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RESEARCH ARTICLE

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Farmers' perception of soil health: The use of quality data and its implication for farm management

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Abstract

Preventing and reversing soil degradation is essential to maintaining the ecosystem services provided by soils and guaranteeing food security. In addition to the scientific community, it is critical to engage multiple stakeholders to assess the degree of soil degradation and mitigation strategies' impact and meet the United Nations' Sustainable Development Goals, European Union's Common Agricultural Policy, and other national and international goals. A semi-structured questionnaire was distributed across countries participating in the EU Horizon-2020 "Transforming Unsustainable management of soils in key agricultural systems in E.U. and China. Developing an integrated platform of alternatives to reverse soil degradation (TUdi)." Using farmers' associations and educational institutions as an intermediate to distribute the questionnaires was an effective strategy for gathering a high number of responses. Results from 456 responses to the questionnaire showed that farm country, size, type of agriculture, and educational level of farm managers were significantly associated with the farmers' perception of soil degradation issues. Farm size and type of agriculture were also correlated with applying a nutrient management plan. The implications of the results for soil conservation measures are discussed. Additionally, we highlight the potential of projects such as TUdi for creating collaboration networks to drive widespread adoption by farmers of technologies to reverse the degradation of agricultural soils.

KEYWORDS
agricultural stakeholders, conservation agriculture, Europe, questionnaire, soil degradation

1 | INTRODUCTION

As soil is the basis for life, it is crucial to guarantee its conservation. The Sustainable Development Goals (SDGs) of the United Nations for 2030 include zero hunger, good health and well-being, climate action, and life on land, which depend on healthy soils and productive agricultural systems. In addition, healthy soils provide a range of ecosystem services (ES), such as the support of land habitat for fauna and the protection of water quality through the regulation of infiltration. Despite its crucial importance for supporting life, one-third of the world's soils are degraded, according to the FAO Global Soil Partnership 2021–2022 (FAO, 2022).

Hence, maintaining soil health and reversing soil degradation is crucial. Substantial progress has been made in assessing the degree of both physical and chemical degradation (Borrelli et al., 2021; Dalgaard et al., 2012; Klages et al., 2020; Panagos et al., 2015), which has shown that the average soil loss rate across the world considerably exceeds soil production rates (Montgomery, 2007), despite the application of policy interventions, which has reduced soil loss rate by 9.5% on average in Europe (Panagos et al., 2015). However, sharper change must occur to achieve the SDGs for 2030.

Succeeding in reversing soil degradation depends on the collective commitment of different stakeholders: farmers, companies, policymakers, and scientists. The work currently developed within the scope of the EU Horizon-2020 "Transforming Unsustainable management of soils in key agricultural systems in EU and China. Developing an integrated platform of alternatives to reverse soil degradation (TUdi)" (project No. 101000224) aims to use scientific knowledge to drive widespread adoption by farmers of technologies to reverse the degradation of agricultural soils.

The challenge in bridging farmer and scientific knowledge arises from their intrinsically different natures: science attempts to deal with universal and general knowledge, whereas local realities are complex and heterogeneous (Bicalho & Peixoto, 2016). Despite the progress that has been made in the past decades to assess soil quality through various methods of remote sensing (Angelopoulou et al., 2019; Vrieling, 2006; Yiming et al., 2018), modelling (Borrelli et al., 2018; Krasa et al., 2019) as well as the amount of official data publicly available, we still need to bridge the gap between the scientific knowledge and the end user – farmers. Farmers are the ultimate executors of any conceived conservation methods and, therefore, the primary players in the conservation of soils (Burek et al., 2015; Doran, 2002; Ingram et al., 2010; Ogieriakhi & Woodward, 2022).

In scientific studies, the delimitation of the research questions and the investigation of specific hypotheses often require a simplification of complex interrelationships. This becomes even more pronounced when cause–effect relationships support management recommendations. Therefore, there is a dire need to improve the communication between scientists and farmers – clarifying that proposals should target each context and that specific site characteristics should be considered before adopting any proposed solution. Moreover, we consider the importance of the bottom-up approach to engage with farmers and to motivate the adoption of practices targeting the UN's, CAP, and other national and international goals (Bechini et al., 2020; Bijttebier et al., 2018; Hijbeek et al., 2019). Farmers play a central role in food production, so their engagement is fundamental to the success of achieving sustainability goals.

This article examines farmers' perception of their soils, the need, and motivation for their conservation, and relates farmers' impressions to their demographic traits. The input information is questionnaires answered by farmers who responded to the survey carried out by the TUdi project. In this survey, the authors assessed the respondents' soil health awareness, demand for additional soil parameter information, and willingness to implement different developed tools.

2 | METHODOLOGY

We took an inductive approach to this study. Firstly, we prepared a semi-structured questionnaire to explore farmers' socioeconomic traits, their perception of soil health in their fields, and their motivation for implementing soil conservation practices (see Appendix S1 and Section 2.3). Next, the project partners contacted farmers using different approaches, which were discussed subsequently (see Section 2.2). Once we received the responses, we tested for relationships between variables with chi-square at a 95% confidence level (see Sections 2.4 and 3). The following sections further discuss each of these steps in more detail.

2.1 | Participants

The study focused on the partner countries of the TUdi project: Austria, Bulgaria, China, Czech Republic, Italy, Hungary, Spain, and the United Kingdom. Because the TUdi project aims to develop decision support tools for farmers' use, the targeted public for the questionnaire was private farms based on family farming.

2.2 | Questionnaire

The questionnaire consisted of 33 questions and can be found in the Appendix S1. These answers create a basis of data for this manuscript. In addition, the questionnaire was semi-structured, allowing fast information collection, data standardization, and comparative analysis (Nunes et al., 2016).

The questionnaire consists of three main parts. Part 1 included general questions about the farm manager and the farm itself: age, gender, level of education, and type of farming. Part 2 asked for the perception of soil health and nutrient management on his farm. Finally, part 3 dealt with social, soil general knowledge, and communication channels used.

We would like to mention that the terminology used on the questionnaires does not always coincide with some definitions commonly used in Academia but instead reflects the terms detected during prior meetings with farmers and associations. For instance, although soil scientists have generally distinguished the definition of soil health and quality (Arshad & Martin, 2002; Karlen et al., 1997), these terms were used as approximate terms in our questionnaire. During the meetings, project partners mentioned that soil health is crucial to keep soil function and that, to succeed, farmers need to supervise and remedy (if needed) soil quality parameters over time.

The questionnaire was performed through both face-to-face and online questionnaires, with support from the academic institutions participating in the TUdi project. The electronic version of the questionnaire was designed using Google Forms. We then translated the questionnaires into each of the national languages of the participating countries. Data were collected between January and June 2022.

2.3 | Data acquisition

Questionnaire dissemination strategies varied between countries.

Within the *Czech Republic*, online meetings took place with the Association of Private Farming of the Czech Republic (ASZ CR) and the Union of Organic Farmers (PRO-BIO). Farmers and farm companies were approached through both associations to respond to the questionnaires, while other farms were contacted individually. A total of 134 respondents come from the Czech Republic.

In *Austria*, TUdi network comprises farmers, researchers, representatives of farmer associations, agricultural advisors from the chamber of agriculture, policymakers, an eco-activist, and the operational manager and teachers at farming schools in Lower Austria. A meeting on 17 November 2021 initiated the Austrian TUdi network for jointly developing soil health remediation strategies and introducing the attendees to the questionnaire. Accordingly, the questionnaires were distributed to Austrian farmers via agricultural advisors and teachers at agricultural schools. Data acquisition was most effective through the distribution of questionnaires by teachers at agricultural schools.

In *Italy*, the staff from UNITO involved in the project contacted several farmers individually. The questionnaires were submitted either by face-to-face interviews or in digital format. A total of 80 questionnaires were filled out.

In *Spain*, the Spanish National Research Council (CSIC) and AgriSat contacted different farmers' associations, farmers, and academics by email. The scope of the TUdi project was explained, and the link to the online questionnaire form was provided. Farmers and scholars were also contacted directly. A compensation consisting of a USB containing informational material about sustainable practices and a bag with a mix of autochthonous seeds for temporary cover crops was sent to those respondents who answered most of the questions. A total of 66 responses were collected from Spain.

In the *United Kingdom*, we distributed the questionnaire through educational institutes such as agricultural colleges, advisory bodies, government agencies, and farmers' unions. However, because of the prolonged COVID-19 restrictions in the UK, this strategy was not as successful as reaching out directly to farmers. There were two main ways for the team to directly reach farmers: exhibiting at a national agriculture show and contacting farmers who already had a relationship with the research team through previous collaborations. All acquired data were collected in digital format. Unfortunately, many questionnaires were sent back to the team incomplete, resulting in only three complete questionnaires.

In *China*, we used the Chinese application WeChat to send the Chinese version of the questionnaire to the director of Farmers Association in Luochuan County, in Shaanxi Province (a region famous for apple production). He then directly contacted local farmers and collected the answers. However, we consider the travel restrictions related to the COVID-19 pandemic prevented the investigation of a more significant number of farmers, and only 17 responses were gathered.

In *Hungary*, ATK staff conducted telephone interviews. The National Chamber of Agriculture is regularly represented at the TUdi stakeholders' meetings but was not authorized to deliver the questionnaire directly to the farmers. The institute staff visited farmers with whom contact had already been made in previous cooperation projects. Of the interviewed farmers, 12 completed the entire questionnaire.

In *Bulgaria*, the project team from New Bulgarian University organized the survey based on the involvement of the National Agricultural Advisory Service experts in Bulgaria. Face-to-face interviews with 60 selected respondents submitted the questionnaires. The selection of respondents aimed to represent Bulgarian farmers, considering farm size and crop type.

Moreover, the team assessed the importance of not overloading the farmers with demands; we considered it essential not to pester farmers repeatedly with the questionnaire and attempt to make communication as effective as possible, which was also the motivation behind using associations as a messenger for disseminating the questionnaires.

2.4 | Statistical approach and data evaluation

We combined the responses received in physical paper form with the ones collected from Google Forms. Subsequently, we tested for relationships between variables with chi-square at a 95% confidence level, using SPSS version 29.0.0.0 statistical software. For the multiple-response questions, the absolute number of respondents to each option was converted to the percentage of the total number of respondents who answered the question. This allowed for comparing different variables in the multiple-response question and across countries.

Descriptive statistics were used to present the response distribution for closed questions. Answers for age and farm size were provided in numerical form, and we converted them into categories, so each class would represent different age and farm size groups (e.g. younger farmers contrasted with older farmers and small farmers contrasted with larger farms). We classified age into three categories: up to 40, between 40 and 60, and older than 60. We merged farm size into three classes: up to 30, between 30 and 60, and above 60 hectares. As for the type of farming, initially, the options provided to respondents were conventional, agroecological, and biological. We merged the latter two, considering they represent farms that apply conservation farming techniques. A similar merging was done for the education variable. On the questionnaire, respondents were given the options of Primary, Secondary, Higher Secondary, University, and Post-graduate. We merged classes as Primary, Secondary, and Higher Secondary. The percentages were calculated relative to the total of valid answers to each question; blank responses were disregarded.

We determined the appropriate sample size for a confidence interval of 10% and a confidence level of 95% based on data on number of farms and proportion of farms practising non-conventional farming extracted from the Department for Environment Food & Rural Affairs of the United Kingdom, Eurostats, and from the Chinese Census Data.

3 | RESULTS

Based on data on the total farmers' population and the proportion of farms practising non-conventional farming available for the participating countries, we calculated the necessary sample size for the admitted confidence interval (CI) of 10%, at the 95% confidence level (CL) used. The countries that comply with these requirements were Austria, Bulgaria, Czech Republic, Italy, and Spain, where the number of responses was greater than the necessary sample size for a CI of 10% and a CL of 95%.

We note that achieving an error of 5% requires a considerable increase in the required sample size.

As a result of not meeting the necessary sample size for the permissible error considered, responses from Hungary, the United Kingdom, and China were presented in the distribution tables but were not statistically analysed.

Additionally, because of the low number of responses from China, the particularities of the Chinese context, where the agricultural, topographical, and soil conditions differ substantially from the European countries, also contributed to the decision to disregard its responses.

3.1 | Response distribution of variables

Table 1 shows the response distribution of descriptive sociodemographic variables. This study evaluated answers to the questions referring to the perception of soil health, the application of nutrient management plans, and used sources of communication's association with sociodemographics. For all countries, male farm managers were more frequent respondents than females. The results are generally higher than those of the European Union: 71.5% of farm managers are male (Eurostat, 2016). For all participating countries, at least half of respondents were between 40 and 60 years old, except Bulgaria at 48%, overall younger than farm managers across the EU, where 58% are at least 55 (Table 2).

Conventional farming was the most common farm type; more than 75% of answering farmers practise conventional agriculture. As previously noted, we presented the responses from Hungary and the United Kingdom on the distribution tables. Still, we did not consider them in the chi-squared tests of associations presented below because of the insufficient number of responses.

The type of agriculture is significantly associated with the country, with Bulgaria and Italy having more respondents who practice the conventional kind of agriculture (Table S1, Appendix S2). More than half of the farmers surveyed had at least a higher secondary level of education. In addition, a statistically significant association between country and education was found; Spain has a higher percentage of farm managers with up to a primary level of education (22%), whereas Bulgaria and the Czech Republic have a higher rate of respondents with secondary level of education (48 and 53%, respectively) and fewer respondents with higher than secondary as compared to the other three countries. The country was also significantly associated with farm sizes; Austria, Czech Republic, and Spain were generally larger – over 50% of respondents are from farms larger than 60 hectares (ha).

The presence of livestock as part of the production on a farm is a relevant aspect because it provides the possibility to apply manure as an alternative fertilizer. On the other hand, not all farms use a mixed production chain that allows them to use self-produced manure. The Czech Republic has the most livestock use in production (71% of respondents), whereas other countries range from 14 to 38%.

Furthermore, there is a significant difference for all but one of the questions analysed (Table S2, Appendix S2). Across all surveyed countries, farmers consider soil health to be an essential aspect of their fields. Czech farm managers are the least likely to use soil quality parameters to decide on soil management (28%) over approximately half of the other countries. However, respondents from the Czech Republic mostly use soil quality information to determine soil management, but only 30% answered positively. Only 2% of Bulgarian and 4% of Italian respondents use such databases.

Responses revealed that approximately half of the study participants across all countries claim to have insufficient information concerning soil quality in the field. However, responses also showed that most European farmers are willing to use simple and cheap soil degradation indicative analyses. This suggests the potential for further cooperation between soil scientists and farmers. Few farmers claim to have enough information on soil parameters in their field while claiming to use soil quality information to decide on management. However, one must interpret the United Kingdom and Hungary results cautiously since the number of responses was low.

Czech, Austrian, and Italian respondents are the ones who use central/national databases the most. Still, the percentage of users of these databases is not prominent. The most cited sources include experimental institutes testing agricultural soils (their website) and digital maps.

As for the respondents who claimed to use soil property to decide on soil management, responses from Austria mentioned mainly factors associated with machinery (such as tire pressure) and crop rotation. Hungarian respondents most often cited soil structure, Bulgarians cited

TABLE 1 Calculated sample size for different permissible error in the estimate, at $p = .05$.

	Permissible error in the estimate	
	5%	10%
Country	Required sample	Required sample
Austria	294	74
Bulgaria	26	7
China	323	81
Czech Republic	202	51
Hungary	87	22
Italy	215	54
Spain	149	38
United Kingdom	45	12

TABLE 2 Descriptive sociodemographic variable distribution.

Variable	Options provided	AT	BG	CZ	IT	ES	GB	HU	CN
Total responses	–	83	60	134	80	66	3	12	17
Gender	Female	12%	29%	15%	15%	11%	0%	10%	0%
	Male	88%	72%	85%	85%	89%	100%	90%	100%
Age	<40	21%	35%	24%	21.5%	21%	0%	0%	20%
	40–60	69%	48%	56%	57%	52%	33%	80%	53%
	>60	10%	17%	20%	21.5%	28%	67%	20%	27%
Type of agriculture	Conventional	70%	93%	66%	80%	73%	100%	46%	17%
	Non-conventional	30%	7%	34%	20%	27%	0%	54%	83%
Level of education	Primary	5%	7%	5%	4%	22%	0%	0%	0%
	Secondary	39%	48%	53%	30%	9%	33%	0%	0%
	>Higher Secondary	56%	45%	42%	66%	63%	67%	100%	100%
Farm size	<30 ha	28%	46%	17%	47%	40%	0%	30%	92%
	30–60 ha	12%	10%	22%	25%	9%	33%	0%	8%
	>60 ha	60%	22%	61%	38%	51%	67%	70%	0%
Livestock	Yes	30%	22%	71%	14%	38%	67%	91%	76%
	No	70%	78%	29%	86%	63%	33%	9%	24%

TABLE 3 Distribution of yes/no answers in percentage.

Question	Options	AT	BG	CZ	IT	ES	GB	HU	CN
10. Do you consider soil health in your fields an important issue?	Yes	98	97	99	97	100	100	100	75
	No	2	3	1	3	0	0	0	0
12. Do you have enough information concerning soil quality parameters in your fields?	Yes	48	18	39	51	47	67	73	0
	No	52	82	61	49	53	33	27	100
13. Do you use soil quality information to decide on soil management?	Yes	47	53	72	49	57	100	100	24
	No	53	47	28	51	43	0	0	76
14. Do you use any central/national databases of soil analytical parameters?	Yes	14	2	30	14	4	0	0	6
	No	86	98	70	86	96	100	100	94
16. Do you analyse parameters related to soil health directly on your farm?	Yes	25	8	22	33	11	0	60	0
	No	75	92	78	67	89	100	40	100
19. If you got simple (and cheap) soil degradation indicative analyses, would you apply them?	Yes	56	88	93	98	88	100	82	0
	No	44	12	7	2	12	0	18	100

soil texture, and respondents from other countries cited soil chemical parameters (pH and nutrient content).

3.2 | Interactions between variables

Table 3 shows the test results between sociodemographic variables and dependent variables. Gender, age, and type of agriculture had no significant relationship with any of the dependent variables. However, the level of education was significantly associated with questions 13 and 16 regarding soil quality information to decide on soil management and the analyses of parameters related to soil health directly in the farm. Farm managers with at least a secondary level of education use more soil quality information to decide on soil management than farmers with primary education (approximately 60% against less than 30%). Besides, farmers with more than secondary education analyse parameters related to soil health directly on the farm more often than farmers with secondary education or lower (25% against 12% on average).

Farm size was unrelated to the type of agriculture: conventional agriculture represented approximately 75% of farms across all size categories.

On the other hand, farm size was significantly related to all variables but questions number 10 and 19: larger farms more often assessed to have enough information concerning soil quality parameters, soil quality information is used to decide on soil management, the more central/national databases are used, and the more parameters related to soil health are analysed directly in the farm (Table 4).

3.3 | Results concerning the soil's physical properties

Question 11 of the questionnaire asked respondents to assess the parameters and processes related to soil degradation in their farm and the degree to which each parameter was perceived. The parameters aimed to comprehend degradation processes associated with soil physical, chemical, and biological parameters: (1) soil structure, (2) organic carbon content, (3) land/soil waterlogging, (4) drought, (5) surface compaction, (6) Subsurface compaction, (7) sheet erosion, (8) rills and gullies, (9) depositional areas, (10) pH, (11) stoniness, (12) soil profile depth, (13) biota activity (worms), (14) over-fertilizer application, (15) under-fertilizer application, and (16) salinity. The distribution of farmers' evaluation (including all countries) (Figure 1).

Results show the perception of all soil degradation issues was significantly related to the country (Table S3, Appendix S2). Bulgarian farmers declared to be the least affected by degradation issues related to soil structure, organic carbon content, land/soil waterlogging, subsurface compaction, soil erosion by rills and gullies and depositional areas, and biota activity, and the most affected by surface compaction (40% of respondents). Austrian farmers are the most affected by soil structure and insufficient biota activity degradation and the least by under-fertilizer application (along with Bulgarian farmers). Farmers felt drought the most, affecting almost 76% of Spanish farmer respondents. The latter is also the most affected by erosion (both sheet and rills and gullies), pH, soil profile depth, and stoniness (along with respondents from Czechia). Bulgarian and Czech farmers are the least affected by

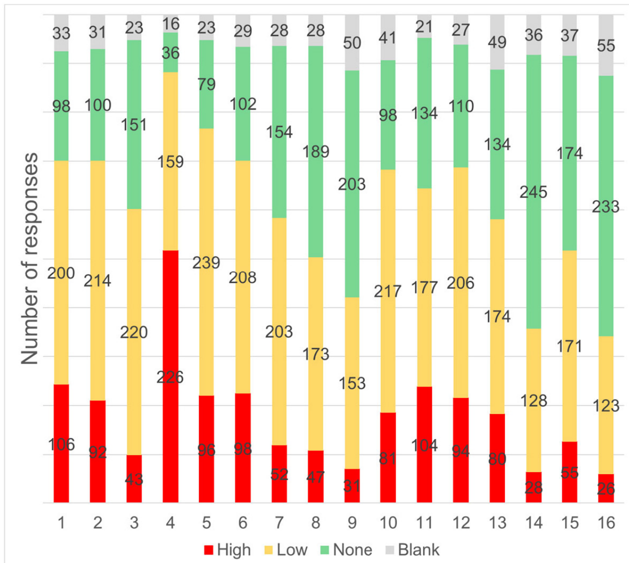

FIGURE 1 Number of farmers who claim to observe degradation processes 1–16 in their farm.

TABLE 4 Observed *p*-values for the chi-square association test between yes/no answers and sociodemographic traits.

	Gender	Age	Type of agriculture	Level of education	Farm size	Livestock
	p-Value	*p*-Value	*p*-Value	*p*-Value	*p*-Value	*p*-Value
10. Do you consider soil health in your field as an important issue?	.224[a]	.883	.312	.791	.058	.006*
12. Do you have enough information concerning soil quality in your field?	.276	.131	.401	.057	<.001*	.002*
13. Do you use soil quality information to decide on soil management?	.958	.205	.091	.004*	<.001*	.026*
14. Do you use any central/national databases of soil analytical parameters?	.402	.878	.240	.402	<.001*	.122
16. Do you analyse parameters related to soil health directly on your farm?	.183	.498	.635	.017*	<.001*	.674
19. If you got simple (and cheap) soil degradation indicative analyses, would you apply them?	.712	.286	.743	.231	.507	.143

Note: Chi-square test for association, *presents statistical significance (p-value < .05).

[a]More than 20% of the cells in this subtable have expected cell counts of less than 5.

depositional areas on their farms and over-fertilizer application.

Gender was not related to any of the perceived soil degradation issues.

The authors were also interested in evaluating whether farm size was related to the perception of the soil degradation process. Farm size was significantly associated with drought ($p=.006$), surface compaction ($p=.013$), and stoniness ($p=.011$): a higher percentage of respondents from larger farms declared suffering from drought and stoniness, whereas surface compaction affects smaller farms more often.

Higher education levels were significantly associated with higher responses for over-fertilizer application ($p=.002$) and depositional areas ($p=.032$).

Type of agriculture (conventional or non-conventional) had a significant relationship with the soil degradation issues related to biological activity ($p=.044$) and insufficient fertilizer application ($p=.027$). Twice as many non-conventional farm managers claimed an under-fertilizer application issue (22.6% as opposed to 11.3%). Surprisingly, more non-conventional farm managers claimed higher biological activity problems than conventional ones.

3.4 | Results concerning nutrient management

Regarding the application of a nutrient management plan (NMP) on their farm, there was a statistically significant relation with the country ($p<.001$) (Table S4, Appendix S2). Respondents from Spain and Italy applied NMP the most (51% and 73%, respectively). Gender was not significantly related to the application of the nutrient management plan.

Type of agriculture was also significantly associated with applying NMP ($p<.001$), with conventional farm respondents using NMP more frequently than non-conventional farm managers.

Level of education was also correlated to the application of NMP – the higher the education level, the more often respondents answered positively. Likewise, for farm size, larger farms apply NMP more often. Finally, the presence of livestock was also associated with the application of NMP: farms without livestock use NMP more often.

3.5 | Where do the farmers get the information from?

Considering the need to bridge the gap between academic knowledge and the end users – farmers, it is crucial to understand the preferred source of information of the latter. On the questionnaires, farmers responded, which was their most used source of information on soil health (Figure 2).

Overall, the preferred source of information is experienced colleagues (41%), followed by literature (37%) and Advisors/Consultants (36%). Commercial companies are the least used source of information (208 respondents do not rely on these), along with state administration (in the form of ministries, 187 respondents). Leaflets and social media are also not many relevant sources of information (only 62 respondents claimed these to be their primary sources).

All but two sources of information (YouTube and other social networks and neighbours) were significantly related to the country (Table S5, Appendix S2). Austrians use formal education as a source of information the most (73%). In contrast, Bulgarian and Czech farmers use it the least (only 10 and 17% of respondents claimed to use formal education as a primary source of information, respectively).

Type of agriculture was significantly associated with literature ($p=.03$) and associations ($p=.027$). Farms practising non-conventional agriculture use literature as a source of information more often, and more farm managers of conventional agriculture claimed not to use associations as a source of information. On the other hand, a similar percentage of conventional and non-conventional farm managers claimed to use associations as a main source of information (26% for the former and 24% for the latter).

Age was only significantly related ($p=.032$) to the use of consultants as a source of information: 44% of young farmers (age up to 40 years old) claimed to use consultants occasionally, and 20% claimed never to consult them, whereas, across the other two age groups, the distribution was nearly even.

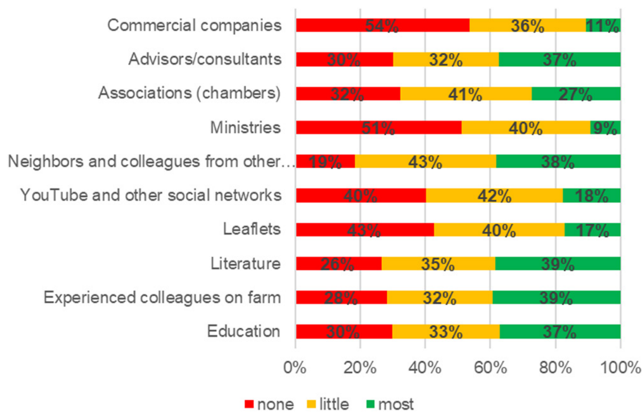

FIGURE 2 Distribution of most used source of information in percentage.

Gender had no significant association with any of the sources of information.

Level of education was significantly related to formal education ($p < .001$), literature ($p = .017$), and ministries ($p = .017$) as sources of information. Farm managers with at least a higher secondary level of studies use formal education and literature as essential sources of information (46 and 43%, respectively). On the other hand, farm managers with studies up to the primary level make more use of state administration as a source of information (nearly 70% use this at least occasionally).

Farm size is significantly associated with formal education ($p = .042$), leaflets ($p = .039$), and associations ($p = .004$): smaller farm managers use formal education less and use leaflets more often. Farms with a total area ranging from 30 to 60 ha are more likely to use associations as a source of information.

4 | DISCUSSION AND CONCLUSIONS

The present effort in gathering the survey responses resulted in a number of responses either comparable to or surpassing those obtained in similar studies (Bagnall et al., 2020; Burek et al., 2015; Fantappiè et al., 2020; Nunes et al., 2016; Rust et al., 2022). We consider the COVID-19 epidemic disease period influenced the process of gathering responses for the questionnaire, although we could still collect a meaningful number of responses. The collaboration with the farmers' associations proved to be a promising approach to gathering more responses from farmers. However, it is crucial to consider the research objectives: concentrating on a smaller group of respondents may be the most effective approach if the aim is to obtain a more comprehensive understanding of the topic, as done by other studies (Ingram, 2008; Lanker et al., 2020; O'Neill et al., 2021). It is also worth noting that, despite having gathered a substantial number of responses, the methodology used to distribute the questionnaires leads to an unknown number of reached farmers, so we were not able to assess the effective return rate of responses, such as was done in other studies where subjects were directly reached by the researchers (Bacic et al., 2003).

Furthermore, we recognize we were unable to fulfil part of the aim of the study, which was to compare the European and the Chinese context. The context during the COVID-19 epidemic has contributed to the difficulty in gathering sufficient responses, particularly in China. Considering the contrasting context of the Loess Plateau in terms of agricultural practices, crop type, and soil conditions, we have decided to exclude it from the present study, making it more European-centric. In addition, considering the scant number of responses from Hungary and the United Kingdom, we decided to exclude them from the statistical tests.

The present study did not elucidate particularities associated with the female respondents regarding the perception of soil degradation issues, application of NMP, or preferred sources of information. Furthermore, studies on women in agriculture in Europe and China are of crucial importance to achieving the SDGs agenda (Balezentis et al., 2021), particularly SGD 1,2, and broader SDGs, such as reducing inequalities (SDG 10) and empowering women and girls (SDG 5) (FAO, 2018). The FAO (2011) has also shown women are significant contributors to agricultural production. However, they still face substantial gender-specific barriers and are underrepresented in farm managing positions and land ownership. Addressing these barriers should be a high priority for attaining more equitable and sustainable agricultural development and food security, as financing for sustainable development should be focused where it is most needed (OECD, 2019).

As the present study aimed at farm managers' perception of soil degradation issues, we relied on the respondents' judgement. We found considerable differences among soil degradation issues perception and country, as well as the type of agriculture. Considering the application of conservation practices has been widely reported to ameliorate soil properties, we believe that the subjective perception of soil degradation issues might be explained by different expectations from farmers practising different types of agriculture. Therefore, further investigation on the documented farmers' perception and site-specific measured properties could be conducted to assess subject bias (Barbero-Sierra et al., 2018; Nord & Snapp, 2020; Yageta et al., 2019), which may elucidate whether smaller and non-conventional farmers have different expectations on soil health. The subject bias may also play a role in farmers' search for subsidies, which is particularly important for small farmers to invest in best management practices (Getnet et al., 2014). Even within the European Union, the country was significantly associated with the application of nutrient management plan, with the preferred source of information on soil management, and the perception of soil degradation processes. Therefore, agricultural policies must be tailored considering the specificities of each context.

As for the nutrient management plan, we found that farms without livestock more often apply an NMP. On the other hand, farms focusing on livestock might have less crop production and, therefore, less demand for biofertilizers. Considering the potential of the use of livestock waste as biofertilizers in improving soil health (Hijbeek et al., 2019; Subedi et al., 2016), more research is needed to evaluate the financial benefits to farmers from applying an NMP and assessing demand and supply of biofertilizers within the European and Chinese markets.

Additionally, the study investigated farmers' preferred sources of information, providing scientists with insights into the most effective method to convey information to the targeted audience. Rust et al. (2022) emphasized the importance of trust in how farmers inform themselves about restoration recommendations and their relatively low trust in external scientists. Indeed, agreeing with Rust et al. (2022), our study showed the priority farmers place on experienced colleague farmers as information sources. Nonetheless, the elevated positive feedback on willingness to use soil degradation indicative analysis suggests the potential for further cooperation between soil scientists and farmers from the participating countries. Understanding the preferred source of information can assist the scientific community in reaching farmers and coordinating soil restoration efforts.

The World Meteorological Organization (WMO) has just released the Global Annual to Decadal Climate Update, in which predictions suggest that the annual global near-surface temperature for each year between 2023 and 2027 is predicted to be between 1.1 and 1.8°C higher than the average for preindustrial levels. Recently, the global temperature has exceeded 2°C above preindustrial levels for the first time in recorded history (Copernicus CCS, 2023). Consequently, the likelihood of extreme events increases. As most respondents claimed drought is the most pressing issue, this reaffirms the critical and urgent need for actions to secure agricultural resilience and food security. Although addressing issues related to climate change might be complex for farmers to tackle at an individual level, the improvement of soil organic carbon, soil structure, and soil compaction are known to improve soil's ability to retain water (Acín-Carrera et al., 2013; Hijbeek et al., 2019). Therefore, further studies on the effects of improving these soil parameters on soil water holding capacity could assist in delineating priorities for public policies.

In conclusion, our study showed that sociodemographic traits are associated with the farmers' evaluation of soil degradation, the use of quality information in decision-making, the use of NMP, and the choice of source of information. The European Union has recognized the need to target specific groups of farmers, as seen in the CAP 2023–2027 strategies involving young farmers, female farmers, and smaller farms (EC, 2021). The study confirmed that farmers primarily benefit from experienced colleague farmers as information sources; this preference varies among countries. Our study confirmed that interpersonal relationships build farmers' trust and, ultimately, possibly in farm-level decision-making. As the successful implementation of conservation practices depends on the engagement of different stakeholders, so understanding their motivation, perceptions, and behaviours is fundamental in delineating public policies.

Furthermore, research on case studies of successful, long-lasting cooperation among different stakeholders – farmers, public and private institutions, and scientists could elucidate good practices and promising strategies. Our study showed that individual farmers are reachable and open to discussion in many countries. The correlation between country and farmers' perception of soil degradation suggests that elaborating public policies at the European level should consider country-specificities. A comprehensive investigation at the country level with a particular interest in target farmer groups, including open questions and round table discussions, could be beneficial to ensure the success of CAP, SDG, and other national and international agendas.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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