Mental Models Enlighten Assumptions about Farmers, Land Tenure and Soil Management

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Abstract

Agricultural tenancy is increasing, as is soil degradation and erosion. Theory suggests that these trends may be correlated, yet empirical findings are ambiguous. This paper broadens the perspective on mental models influencing farmers' soil management and disentangles assumed relationships with agricultural land tenancy. Results of a survey of farmers (n=344) in Austria reveal that tenure is less important for understanding farmers' soil management practices than items of mental models. The study sheds new light on the assumption that farmers' soil management practices depend on ownership status and planning horizons, as often suggested by agricultural economic theory.

Keywords: property structure, soil management, socio-psychological factors, questionnaire survey

JEL Code:

1 Introduction

In 2015, Sustainable Development Goals (SDGs) were adopted by United Nations member states. Soil conservation contributes not only to SDG 15 (life on land), but due to soils multi-functionality (Bünemann et al. 2018) even to SDG 2 (zero hunger), SDG 3 (good health and well-being), SDG 6 (clean water and sanitation), SDG 12 (responsible consumption and production), and SDG 13 (climate action). Soil quality is fundamentally related to human health and well-being, and most ecosystem services depend on it, such as the provision of food, water storage and filtering as well as carbon sequestration and storage (Bartkowski and Bartke 2018).

Despite the crucial role of soil for sustaining life and economic development, soil degradation continues to rise through loss of soil cover, soil erosion, salinization, acidification, and compaction. Due to its global dimension, DeLong et al. (2015) call it a "global pandemic". The effects of soil degradation are considerable. While humans obtain more than 99.7% of calories from the land (Pimentel 2006), 20% of the world's cropland show a decreasing trend in productivity and about 10 million ha of cropland are lost each year due to soil erosion (Pimentel 2006; United Nations 2017a). Additionally, soil losses proceed up to 40 times faster than the rate of soil renewal (Pimentel 2006). In Europe, the annual loss of agrarian productivity due to soil degradation from erosion accounts for around 1.25 billion € per year (Panagos et al. 2017).

Agricultural soil management is a significant source of soil degradation (Hamdy and Aly 2014; United Nations 2017b). Soil management is understood as a dynamic "interaction and relationship of anthropogenic activities with the environment" (Gessese 2018) and is defined as "human activities, which are directly related to land, making use of its resources or having an impact on it" (FAO 1995). Thus, farmers' agricultural activities are not only a source of food, feed or fiber but due to the multi-functional role of soil, farmers' soil management also provides a range of services and non-commodity goods like conserving the countryside or protecting biodiversity (Ahlheim and Frör 2003). However, resource users tend to primarily focus on the private returns of extracting resources, rather than on external costs of exploitation and degradation, potentially leading to a *'tragedy of the commons'* (Hardin 1968). In this vein, agricultural economists – since the early days of the discipline (Johnson 1950) – suggest that tenancy decreases farmers' planning horizons, which is assumed to lead to suboptimal resource allocation and degradation (Fraser 2004; Arora et al. 2015). Thus, an increasing share of rented land is considered to affect soil conservation negatively. In this respect, it appears alarming that the share of rented land is continuously increasing in many EU countries (Ciaian et al. 2010) and has more than doubled in Austria since 1960 (Holzer et al. 2013).

We address this issue in our first research question, by investigating *which soil management practices are affected by tenure in Austria* (RQ1). Following the old assumption of agricultural economics, we hypothesize that farmers apply fewer soil conservation measures on rented land than on owned land. In contrast to studies that often focus on single or few measures, such as crop choice in Sklenicka et al (2015) and Fraser (2004), application of manure in Jacoby and Mansuri (2008), conservation tillage in Lee and Stewart (1983), we consider a broader set of different soil management practices.

However, empirical results are not unambiguously supporting the assumed interlinkage of soil conservation and tenancy, depending on the country, type of tenancy, and type of conservation investment. In countries of the Global South, effects of tenure security on conservation investments have shown to be positive to ambiguous (Abdulai et al. 2011; Fenske 2011; Lovo 2016; Higgins et al. 2018), while for countries of the Global North the results tend to be even more inconclusive. In the USA, owners are considered as both less likely (Lee and Stewart 1983) and more likely (Soule et al. 2000) to adopt minimum tillage. In Europe, Sklenicka et al. (2015) showed that financial incentives can reduce initial differences in crop choice between owners and tenants, and Myyra et al. (2005), as well as Walmsley and Sklenicka (2017), identified – as predicted by theory – lower soil quality parameters on rented than on owned plots. In a recent multi-method study in Austria, only a minor impact of tenancy on crop choice was identified – and when interviewed – farmers reported treating rented and owned land differently at all, it was primarily concerning fertilization or liming and if rental was insecure or short-term (Leonhardt et al. 2019).

Thus, the reasons for this ambiguous effect of tenure on farmers' decision making – highlighted by significant and non-significant effects found equally often in an extensive European literature review (Bartkowski and Bartke 2018) – might be that tenure status alone is only one of many other variables interacting with soil conservation variables (Bijttebier et al. 2018). One alternative approach is broadening the perceptive to demographic characteristics. However, as Burton (2004) concluded in his review, demographics fall short of enlightening the social bases of farmers' environmental behaviors. In Austria, Leonhardt et al. (2019) hypothesized that missing differences in soil management on rented and owned land could be explained by close social relations between landlord and tenant. Moreover, the biophysical characteristics of a plot (proximity to the farmhouse, soil quality, etc.) influence conservation practices, but at the same time may be related to tenure status, potentially exacerbating or masking the relationship between tenure and conservation.

Integrating these insights, we examine in our second research question *which plot related factors (size, geographical and social proximity, biophysical characteristics) explain the weak tenure effect found in Austria by Leonhardt et al. (2019)* (RQ2). In qualitative interviews conducted before this study, farmers indicated that long-term contracts, close personal relationships between renter and landowner as well as different minor characteristics between rented and owned plots favor uniform soil management practices (Braito et al. in prep.). Therefore, we hypothesize that similar plot related factors (size, geographical and social proximity, biophysical characteristics) lead to the same soil management practices on rented and owned plots.

Like any other group of humans, farmers are anything but a homogenous group (Darnhofer et al. 2005) that is primarily driven by economic considerations. Already 20 years ago, Ostrom (1999) criticized Hardin (1968) for degrading resource users such as farmers to profit maximizers that can be motivated to change their behavior by economic incentives. Eventually, she proposed a social-ecological system (SES) perspective when analyzing or governing common pool resources and differentiated between a set of second tier variables relating to the resource system, resource unit, governance system, users their interactions and the outcome (Ostrom 2007). Referring to Ostrom's second tier variable of "mental models", van Riper et al. (2018) however, argue that SES studies often fail to consider socio-psychological variables. In this vein, socio-psychological perspectives on farmers' soil management practices are also scarce (Bartkowski and Bartke 2018). The authors pointed to a knowledge gap on social capital, social norms, and peer orientation, which would be helpful to understand European farmers' decision making and soil governance. Similarly, Hodge (2001) urged assessment of primary data on how farmers perceive themselves concerning their resource management, to fully understand the complexity of their daily decision-making processes. In this vein, taking a closer look at farmers' mental models seems a promising approach, as they allow "an understanding of farmers' decision-making with regard to soil management, linking perceptions, attitudes, and beliefs with behavior" (Prager and Curfs 2016, p.36).

Therefore, we examine in our third research question *which mental model items inform farmers' soil management in Austria* (RQ3). We hypothesize that mental models' items differ among farmers who apply soil conservation practices and those who do not. We expect higher ecocentric orientations or human-nature relationships (HNR), such as partner, participant and steward types to be associated with stronger intrinsic motivation for soil conservation (Flint et al. 2013; Braito et al. 2017; Muhar et al. 2017a).

We address these research questions with data from a survey of Austrian crop farmers conducted in 2018. The questionnaire covered farmers' soil management, mental models, and tenure contexts. The study is part of a larger project on farmland rental that included exploratory interviews with stakeholders, plot-level data analysis (Leonhardt et al. 2019), semi-structured interviews, and a Q methodological study (Braito et al. in prep.), all of which have contributed to development and analysis of the survey. We expect that this closer look at mental models will contribute to a better understanding of farmers' soil management and ultimately, to soil conservation policies better tailored to the characteristics and worldviews of those who manage the soil.

This study aims to contribute to a better understanding of soil management, and soil conservation in particular by extending the inquiry into the perspectives of farmers themselves. For the sake of the SDGs and preserving productive soils for future generations, we see the strong need not only to disentangle the ambiguous tenure effect (RQ1, RQ2) but even to better understand farmers' soil management practices in general (RQ3). The paper starts by briefly framing the theory justifying the study. Afterward, we present the methods and results of the survey. We conclude by discussing the implications of these findings.

2 Conceptual framework

Ultimately, it is the farmer who directly influences the soil, its conservation or its degradation. Like other humans, farmers are resource users who are driven by complex decision-making processes and mental models including values, attitudes, norms, emotions or just the willingness/reluctance to change. Besides attempting to run the farm in an economically beneficial manner, farmers align their daily farming decisions to the needs of their families, their social relationships with landowners, neighbors and colleagues, to the local context and policies, to changing markets and customer demands, etc. (Mattison and Norris 2005; Knowler and Bradshaw 2007; Prager and Posthumus 2011; Hamdy and Aly 2014; Karali et al. 2014; Rajendran et al. 2016; Leonhardt et al. 2019). Faced by these complexities, but also by the diversity of personalities and the dynamics of changing roles of farmers between productivism and environmentalism, it is increasingly important to understand how farmers themselves perceive their roles concerning resource management (Hodge 2001).

Mental models may be shaped by the role of resource users in a social system, their personal, educational and cultural backgrounds as well as their previous experiences and biases (Pahl-Wostl et al. 2011). They are considered a key aspect of effective natural resource management practices (Bang et al. 2007; Jones et al. 2011). They can help explain differences in perceptions of soil management, which should, therefore, be considered by communication or governance strategies (Prager and Curfs 2016). Mental models and accordingly framed communication strategies can strengthen conservation planning and policies (Biggs et al. 2011; Pahl-Wostl et al. 2011) and can be usefully applied by policymakers, extension services or schools to support learning processes on human-nature interaction and long-term paradigm change (Bang et al. 2007; Pahl-Wostl et al. 2010).

Therefore, at the core of our conceptual framework is the farmer's mental model (see Figure 1), which they have constructed based on their unique life experiences, perceptions, and understandings of the world (Jones et al. 2011), or more specifically of soil management. Accordingly, we assume that soil management is influenced by the farmers' mental model of soil management. Mental models are unique to each farmer and include information on the biophysical context of the farm and the plots (*resource systems*), the crops farmers want to harvest in order to generate their economic benefit (*resource units*), but also agri-environmental policies – such as agri-environmental schemes (AES), tenure formalities or time constraints (*governance systems)*. Mental models also include individuals' conceptualizations of nature and the position of themselves within it (Bang et al. 2007). These HNR perspectives are dynamic and contextual (Flint et al. 2013) and are related to human behavior (Braito et al. 2017), including particular farming motivations and practices (Yoshida et al. 2017). By linking all information, perceptions, attitudes, and beliefs with behavior, mental models are used to reason and to make soil management decisions (Prager and Curfs 2016). Each new exercise causes soil management outcomes (e.g., changes in soil fertility or erosion), which are evaluated by the farmer and result in feedback loops, which might disrupt or strengthen the farmer's previous mental model of soil management (dotted arrow in Figure 1).

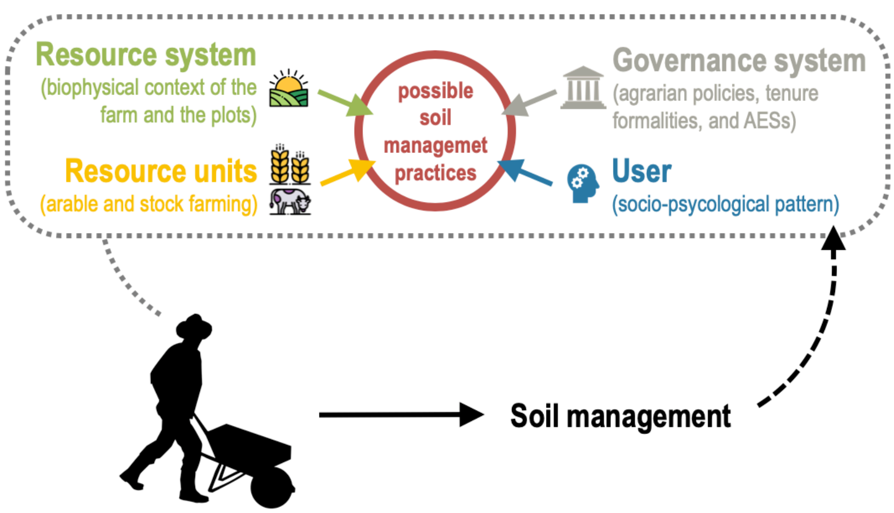

Figure 1: Conceptual framework of the farmer's mental model on soil management

3 Material and methods

In this section, we present our study design. We first explain the variables operationalized in the survey questionnaire that we used to address the research questions of this paper. Afterward, we describe the sample, how we approached the farmers and how we analyzed the data.

3.1 Questionnaire

To address the research questions outlined in the introduction, we designed an online questionnaire to incorporate diverse aspects of farm tenure and soil management, with a particular focus on mental model items. In line with insights from literature and semi-structured interviews with Austrian farmers (Braito et al. in prep.; Leonhardt et al. 2019), we incorporated different circumstances of farm tenure that might affect soil conservation practices. In two subsequent parts of the questionnaire, respondents were asked first to characterize a typical plot of rented, and then a typical plot of owned farmland they cultivate. We asked them to specify the relationship with the owner (or former owner), the distance between farm and plots, slope, the object of particular nature conservation or water conservation regulations, and which soil conservation they applied. As mental model items, we incorporate various aspects identified in the literature as affecting farmers' soil management, including norms, beliefs, and attitudes and other socio-psychological factors as suggested by Arora et al. (2015) and operationalized for farm conservation behavior by Beedell and Rehman (1999).

Table 1 lists all 31 farmers' mental model items extracted from soil management and governance literature and interviews. We categorized the items along Ostrom's (2007) first tier SES variables and the conceptual framework shown in Figure 1. We followed the suggestion of Bang et al. (2007) and Muhar et al. (2017b) that farmers' conceptualizations of nature and the position of themselves within it is a very helpful explanatory variable when investigating behavior that is taking place in nature. We used items from the HNR scale already successfully tested regarding their explanatory power for environmental behavior of non-farmers (Braito et al. 2017) and farmers (Yoshida et al. 2017). Furthermore, the questionnaire also included a farm identifier to link the questionnaire data with the micro-economic FADN (Farm Accountancy Data Network) data. The questionnaire was pretested with farmers and farming experts.

Table 1: Operationalized mental model items

			mental model facets	items in the questionnaire
governance system	**duration**	1	**duration security**	The number of years that I will still farm a plot determines how I deal with my soil.
	agricultural policies	2	**align to AES**	How I deal with my soil depends on agri-environmental schemes.
		3	**orient at AES**	… I orientate myself at voluntary programs and schemes (AES), no matter whether I formally participate. *
		4	**laws & sanctions**	How I deal with my soil is determined by laws and governmental sanction.
resource system	**biophysical**	5	**weather**	The weather determines how I deal with my soil.
		6	**natural influences**	… I avoid damages by natural influences (e.g., climate change, pests).
		7	**distance**	The distance between a plot and my farm determines how I deal with my soil.
resource unites	**economic considerations**	8	**profitability**	… the profitability of my farm is top priority. *
		9	**avoid expensive investments**	When dealing with my soil I avoid expensive investments.
	resource considerations	10	**customers' expectations**	… expectations of my customers. *
		11	**societies' expectations**	… I implement expectations of society. *
		12	**food provision**	… I especially think about my duty to provide food for society. *
user	**knowledge**	13	**own knowledge**	… I rely on my own education and experience. *

	14 **traditional knowledge**	Traditional and passed-down knowledge determines how I deal with my soil.
	15 **others' knowledge**	... is guided by experiences of colleagues. *
	16 **training**	I attend training and extension services to learn more about soil. *
care for others	17 **responsibility for employees**	… I have a responsibility for employees and assisting persons. *
	18 **future generations**	… I think about future generations. *
	19 **care for neighbors**	… I avoid any negative impact on my neighborhood. *
	20 **coordinate with neighbors**	... I coordinate with my neighbor. *
personality	21 **time availability**	I would deal with my soil differently if I had more time.
	22 **freedom**	… my freedom as a farmer is my main concern. *
	23 **pleasure**	… ought to give me pleasure. *
	24 **openness to change**	… I often try new things. *
social norms	25 **tidy plots**	I pay attention to the tidiness and neatness of my plots.
	26 **gossip**	… I avoid doing things that would make me the subject of gossip. *
HNR	27 **Master**	… I steer nature for my own use. *
	28 **Participant**	… I feel as a part of nature and its cycles. *
	29 **Partner**	… I work together with nature. *
	30 **Apathy**	… I do not think about nature. *
	31 **Steward**	… I have a responsibility for nature. *

* …items where prepended by "When managing my soils, …"

Respondents were asked to indicate for both their typical rented and owned plots whether they applied any of the following conservation measures: conservation tillage (including no-till, strip-till and mulch till), use of machinery that prevents soil compaction, precision farming, application of compost, commitment to using no fertilizer, no pesticides, no sewer sludge, no fungicides, organic farming, a diversified crop rotation, cultivation of cover crops (with a choice of two different intensities in line with AES – cover of 10% of cropland or 85% of cropland at all times), cultivation of winter-hardy cover crops, preservation of valuable landscape elements, regular soil testing, creation of wind protection elements (such as hedgerows), and "other measures" that farmers could specify in a text box. Many of these measures are part of voluntary AES in Austria under the 2nd pillar of the EU's common agricultural policy.

3.2 Study area and sampling

Austria is experiencing land market trends similar to that seen in other European countries. The number of farms declined from 402,286 in 1960 to 161,317 in 2016 (BMLFUW, 2017: 165), while the cultivated land per farm increased from 10.4 ha in 1960 to 19.9 ha in 2018 (Statistik Austria, 2018: 85). Farm enlargements are also based on a rising share of rented agricultural land from 351,660 ha (1960) to 1.03 million ha (2016) (Holzer et al. 2013), which now corresponds to 38.5% of Austria's total agricultural land (Statistik Austria, 2018, 170). Due to the Alpine morphology in the western part of Austria, farms cultivating arable land are concentrated in the North-Eastern part of Austria (see Figure 2).

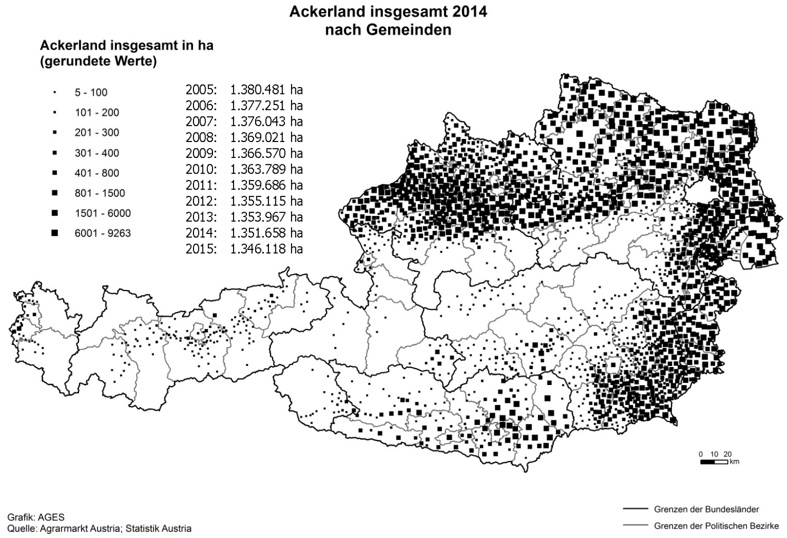

Figure 2: Overall arable land per municipality in 2014 in Austria

The FADN collects annual micro-economic data for official reports on farm income and the effectiveness of the Common Agricultural Policy for European and national authorities of EU member countries. Holdings are selected to include different types of farming, regions, and economic size however only those which could be considered commercial (due to their size). As sub-contracted service, the Austrian FADN organization helped in pretesting our questionnaire, identifying arable farmers, contacting, and reminding them (electronically and via phone) to fill out the questionnaire. Out of Austrian farmers who are members of the FADN and cultivate arable lands, we invited those 1,200 farmers to participate in the survey who both rent at least 5 ha and own at least 5 ha of cropland. We collected 344 fully completed questionnaires, which corresponds to a decent response rate of nearly 29% (Sánchez-Fernández et al. 2012) and ensures reasonable statistical power (Faul et al. 2007).

3.3 Data analysis

We cleared our dataset from missing data and outliers (Hoaglin and Iglewicz 1987). We treated the variables related to the farmer's mental model, measured on a 5-point equally distanced Likert scale, as continuous (Carifio and Perla 2007; Brown 2011). We checked this mental model scale for normality of the variables using the Shapiro-Wilk test. As data were not normally distributed, we conducted non-parametric group comparisons.

In order to investigate RQ1[1], we compared farmers' stated soil management practices on a typical rented and owned plot. We ran the McNemar's test, which determines differences on a dichotomous dependent variable between two related groups in a 2×2 contingency table (McNemar 1947). Basically, in this test, 2×2 contingency tables with matched pairs (typical rented versus typical owned plot) are used to determine whether the row and marginal column frequencies are equal (that is, whether there is "marginal homogeneity"). We ran the McNemar's test with continuity correction (Edwards 1948) to determine if there was a difference in the proportion of how farmers manage their soil on a typical rented and a typical owned plot.

[1] Which soil management practices are affected by tenure status?

In order to analyze RQ2[2], we tested if plot-related variables (size, geographical proximity, social ties, plot-related bio-physical characteristics) differed for farmers' typical rented and owned plots. Depending on the nature of the independent variables, we conducted the Wilcoxon signed-rank test (differences in size and geographic proximity between the paired typical rented and owned plots), the Chi-Square to test if there are differences in social ties to owner (typical rented plot) or previous owner (typical owned plot) or plot related difficulties (none, slope, protected area, difficult soil) between rented and owned plots. For the Wilcoxon signed-rank test we inspected the histogram with the superimposed normal curve to assure the distribution of the differences between the two related groups to be symmetrical in shape. For the Chi-Square tests for association we used a Bonferroni correction to calculate the adjusted p-values (Garcia-Perez and Nunez-Anton 2003) to avoid a type I error of rejecting a true null hypothesis.

In order to assess RQ3[3] and to identify mental model items that are influential to farmer's soil management practices, we conducted Mann-Whitney U tests (Mann and Whitney 1947). After confirming shape similarity by inspecting the population pyramid of each group, we determined whether there are differences in the medians between farmers practicing (or not) particular soil management practices.

4 Results

The sample consists of 344 respondents (average 49 years old). The questionnaire was mostly filled out by a male (88%) which is the likely consequence of males generally being more responsible for the farms business. 66% of respondents enjoyed improved agricultural education such as master craftsmen (42.8%), high school (17.6%) or university (5.6%). The rest enjoyed primary education such as compulsory school (3.2%), apprenticeship (7.3%) or specialist training without certificate (23.5%). Matching Figure 2, the majority of respondents are located in those parts of Austria, where most arable lands are: Lower Austria (50.9%), Styria (20.1%), Upper Austria (14.8%), Burgenland (10.2%). We got any questionnaire from Vorarlberg, and only 1 from Tyrol, 2 from Salzburg and 10 from Carinthia.

4.1 Soil management on a typical rented or owned plot

Table 2 reports the results of the McNemar's statistics, which analyzed in sixteen 2×2 contingency tables each soil management practice (yes or no) for the matched pairs of a farm's typical plots of rented and owned land (see *stated soil management practices* in Table 2). The results reveal that respondents very rarely indicated different soil management practices between a typical rented respectively owned plot. The most frequent soil management practices that more than 75% of all farmers apply on both, rented and owned plots are crop rotation (93.0%) and the cultivation of cover crops (in the 10% of cropland version) (79.9%). In contrast, more than 85% of all farmers indicated not using precision farming (85.8%), not applying compost (85.5%), and not creating wind protection elements (92.2%) on either rented and owned plots. When looking at the columns that show soil management practices that farmers apply on only one of their two typical plots; it becomes apparent that they rarely differ soil management on rented or owned plots. However, preserving valuable landscape elements (15.4%) and taking regular soil samples (9.3%) are soil management practices that some farmers apply only on one of their typical plots. The last column in Table 2

[2] Which formal and bio-physical plot related factors (security, social and geographical proximity) might explain different or similar soil management practices?

[3] Which mental model items inform farmers' soil management?

shows the asymptotic p-values.[4] Of 16 soil management practices, only 2 stand out: *not using fertilizer* and *not using sewer sludge*. Accordingly, the difference in the proportion of farmers using these soil management practices on rented and owned plots was statistically significant. Farmers were more likely to not use fertilizers on rented plots (8) than on their own plots (1). A slightly more significant difference was identified for "no sewer sludge", as 22 farmers do not use sewer sludge only on rented plots and 7 only on their owned plots.

Table 2: McNemar's test statistics for all 16 soil management practices

How would you describe your soil management on one of your typical rented/owned plots?	**stated soil management practices** on **BOTH**	on **NEITHER**	on **EITHER**	on **rented only**	on **owned only**	**test statistics** matched pairs[a]
	n (%)			n		$\chi^2(1)$
conservation tillage	164 (47.7)	166 (48.3)	**14 (4.1)**	10	4	.79
soil protecting machineries	113 (32.8)	216 (62.8)	**15 (4.4)**	7	8	
precision farming	44 (12.8)	295 (**85.8**)	**5 (1.5)**	3	2	
compost	31 (9.0)	294 (**85.5**)	**19 (5.5)**	9	10	
no fertilizer	*54 (15.7)*	*281 (81.7))*	***9 (2.6)***	*8*	*1*	*4**
no pesticide	64 (18.6)	267 (77.6)	**13 (3.8)**	8	5	.31
no sewer sludge	*165 (48.0)*	*150 (43.6)*	***29 (8.4)***	*22*	*7*	*.76***
no fungicide	116 (33.7)	215 (62.5)	**13 (3.8)**	7	6	
organic farming	77 (22.4)	260 (75.6)	**7 (2.0)**	4	3	
crop rotation	320 (**93.0**)	11 (3.2)	**13 (3.8)**	7	6	
cover crops (10%)	275 (**79.9**)	49 (14.2)	**20 (5.8)**	10	10	
cover crops (85%)	96 (27.9)	238 (69.2)	**10 (2.9)**	4	6	.1
winter-hardy cover crops	84 (24.4)	245 (71.2)	**14 (4.1)**	11	4	.4
preservation of valuable landscape elements	141 (41.0)	150 (43.6)	**53 (15.4)**	25	28	.07
regular soil samples	177 (51.5)	135 (39.2)	**32 (9.3)**	17	15	.03
creation of wind protection elements	13 (3.8)	317 (**92.2**)	**14 (4.1)**	5	9	.64

[a] McNemar's null hypothesis: proportion of practices on rented plot = proportion of practices on owned plot
* $p < .05$; ** $p < .01$; *** $p < .001$

4.2 Plot-related factors

Thus, our study reveals that tenure does not have a substantial effect on how farmers manage their soils; only two management practices were found to vary between rented and owned plots slightly. Therefore, and regarding RQ2, we subsequently investigated the hypothesis that similar plot-related factors of rented and owned plots explain the low tenure effect. We first compared *size* and *distance* of farmers' rented and owned plots. The test statistics elicit a statistically significant median difference of both variables regarding rented and owned plots. According to the Wilcoxon signed-rank test, owned plots tended to be 2.35 ha larger than rented plots. This median increase from a typical rented plot (3.12 ha) to a typical owned plot (5.47 ha) is statistically significant, $z = 7.66$, $p < .0005$. Furthermore, the test indicates that typical owned plots are closer to the farm (1.85 km) than rented plots (3.29 km). Again, this is according to the Wilcoxon signed-rank test a statistically significant median increase in distance of 1.43 km, $z = -10.36$, $p < .0005$.

Next, we investigated if social ties (*from whom have you rented*) could illuminate the low or even missing tenure effect. According to our survey, only 4.4 % of farmers rented their typical rented plot from personally

[4] For sample sizes above 25, SPSS Statistics considers them to be a good enough approximation to the real (exact) p-value.

unknown landlords. All other farmers rented them from their family/relatives (20.6%) or personally known (75.0%) landlords. In the case of farmers' typical owned plot, all acquirer it from personally known previous owners, such as family/relatives (95.3%) or personally known (4.7%). Thus, whether rented or owned, farmers have close social proximity with their landlords or previous owner.

Finally, we investigated to what extent plot specific challenges could illuminate the tenure effect. As shown in Table 3, we used three items for assessing well-known difficulties farmers are often confronted with, and that might force farmers to apply specific soil management practices: slope, protected area, and bad soil quality. We first used a McNemar's test for matched pairs to investigate if the proportion of difficulties on rented plots were the same as on owned plots. We did not find enough evidence to declare the difference in proportions statistically significant. I.e., we cannot reject but retain the null hypothesis of farmers' typical plots are similarly challenging in regard of plot related difficulties.

Table 3: Plot related difficulties

	stated difficulties			
Are you confronted with specific difficulties?	on **BOTH**	on **NEITHER**	on **rented only**	on **owned only**
		n		
none	89	220	18	17
slope	241	68	14	21
protected area	315	19	3	7
bad soil quality	258	49	18	19

4.3 Mental model items

The Mann-Whitney U test was run to investigate if the distribution of mental model items' scores was equal (null hypothesis) or different (alternative hypothesis) for the two groups of the independent variables (soil management practices [0 = No, 1 = Yes]), in order to examine RQ3. Distributions of the mental model items' scores for farmers who apply the addressed soil management practice or not were similar, as assessed by visual inspection. Table 3 presents the 496 Mann-Whitney U test statistics that we ran: 31 mental model items × 16 soil management practices. In cases where the test elicits statistically significant differences in mental model scores, we report the effect size (r) and the significance level of p. The algebraic sign in front of the effect size is related to the mean ranks, indicating the direction of the effect: [-] signals that the mean ranks of the group who does not apply the soil measure is larger, [+] signals that the mean ranks of the group who does apply the soil measure is larger. Basically, the "[…] larger an effect size, the bigger the impact the experimental variable is having, and the more important the discovery of its contribution is" (Fritz et al. 2012, p.14). According to Cohen (1988), we can distinguish between large (r = .5), medium (r = .3) and small (r = .1) effect size. Accordingly, the effects of the mental model items in explaining soil management practices are rather small. However, we need to keep in mind that each mental model item is only one out of thirty-one. The table can be interpreted twofold: from left to right to understand which mental model items support which soil management practice, or from top to bottom to understand, which soil management behavior is supported by which mental model items.

Regarding mental model items, the results reveal items related to the categories *governance* and *resource system* (1-7) are not significantly different, as they are equally distributed among farmers participating or not in soil management practices. On the other hand, we see items belonging to the category of *User* to be more frequently distributed differently between participants and non-participating farmers. In this vein, social norm items seem to be helpful to understand why farmers apply (or not) soil conservation practices: e.g., farmers who avoid doing things that would make them subject of gossip (26) are less likely to apply compost on their plots, less likely to use no fertilizer, pesticides or fungicides, less likely to farm organic or to cultivate cover crops (at 85% of cropland). Oppositely, farmers who hold the HNR concept of the partner (I work together with nature, 29) are more likely to apply soil conservation measures, such as no use of fertilizers and pesticides, growing organically, rotating crops and taking regular soil samples. The strongest mental model items with the most significant effect size and the highest significance levels are the openness to change (24) and training (16).

Regarding soil management practices, the results reveal that mental models do not help much to explain the use of diversified crop rotation. However, they do provide insights into not using fertilizers and sewer sludge, the two soil management practices that the McNemar's test identified as significantly different between rented and owned plots. Accordingly, not using fertilizer is supported by farmers whose mental models see their soil management influenced by customer expectations (10), training (16), future generations (18), openness to change (24), HNR of participant (28), HNR of partner (29), and HNR of steward (31). In contrast, farmers are less likely to use no fertilizers if they consider their soil management to rely on their knowledge and experience (13), care for tidy plots (25), and avoid becoming the subject of gossip (16). Not using sewer sludge, in comparison, is supported by farmers who state that their soil management is influenced by attending training (16), feeling responsible for their employees (17), caring for future generations (18), by activities that give them pleasure (23), openness to trying new things (24), and feeling responsible for nature (31). A stronger emphasis on the number of years that they will still cultivate the plot (1), AES (2), as well as colleagues' experience in farmers mental models increases the probability to apply sewer sludge on plots.

Table 4: Mann-Whitney U test statistics for all 31 mental model items and all 16 soil management practices

			item labels	conservation tillage	machinery	precision farming	compost	no fertilizer	no pesticide	no sewage sludge	no fungicide	organic	crop rotation	cover crops (10%)	cover crops (85%)	winter-hardy cover crops	lanscape elements	soil samples	wind protection
governance system	duration	1	duration security							- .11 *						+ .12 *			
	agricultural policies	2	align to AES		- .11 *					- .12 *									
		3	orient to AES				- .11 *												
		4	laws & sanctions																
resource system	biophysical	5	Weather																
		6	natural influences																
		7	Distance	+ .11 *							+ .11 *							- .11 *	
resource unites	economic cons.	8	Profitability			+ .14 *	- .11 *				- .14 *	- .14 **							
		9	avoid expensive investments		- .11 *	- .11 *	- .12 *								- .11 *			- .16 **	
	resource cons.	10	customers' expectations	+ .15 **				+ .13 *	+ .12 *			- .12 *							
		11	societies' expectations													+ .12 *			
		12	food provision											+ .12 *			+ .15 **		
user	knowledge	13	own knowledge				- .15 **	- .13 *	- .17 ***		- .14 **	- .14 *							+ .13 *
		14	traditional knowledge		- .14 **														
		15	others' knowledge		- .11 *					- .11 *									
		16	Training	+ .18 ***	+ .25 ***	+ .24 ***		+ .11 *		+ .13 *				+ .12 *		+ .12 *	+ .18 ***	+ .20 ***	
	care for others	17	responsibility for workers		+ .13 *				+ .11 *	+ .18 ***						+ .13 *	+ .14 **		
		18	future generations		+ .13 *	+ .13 *		+ .17 **	+ .20 ***	+ .16 **		+ .15 **				+ .17 **			
		19	care for neighbors																
		20	coordinate with neighbors																
	personality	21	time availability																
		22	Freedom											+ .12 *		+ .13 *			
		23	Pleasure							+ .22 ***				+ .12 *			+ .11 *		
		24	openness to change		+ .22 ***	+ .20 ***		+ .26 ***	+ .27 ***	+ .20 ***	+ .14 **	+ .16 **			+ .13 *	+ .25 ***	+ .13 **	+ .12 *	
	social norms	25	tidy plots					- .12 *	- .17 ***		- .23 ***	- .25 ***		+ .14 *					
		26	Gossip				- .13 *	- .12 *	- .14 **		- .12 *	- .15 **			- .13 *				
	HNR	27	Master																
		28	Participant					+ .13 *											
		29	Partner					+ .17 **	+ .14 **			+ .17 **	+ .15 **					+ .15 **	
		30	Apathy																
		31	Steward					+ .17 **	+ .15 **	+ .12 *		+ .15 **							

* p < .05; ** p < .01; *** p < .001

5 Discussion and conclusion

With this paper, we analyze once more the old assumption of tenure insecurity affecting farmers soil management and also address the broader question of which mechanism do determine how farmers manage their soil. We do so by taking a closer look at items of mental models, which so far have only very rarely been considered related to farmers' soil management practices.

Data analysis provides evidence that may overturn assumptions about farmers, tenure, and soil conservation practices. We did not find large variations between typical rented and owned plots regarding basic parameters such as specific cultivation obstacles, or social relationships linked with the plot, except plot size and distance to the farm. Regarding soil conservation behavior, respondents indicated utilizing the same 16 practices, with small but mostly insignificant variations. Thus, this study indicates that farmers soil conservation behavior does not depend on tenure. The results further show that farmers' soil conservation practices are mostly driven by socio-psychological factors, such as their perceived HNR, their social norms, or their self-identity of being a farmer, which comes along with responsibilities for nature, society, and future generations.

5.1 The tenure effect on soil conservation

The McNemar's of stated soil management practices showed only two significant differences between plots considered typical for the farm's rented or owned land. On the one hand, if farmers make differences in the use of sewer sludge between owned and rented land, they rather do not use sewer sludge on rented land. This is in line with responsibilities, and social norms interviewees reported about making a good impression to the owner of the land and neighbors (Leonhardt et al. 2019). Moreover, some templates for rental contracts provided by extension services propose a facultative clause forbidding the use of sewer sludge. It could thus be the case that for some renters, the (non-)use of sewer sludge is regulated in rental contracts. Furthermore, the use of sewer sludge is forbidden entirely in some of Austria's federal states (and by some major buyers of agricultural commodities), which, however, cannot explain the fact that some respondents stated differences between rented and owned plots.

On the other hand, respondents who reported a difference in soil management between rented and owned plots, tend to use fertilizer on their own land rather than on rented land. With our data, we cannot differentiate between different types of fertilizer, like a study from Ghana, where farmers on fixed-rent were more likely to invest in yield-increasing inputs such as mineral fertilizers than owners, who were more likely to invest in tree planting or mulch, but not in mineral fertilizer (Abdulai et al. 2011). The higher propensity for not using fertilizer on rented land, albeit small, confirms results from qualitative interviews in Austria (Leonhardt et al. 2019), where some interviewees problematized costs or the imminent end of rental as a (hypothetical) reason for not applying long-term fertilization (phosphorus potassium PK) or liming on rented land. Applying PK-fertilizer is an investment with a more extended payback period than N-fertilizer, which has immediate effects in the same year that it is applied – but in the case of synthetic fertilizer might have detrimental effects for water quality. Thus, while not using synthetic fertilizer could be considered to be a conservation policy, leading to the conclusion that farmers appear to apply more conservation measures to rented land, the opposite could also be true. Not using PK-fertilizer, in particular, could be seen as depriving the soil of nutrients over the long run. This would then, in the context of this study, show that farmers tend to exploit the soil on rented plots more than on owned plots. However, whichever interpretation may be correct, the fact that only nine respondents indicated to make any difference between rented and owned in this respect warrants caution for generalizations.

On a more general note, most farmers in our sample appear to make no differences in soil conservation between their typical rented and owned plots. Some farmers, however, state to alter their soil management, but where this is the case (e.g., preservation of valuable landscape elements), there is often an equal number of farmers that apply the measure on rented or owned land only. Therefore, there is no clear direction of this small tenure effect (with the exceptions described above). In line with the interview data by Leonhardt et al. (2019), we see that a vast majority of farmers rents from family members or landowners that they know in person. While we do not know any more details about how well tenants and landowners know each other, it is likely that personal relationships decrease a potential adverse effect of rental, even if we cannot prove the non-existence of such a relationship in those cases where a tenure effect does exist.

Our results thus confirm studies that find little or no association between the ownership status of land and the soil conservation measures that farmers apply. In this context, it should be noted that in Austria, many of the soil conservation measures that were included in the questionnaire are part of subsidized AES. Where this is the case, it is often required to apply the measure on all or a majority of farmed plots – irrespective of ownership status. This will by default decrease differences between rented and owned plots for AES participants and may thus be another explanation for the results of this study. However, even for measures that are not part of an AES, (such as using soil-protecting machinery, precision farming, application of compost or wind protection elements) we do not see substantial differences, confirming the lack of an overall adverse effect of rental.

As expected, we see some differences in the biophysical characteristics of rented and owned plots. Rented plots tend to be smaller and further away from the farmhouse than owned plots, while there appear to be no structural differences regarding specific difficulties for farming such as bad soil quality or steep slopes. However, we could not substantiate any claims that this alters a potential effect of tenure for soil conservation. For the distance between plot and farmhouse, in particular, this could be because even though rented plots tend to be further away, the distance still is comparatively small and may thus not influence conservation measures. In this case a "typical" plot may be different from a potential "extreme" plot; i.e., while some rented plots might indeed be at a distance to the farm that does have an effect on how that plot is treated, this may not be the typical plot a farmer thinks of when answering the questionnaire.

5.2 Farmers' mental models of soil management

There are much hope and first empirical evidence regarding the role of mental models for understanding and implementing effective natural resource management, conservation and governance (Bang et al. 2007; Biggs et al. 2011; Jones et al. 2011; Pahl-Wostl et al. 2011; Prager and Curfs 2016). Nevertheless, mental models have only rarely been analyzed in the context of soil conservation (Prager and Posthumus 2011). While Prager and Curfs (2016) developed a diagram-based representation of a typical farmer's mental model based on semi-structured interviews with 16 farmers, we opted for a survey of 344 farmers identifying those items that might together form the individual farmers' mental models of soil management. Therefore, when interpreting the results, we have to consider that we only have information on the individual items of a farmer's mental model of soil management, i.e., those items they consider as relevant for their soil management and cannot take into account the interactions between these aspects.

In aiming to answer our third research question on farmers' mental models, we show that soil management practices are linked to different items of mental models. Here it appears particularly useful that we had the opportunity to investigate a wide range of soil management practices, as this allows us to derive more differentiated results. To illustrate this by an example, consider precision farming and organic farming and the mental models' items they relate to. Both practices have a strong potential to contribute to soil conservation as well as other ecosystem services such as clean water, but they differ substantially in what is required to apply them. This is mirrored in Table 4 that distinguishes participants and non-participants in either precision farming or organic farming. Compared to other respondents, farmers who apply precision farming instead state that their soil management is driven by profitability and training, but do not much consider discouraging expensive investments. They – similar to organic farmers - see their soil management, influenced by their openness to change and responsibility for future generations. However, compared to other respondents, organic farmers consider profitability to be less critical for their soil management, they consider their soil management less influenced by customer expectations and are less likely to think that their own knowledge is the best source of knowledge. They care less about the appearance of their fields and gossip than non-organic farmers. These results are very plausible: organic farmers are clearly out-siders (if by mere numbers), and rely on trial and error and specialized training and education to manage their complex cropping systems – potentially explaining the results concerning gossip, plot aesthetics, and knowledge.

Moreover, organic farming is fundamentally different from conventional farming in many ways and often brings lower yields, suggesting that profit might not be a primary motivation to convert. Precision farming, on the other hand, uses inputs in a highly efficient way but might require a substantial upfront investment into machinery, GPS, etc., congruent with the results concerning emphasizing profitability and the willingness to make investments. Both types of farming require a strong willingness to try new things and openness to change. While these two examples are evident and easy to argue, others are less straightforward. In particular, for crop rotation and wind protection there appear to be almost no mental model items differentiating between users and non-users. However, this might be due to our sample, where nearly all farmers practice crop rotation, and nearly none created wind protection elements, rendering statistical comparisons futile.

Based on a cross-country comparison and a review of international literature, Bijttebier et al. (2018) and Knowler and Bradshaw (2007) conclude that many variables influence farmers soil management, tenure status only being one among many others, which is once more is confirmed by our analysis in Austria. They suggest tailoring soil governance to particular geographical contexts (Knowler and Bradshaw 2007; Bijttebier et al. 2018), our results suggest that policies and communication strategies for specific soil conservation measures might better be tailored to farmer groups sharing specific mental model items supporting the uptake of these measures.

For example, for those groups of soil management practices where mental models regarding profitability play an essential role, it might be worth considering monetary incentives and communicating the economic profitability of these measures. Where, however, partnership or stewardship relationships with nature differentiate participants from non-participants, it might be more worthwhile to stress the ecological benefits of certain practices and strengthen non-participants' views on their relationship with nature. Overall, farmers' openness to change, views on the importance of training and education by professionals, and care for future generations are linked to the application of the greatest number of conservation measures. Influencing farmers' management practices by aligning communication strategies with these three mental model items could thus be a promising route for policymakers who wish to foster effective soil conservation. Persuading people of the positive aspects of change or mitigating associated risks, assuring farmers of the utility of training and encouraging them to consider future generations may be difficult endeavors but in light of our results certainly worth the effort.

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