yes
Sample to touch and smell	Yes	Yes	Yes	Yes
Basic information	Yes	Yes	Yes	Yes
Detailed information	No	No	No	Yes
Winning bid feedback between rounds	No	No	No	No

Table 3 Socio-demographic characteristics

	(T1) (56 units)	(T2) (55 units)	(T3) (56 units)	(T4) (56 units)	Total sample (223 units)
Gender					
Male	92.9%	94.5%	94.6%	96.4%	94.6%
Female	7.1%	5.5%	5.4%	3.6%	5.4%
Fisher's exact test *p* value 0.613					
Age					
18–39	32.1%	38.2%	37.5%	25.0%	33.2%
40–49	32.1%	29.1%	39.3%	44.6%	36.3%
50–65	30.4%	21.8%	16.1%	25.0%	23.3%
> 65	5.4%	10.9%	7.1%	5.4%	7.2%
Fisher's exact test *p* value 0.459					
Educational rate					
Elementary school	3.6%	9.1%	7.1%	3.6%	5.8%
Middle school	28.6%	29.1%	39.3%	46.4%	35.9%
High school Diploma	35.7%	38.2%	39.3%	30.4%	35.9%
Degree	30.4%	21.8%	14.3%	17.9%	21.1%
Other	1.8%	1.8%	0.0%	1.8%	1.3%
Fisher's exact test *p* value 0.407					
Farm income (€/year)					
Less than 10,000	14.3%	12.7%	16.1%	8.9%	13.0%
10,000–19,999	28.6%	27.3%	32.1%	23.2%	27.8%
20,000–39,999	25.0%	25.5%	30.4%	19.6%	25.1%
40,000–49,999	5.4%	1.8%	8.9%	1.8%	4.5%
> 50,000	26.8%	32.7%	12.5%	46.4%	29.6%
Fisher's exact test *p* value 0.732					
Crops					
Seed	53.6%	43.6%	69.6%	42.9%	52.5%
Fruit	7.1%	9.1%	10.7%	10.7%	9.4%
Citrus	8.9%	7.3%	5.4%	8.9%	7.6%
Livestock	10.7%	12.7%	1.8%	1.8%	6.7%
Field Horticulture	17.9%	23.6%	1.8%	35.7%	19.7%
Greenhouse Horticulture	0.0%	1.8%	5.4%	0.0%	1.8%
Other	1.8%	1.8%	5.4%	0.0%	2.2%
Fisher's exact test *p* value 0.370					

Table 4 Willingness to pay for digestate (Euro/ton) per treatment

Treatment	Mean [€/t]	Median [€/t]	Minimum [€/t]	Maximum [€/t]	St-dev
T1	15.82	10.00	0.00	80.00	16.89
T2	13.72	10.00	0.00	64.00	12.76
T3	5.77	2.87	0.00	53.00	8.63
T4	11.09	9.63	0.00	53.00	9.31
- T4a	*6.27*	*2.95*	*0.00*	*28.00*	*6.58*
- T4b	*15.92*	*11.65*	*0.00*	*78.00*	*15.10*

Table 5 Statistics of best–worst scores for soil conditioners' attributes

	T1	T2	T3	T4
Organic origin	0.46	0.67	0.11	− 0.16
Fisher's exact test *p* value = 0.0801				
Soil fertility	1.66	1.36	1.71	1.61
Fisher's exact test *p* value = 0.7682				
Environmental sustainability	0.79	0.65	0.27	0.34
Fisher's exact test *p* value = 0.4410				
Local production	− 1.43	− 0.82	− 1.16	− 0.57
Fisher's exact test *p* value = 0.1297				
Safety	− 0.57	− 1.00	− 0.88	− 0.63
Fisher's exact test *p* value = 0.5412				
Price	− 0.66	− 0.60	− 0.07	− 1.09
Fisher's exact test *p* value = 0.2757				
Natural product	0.48	0.55	0.27	0.77
Fisher's exact test *p* value = 0.2067				
Microbial activity	0.21	0.33	0.34	0.61
Fisher's exact test *p* value = 0.7319				

attributes with the exception of the 'organic origin' attribute which was evaluated negatively only by the farmers who participated in treatment T4. This highlights that in all treatments, farmers had similar opinions on all the researched attributes. This homogeneity makes the results very comparable.

Effect of soil conditioners' attributes on farmers WTP for digestate

To estimate effects of soil conditioners' attributes on WTP for the digestate, four OLS regressions were estimated in which the WTP for the digestate was specified as a function of the BW scores. The dependent variables in the four OLS regressions were as follows: 1) WTP for the digestate with no delay and without information on digestate's attributes (T1), 2) WTP for the digestate with average delay and without information on digestate's attributes (T2), 3) WTP for the digestate with long delay and without information on digestate's attributes (T3), 4) WTP for the digestate with delayed information (T4). The independent variables in each regression are the scores related to the eight attributes obtained through the BW scaling. The score of the attribute 'local production' was omitted to avoid perfect collinearity (the sum of all BW values is always zero by construction).

The regressions showed which digestate attributes influence WTP by varying wait times and the possibility of acquiring further information. Table 6 shows that WTP for digestate is influenced by variables according to treatment. In treatment T1, where participants bid without a wait time nor with any information on the digestate, their WTP is significantly negative only for the 'security' attribute. In treatment T2, when participants could make five bids, WTP was influenced not only by 'security' but also by 'natural product' and 'microbial activity'.

'Environmental sustainability' and 'price' were statistically significant in T3 where participants had long wait times to decide on their WTP (ten bids).

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Table 6 OLS regression of attributes affecting willingness to pay for digestate

Attributes included in the models	T1	T2	T3	T4a	T4b
Const.	11.774 (0.0001) ***	9.4533 (0.0001) ***	2.8795 (0.0001) ***	3.9313 (0.0002) ***	13.417 (0.0000) ***
Organic origin	0.4975 (0.4212)	0.3214 (0.7042)	− 0.1993 (0.5890)	− 0.2564 (0.6120)	− 2.6421 (0.0084) ***
Soil fertility	0.9465 (0.3159)	− 0.2672 (0.6540)	0.3260 (0.2872)	− 0.1544 (0.7044)	− 2.2206 (0.0001) ***
Environmental sustainability	− 0.4454 (0.6843)	− 1.2449 (0.1311)	− 0.4731 (0.0629) *	− 0.57858 (0.1294)	− 2.1899 (0.0002) ***
Safety	− 1.8563 (0.0859) *	− 2.8498 (0.0016) ***	− 0.6556 (0.2117)	− 0.4310 (0.3795)	− 3.1472 (0.0023) ***
Price	− 0.5677 (0.4405)	− 0.2078 (0.7163)	− 0.7885 (0.0015) ***	− 0.5360 (0.2100)	− 1.8548 (0.0046) ***
Natural product	0.3112 (0.7855)	3.1440 (0.0028) ***	0.4772 (0.3047)	1.1918 (0.0289) **	− 0.3263 (0.7267)
Microbial activity	0.1671 (0.8206)	− 0.7236 (0.0894) *	0.2637 (0.5272)	− 0.0036 (0.9878)	− 1.0926 (0.0170) **
	$R^2 = 0.23$	$R^2 = 0.75$	$R^2 = 0.37$	$R^2 = 0.30$	$R^2 = 0.40$
	Adjusted $R^2 = 0.12$	Adjusted $R^2 = 0.72$	Adjusted $R^2 = 0.27$	Adjusted $R^2 = 0.20$	Adjusted $R^2 = 0.31$

Values in the brackets are *p* values: *10%; **5%; ***1%

Finally, in T4, there were significant differences in the attributes which influence WTP. In the first five rounds (T4a), when participants had little detailed information on digestate, only 'natural product' was significant. By contrast, in the last five rounds (T4b), when participants had extra information on digestate, WTP was statistically influenced by all the attributes except by 'natural product'.

Discussion

The results of our study show above all farmers' WTP for digestate as an organic soil conditioner for their farms. It confirms therefore that which has been highlighted by other studies—farmers' interest in digestate (Saveyn and Eder 2014; Dahlin et al. 2017). This is a positive result which can help grow the environmental sustainability of anaerobic digestion on farms and increase income from biogas, traditionally dependent on state subsidies.

Furthermore, the studies' results confirm previous studies on the existence of commitment costs and their influence on the WTP for a certain asset (Lusk 2003; Bazzani et al. 2017). In fact, a greater WTP for digestate was obtained when the participants were provided with detailed information on its attributes (treatment 4b).

This signifies that the information provided might have diminished the degree of participant uncertainty about digestate attributes, lowering commitment costs and consequently increasing the WTP. Moreover, confirming the results of previous studies (Corrigan 2005; Corrigan et al. 2008; Kling et al. 2013), the WTP values obtained in this study change according to how much time participants had to come to a purchase decision. In particular, the WTP for digestate was lowest when participants had more time for their bids (T3); whereas, it was highest when there was least decision time (T1).

Nevertheless, our studies' results go beyond those of the existing literature because in addition to highlighting commitment costs in the purchase process of digestate, the research tried to identify which digestate attributes are connected with the WTP by changing wait times and the level of available information. Identifying such attributes in

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different contexts might contribute to explaining why commitment costs arise in the digestate purchasing process.

Our study highlighted that the digestate attributes, which influence the WTP probably due to commitment costs, change according to the influx of extra information. With extra information on digestate, nearly all the attributes influenced, even if negatively, WTP. This has important implications for biogas and digestate since notwithstanding their undoubted interest, the farmers have a negative perception of the organic origin of digestate, the environmental sustainability of the production process, security, price and its effects on soil fertility.

These last results were not presented by T1, T2 or T3, which might lead to a misinterpretation regarding the factors influencing the purchase of digestate. To reinforce and make more widespread the use of digestate as a soil improver for farms, the causes should be investigated into the commitment costs factor to overcome farmers' perplexities about the properties of digestate. The lack of specific information on digestate characteristics significantly lowers their WTP due to commitment costs about the real characteristics and benefits for agricultural soil.

Conclusions

In this study, the WTP for digestate as an organic soil conditioner for their farms was evaluated for a sample of Sicilian farmers. The results highlight a positive WTP, but farmers are strongly influenced by how much information is available on digestate. Without it, farmers' WTP decreases drastically probably due to phenomena correlated to what economic theory calls commitment costs.

Results of our study could have important implications for organic soil conditioner market and biogas sector. Understanding attributes affecting farmers' WTP for digestate can promote the market of digestate among farmers with positive effects on soil quality and soil fertility due to its promptly available nutritional contribution to crops. Moreover, our results could be important for biogas industry since digestate is currently mainly used in those geographic areas where anaerobic digesters are widespread. Understanding factors affecting purchasing process of digestate can boost the diffusion of digestate also in other areas like the Mediterranean basin where high quantities of biomasses are available, but the use of digestate as soil conditioner is even limited since it is not well-known among farmers. Moreover, since the profitability of digesters is traditionally dependent on state subsidies, opening new markets to commercialise digestate could create new income opportunities for digester managers especially in those areas where the spread of anaerobic digesters is still low.

The authors are aware of certain limits in this study such as the location where the research was carried out or the number and appropriateness of attributes of the organic soil conditioners considered. Future research could further explore other digestate attributes which could influence WTP or verify the analysis model we adopted in other locations. However, our results highlight a positive perception of digestate by farmers which may have important implications for both the organic soil conditioner market as well as for the biogas industry within which digestate is a significant output.

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Availability of data and materials
All data were acquired and elaborated by the authors. Data supporting the research are available by requesting to the authors.

Authors' contributions
The work is the result of the full cooperation of all authors. However, the first author wrote all the section 'Methods' and the paragraph 'Summary statistics'; second author (corresponding author) wrote paragraphs 'Background information', 'Effect of soil conditioners' attributes on farmers WTP for digestate' and the section 'Discussion'; fourth author wrote the principal description of the section 'Background'; third and fifth authors wrote the section 'Conclusions', and they supervised the work. All the authors read and approved the final manuscript.

Competing interests
The author declares that he/she has no competing interests.

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