The authors aiming for comparison of different regenerative soil management systems in comparison to conventional managed systems. They use various measures of soil structure and water retention to evaluate the quality of the management options. The topic is highly relevant for the adoption of cropping systems to climate change.

Unfortunately, the quality of the study does not convince me to suggest a publication in SOIL. The study is very weak in terms of field replications and study sites that leading in total to 6 samples. The analytical tools are basic and provide no innovative approaches. For such a small sample set one could expect much deeper analytical afford. Method descriptions partially missing and some data I found by luck in the supplements. In the cause of the review process I stopped marking down all individual specific comments. There was simply too much to correct and my time is limited.

General comments

The introduction should summarize the state of the art and introduce to the relevance of the topic. Unfortunately a larger part of the introduction (L51-70) contained technical information and methodological information. I recommend to go deeper into literature on soil management options of arable land and the connection between management of soil structure and water budget.

The study site is not characterized well. Climate data are missing at all and the distance between the two study sites is unclear. A map would help. No information on the type of management (experimental field trial or on farm research) is provided. Since this are calcareous soils, information about parent material would be helpful. How deep below soil surface starts the bedrock? Soil texture should be measured in replicates. The method must be described. Please show the data in the main manuscript from each sample. There must be a prove (correlation etc.) that there are no texture based differences on soil properties such as soil OC or CEC. It is recommended to show values from deeper soil layers (>30cm). Otherwise the effect of texture should be evaluated. There are also several uncertainties on fertilizer management: What form of OM amendments, how much, when in the crop rotation? What kind of cover crops? Please provided more details to the sampling design: Size of the fields, distance between the sampling points in a map.

Unsing an ANOVA approach for statistic comparison requires the assumption of normality. Further, the sample size of 3 is very low and likely not the suitable measure. I recommend using a simple T-test, depending on the distribution of the data.

The data set on microbial parameters should be incorporated in the main manuscript. Methods must descried properly. The same is true for the OC measurements. Have the carbonates be removed from the samples?

In the conclusion there something written with vegetable cover, that was not discussed before. I did not get this point. The author’s proclaimed the “optimized managtemen” practices for the whole Mediterranean region. From this very limited data set at one sampling site it is not possible to scale up the management tools across the whole Mediterranean environment. Also the effects in the subsoil have not been taken into account.

I also highly recommend a professional language check. Many basic rules for preparing a scientific publication are ignored. For example: The manuscript is overloaded with double brackets, grammar errors or punctuation errors. Many paragraphs are not accessible, even after reading several times.

Specific comments:

L39 change eliminate to avoid. Further, cover cropping have nothing to do with soil tillage practices, examples for reduced soil tillage are e.g. mini tillage (0-10cm) , Cultivator application and everything that avoids to invert the soil of 0-30cm.

L43 the annual soil water balance primarily depend on precipitation: I suggest optimisation of the infiltration and water storing capacity

L51-70 this belongs to the materials &method section. If you write a paper on the methods you could bring this here.

L78 managed

L86-88 the sentence is overloaded with brackets. Avoid double brackets and remove some them. Keep this in mind for the rest of the manuscript.

L97-102 this is unclear. Is only the cereal straw removed from the fields? I never heard that straw of legumes and rapeseed is removed?

L107 which form of OM amendments, how much nutrients and OC therein?

L245 - following. Use space between ± and the number. The same is true for >. Only between the numbers an % there should not be a space.

L235-238 no consistency Fig. Figure. The two paragraphs double.

L246 texture homogeneity was not measured.

L311 where does the vegetable cover comes from?

We sincerely appreciate your thorough review and your helpful comments and suggestions that significantly helped to improve our manuscript. We send you a detailed response to each of your comments, hoping that you reconsider your decision. In any case, many thanks for your time and effort.

As the reviewer's comments/suggestions dealt with in different paragraphs, we have grouped them by topics, and headed with key words (in bold) referring to the main subject under discussion:

Research scope*. *Study site characterization. We believe it is appropriate to begin first providing clarifications regarding the experimental site in order to, in turn, better understand other aspects of the work, such as sampling and repetitions, and also to emphasize the relevance and scope of our research.

We agree with the reviewer that our findings are too narrow to be a comprehensive contribution to the sustainability of Mediterranean agrosystems considering all the aspect that sustainability development really involved, as clearly remarks the reviewer. In fact, our main objective is the evaluation of an innovative -and pioneer in our region (Navarre)- soil and crops management strategy on topsoil properties. Indeed, to our knowledge, there is no other agricultural field in the whole region of Navarre where soil and crop management as proposed herein (OPM) is practiced and even less for almost two decades, with the exception of our small (2 hectares) OPM test area were a pioneer farmer works for almost 20 years (farm research). This represents, in our view, the uniqueness of our OPM study. This relevance of our work would be better and clearly pointed out in the text, especially in the Introduction and in section 2.1. (Study site [former 'zone'] and treatments), when a new version is produced after the Editor's decision.

In this sense, we believe that the actual scope of our work could be unambiguously presented as follows. First, deleting the questioned statement that "the study contributes to higher sustainability of Mediterranean agrosystems". Second, reformulating the title following the reviewer's suggestion: *Effects of innovative long-term soil management on topsoil properties of a Mediterranean calcareous soil based on detailed water retention curves.*

State of the art of conservation agriculture. Following the reviewer's advice, we have made a revision and have drafted the following paragraph to be included in the introduction:

"Conservation agriculture (CA), and other soil management strategies implying a reduction of tillage have been reported to reduce soil degradation in different agroecological situations (Verhulst et al., 2010; Sartori et al., 2022), and in some cases are designed for this purpose (Virto et al., 2015).

The reasons reported for its adoption in Europe are several. In Northern Europe soil erosion control, soil crusting in loamy soils and the need to increase soil organic C storage, as well as soil trafficability are widely cited as reasons for CA implementation (Lahmar et al., 2007). In the Mediterranean countries, soil water storage and water-use efficiency can be added to this list of reasons (De Turdonnet et al., 2007). However, different studies show that the effectiveness of CA in solving these problems can be site-dependent (Costantini et al., 2020; Chenu et al., 2019). In fact, the most widely reported benefits of CA in Southwestern Europe in relation to erosion are the increased soil infiltrability and/or the protective effect of crop residues on the soil surface (Gómez et al., 2009; Espejo-Pérez et al., 2013; Virto et al., 2015), although this seems to be related to the type of soil and to the presence and activity of earthworms. In Spain, the soil water-retention capacity has been observed to be greater in semi-arid land under no-tillage (Fernández-Ugalde et al., 2009; Bescansa et al., 2006).

Other positive effects of CA on soil quality observed in semi-arid rainfed agricultural systems in Spain are related to soil organic C and nutrients storage (Ordóñez Fernández et al., 2007)".

Experimental design and sampling. First, it should be clarified that the OPM area is close to the CM area, and the whole surface accounts for around three hectares. In relation to the comparability of the two practices, this means that fields are close enough to consider management as the only relevant factor of change. Three composite samples –including three sub-samples each– for each treatment (OPM and CM) were taken. Both composite samples and subsamples were randomly taken within the whole studied area.

Regarding sampling depth, the bulk density values reported correspond only to the first 5 cm (0-5 cm). However, based on our field observations these values would be extrapolated up to 30 cm depth. Nevertheless, the rest of the indicators were analyzed at 0-30 cm. All these would be clarified in the text (material and methods) and in Table 1 (see below). As already mentioned in the conclusions, similar experiments at deeper soil layers are needed.

Climate and soil characterization. The reviewer is very right, some of the soil information -clay, silt and sand contents- was originally included in the supplementary material of the manuscript. However, since this is relevant information, it would be included in Table 1 along with the methods followed for the data determination, which did not include decarbonation of the soil samples. In addition, a statistical analysis of the parameters in Table 1 will be performed and those showing significant differences ($p < 0.05$) between treatments will be marked in bold. This can be summarized in a paragraph that would be included in the new version, as follows:

“The physical-chemical analysis of the soils shown in Table 1 was done using standard methods. In particular, soil pH was analyzed in a 1:2.5 soil:water solution as in Hendershot and Lalande (1993), organic C content by wet combustion as in Tiessen and Moir, (1993), carbonates were determined in a modified Bernard’s calcimeter following Pansu and Gautheyrou (2003a), and the electrical conductivity in a soil:water solution similar to that for pH analysys (Pansu and Gautheyrou, 2003b). The soil texture was determined by the pipette method. All analyses were conducted on air-dried samples ground to 2 mm. Finally, the bulk density was determined using the Hyprop device (see below) from undisturbed samples extracted from the first 5 cm of the soil profile.

Table 1. Physical-chemical properties of the topsoil (0-30 cm) in OPM and CM treatments and the textural characterization of both treatments. Mean ± standard deviation of the mean (n = 3). Statistically significant differences ($p < 0.05$) are in bold."

Treatment	**Optimized (OPM)**	**Conventional (CM)**
Bulk density (0-5 cm) ($g \cdot cm^{-3}$)	1.26 ± 0.05	1.26 ± 0.15
pH	8.00 ± 0.05	8.01 ± 0.01
Organic C (%)	**1.80 ± 0.10**	**1.51 ± 0.14**
CE ($\mu S \cdot cm^{-1}$)	**483 ± 5.66**	**795 ± 4.24**
Carbonates (%)	**31.6 ± 0.09**	**32.5 ± 0.14**
Sand (Coarse) (%)	5.05 ± 0.08	5.79 ± 0.33
Sand (Fine) (%)	30.9 ± 1.00	31.7 ± 1.25
Silt (%)	47.2 ± 1.23	43.7 ± 0.93
Clay (%)	**16.9 ± 0.46**	**18.5 ± 0.46**
Texture (USDA)	***Loam***	***Loam***

In relation to soil characteristics, attention was paid to sample on the areas corresponding to the same soil unit, on the alluvial plain of the Cidacos River. This soil unit contains deep soils, and the parent materials are quaternary deposits rich in calcareous rocks.

On the other hand, as indicated by the reviewer, a brief description of the climatic properties of the study area will be included in the Material and Methods section:

"This is an area with a dry temperate Mediterranean climate, according to Papadakis (1967). The mean annual precipitation is 550 mm $year^{-1}$, and the Thornthwaite mean annual evapotranspiration is 711 mm $year^{-1}$ (Gobierno de Navarra Meteorología y Climatología de Navarra, 2022)."

Fertilizer management. More information about fertilization should be added to the text, and can be explained as follows: "In both treatments, mineral fertilization consisted of phosphorus addition before seeding (120-150 $kg \cdot ha^{-1}$ of triple superphosphate 0-46-0) and nitrogen supply of 180 kg $N \cdot ha^{-1}$ (split and distributed into two cover dressings at 60 kg $N \cdot ha^{-1}$ and 120 kg $N \cdot ha^{-1}$ in January and March, respectively) as urea. Organic fertilization was not used in any of the study treatments until 2021, in which an organic amendment was applied to the soil without disturbing the surface in the OPM treatment. After harvest, pig slurry was applied with an average concentration of 2.5 kg $N \cdot m^{-3}$, by means of a tanker equipped with a system of hanging pipes that deposit the product a few centimeters above the ground and at a time close to a forecasted rainfall event. The application rate was 60 $m^3 \cdot ha^{-1}$ of slurry. These rates are within the legal limits established by legislation for groundwater protection against pollution caused by nitrates from agricultural sources (EU Directive 91/676 (Council of the European Union, 2008)), as the area is within a vulnerable watershed according to this Directive."

Cover crops. Description of the cover crops should be added to the text, and can be explained as follows: "In OPM, both grain and straw were also removed in the 11 first years of implementation, and only stubble remained on the surface of soil when direct seeding was implemented with minimal soil perturbation. Since then, and for the 7 remaining years, the procedure was slightly modified, and only grain was removed at harvest. Therefore, chopped straw and stubble remained on the surface of the soil before direct seeding with no disruption of the soil surface. At the same time, cover crops were introduced in the system thought it is a risky practice in rainfed Mediterranean agrosystem characterized by warm and dry summers. As such, summer cover was routinely granted in this system by letting spontaneous vegetation grow in the summer, after harvest. This vegetation was dried with herbicides before seeding the cash crops in the Fall. Also, only one year the winter crop used was *Vicia villosa* Roth, and served as a cover crop for sorghum (*Sorghum vulgare* L.), which was successfully grown in the spring-fall season despite the limiting water availability in the area."

Biological properties information. Since our evaluation is mainly based on soil porosity analysis, we had included the information concerning the biological properties of the soil in an annex. But, the reviewer's comment is very right. Thus, we would include a new section "Organic C storage and soil microbial diversity", just passing the information regarding biological issues from the supplementary material to the main text.

Analytical tools. We improved the discussion incorporating two different approaches.

First, we plotted our experimental results as differential functions [dϴ/d(log h) vs log h(h] seeking for a multimodal behavior: all the curves analyzed were of the uni-modal type. But it should be noted that suction values do not exceed 150 kPa and according to Dexter et al. (2008) (cf. their Fig. 3) and Jensen et al. (2019) (cf. their Fig. 2) findings the second peak defining a bimodal behavior seems to appear at suction around 1000 kPa. Then, we tried again incorporating to the dataset the water content-suction measurements at 1500 kPa (obtained using pressure plates apparatus) with the same result, i.e. unimodal behavior. But this could be an artifact of the dataset since there is a wide experimental gap between 150 kPa and 1500 kPa, i.e. no measurements in between.

Despite this, we tried the double-exponential equation for soil water retention proposed by Dexter et al. (2008) (Eq.1) with our experimental results:

$$\theta = C + A_1 e^{\left(-\frac{h}{h_1}\right)} + A_2 e^{\left(-\frac{h}{h_2}\right)} \qquad (1)$$

Where Θ is the gravimetric water content; C is the residual water content (asymptote of the equation); the amount of matrix and structural pore space are proportional to A_1 and A_2, respectively. The values of h_1 and h_2 are the characteristic pore water suctions at which the matrix and structural pore spaces empty, respectively (Dexter et al., 2008).

Table 2 shows the values of the fitted parameters of equation (Eq.1) using our experimental dataset. Unexpected at first sight, the structural pore space would have been reduced by 55 % as a result of no-tillage (OPM) (cf. A_2 values, Table 2), while the matrix pore space values remain rather constant in both treatments (see A_1 values in Table 2). This could be explained by an increase in soil fragments rather than soil aggregates in the CM treatment in comparison with OPM treatment. Soil aggregates and fragments may look similar but are formed by different processes and have different properties (Or et al., 2021): soil fragments form by mechanical forces of tillage; they tend to be mechanically weak and coalesce upon wetting with macroposity collapsing within a single season. Instead, soil aggregation is stimulated by biological activity with biopolymers and hyphae that stabilize and bind soil particles.

Table 2. Average values of the fitted parameters of the double-exponential water retention equation by Dexter et al. (2008) obtained with the experimental dataset.

Treatment	Parameters of the Dex model					
	C	**A_2**	**h_2**	**A_1**	**h_1**	**RMSE**
	$m^3 \cdot m^{-3}$	$m^3 \cdot m^{-3}$	hPa	$m^3 \cdot m^{-3}$	hPa	$m^3 \cdot m^{-3}$
OPM	0.25	0.06	29.94	0.11	865.08	0.005
CM	0.2	0.10	25.16	0.11	737.43	0.003

All this is consistent with our previous results as described next. The fast desorption rate at low suction observed in CM compared with OPM (cf. Fig 2 in our manuscript) could be the result of macropores due to large soil fragments induced by tillage. However, more stable (biologically-formed) macro-aggregates were observed in the OPM treatment compared with CM (cf. Fig 4 in our manuscript).

But all the above should be taken with caution since, as aforementioned, our SWRCs do not show a bi-modal behavior and then the use the Dexter's et al. (2008) equation -and what is inferred therefrom- could be questioned.

Second, taking advantage of our continuous SWRCs we have determined the water retention energy index (WRa) (Eq.2) (Armindo and Wendroth, 2016) obtained from numerical integration including all the points of each SWRC. Needless to say, the accuracy of this index is highly conditioned by the degree of detail of the SWRCs.

$$WR_a = \int_{\theta_{pwp}}^{\theta_{fc}} h(\theta)\, d\vartheta \qquad (2)$$

Where Θfc and Θpwp is the volumetric water content at field capacity and permanent wilting point, respectively; *h* is suction (kPa)

WRa quantifies the total absolute energy that has to be applied by the soil to hold water in its pores between field capacity (Ɵfc) –i.e., after the water drainage process becomes negligible– and wilting point (Ɵpwp) or any moisture point Ɵj, where Ɵpwp ≤ Ɵj< Ɵfc.

This index presents an adequate sensitivity for smaller-scale, high-precision applications and for capturing the dynamic evolution of the soil physical state (Armindo and Wendroth, 2016). More precisely, in the case of two SWRCs measured before and after some natural or anthropogenic changes (e.g., tillage), these energy indices can be used to quantify the change in soil physical quality status (Armindo and Wendroth, 2016). For instance, Fuentes-Guevara et al. (2022) found significantly correlation between hydraulic-energy based indices –including WRa– with some physical properties before and after land leveling operations, indicating their capacity to capture soil structure changes.

We have determined the index for the suction range between field capacity (ca. 10 kPa) and a moisture content corresponding to ca.150 kPa (maximum operating value of the Hyprop device) (Table 3).

Table 3. Absolute water retention energy (WRa) values for the two treatments (OPM, CM).

Treatment	WRa (kPa)
OPM - repetition 1	4.8
OPM - repetition 2	4.9
OPM - repetition 3	4.1
CM - repetition 1	*5.4*
CM - repetition 2	3.5
CM - repetition 3	3.3

The soil under OPM (WRa= 4.6±0.5) seems to have better structured than the soils under CM (WRa= 4.1±1.1) –in brackets, average and standard deviation, respectively– (Table 3) because the former holds the same relative fraction of water with more absolute energy in its porous system (Armindo and Wendroth, 2016). However, this difference between treatments was not statistically significant due to a large value of one the repetition on CM treatment (Table 3, in italics), though the rest of the values showed a relative low dispersion (see Table 3).

Specific comments. All the specific comments were considered and the text modified, accordingly. Note the reviewer that some specific comments related to crop management issues (i.e., cover crop, fertilization) were already treated (see above).

Finally, the English will be improved in the final draft after incorporating all the modifications and suggestions of all the reviewers.

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