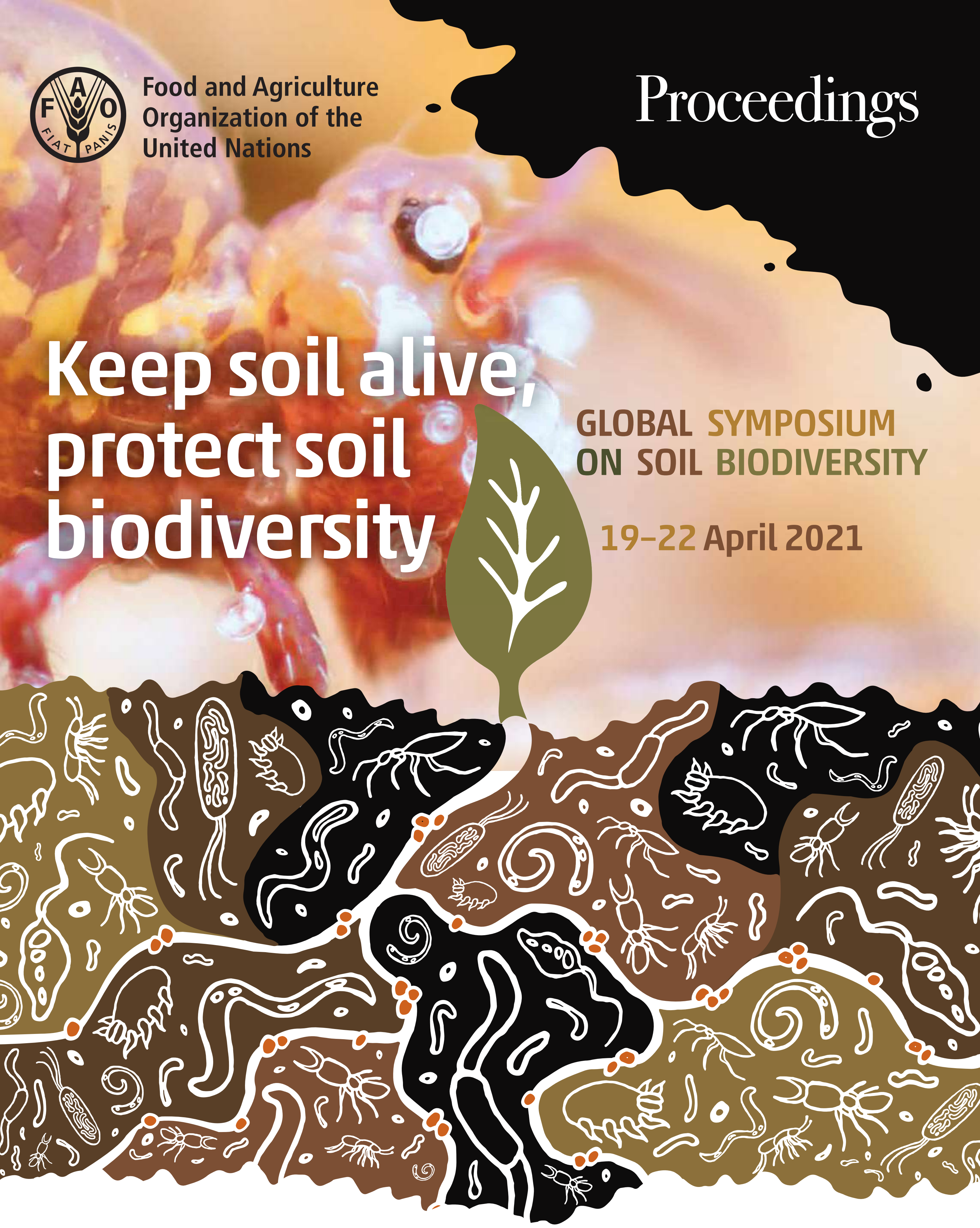

Food and Agriculture
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Keep soil alive, protect soil biodiversity

GLOBAL SYMPOSIUM ON SOIL BIODIVERSITY

19–22 April 2021

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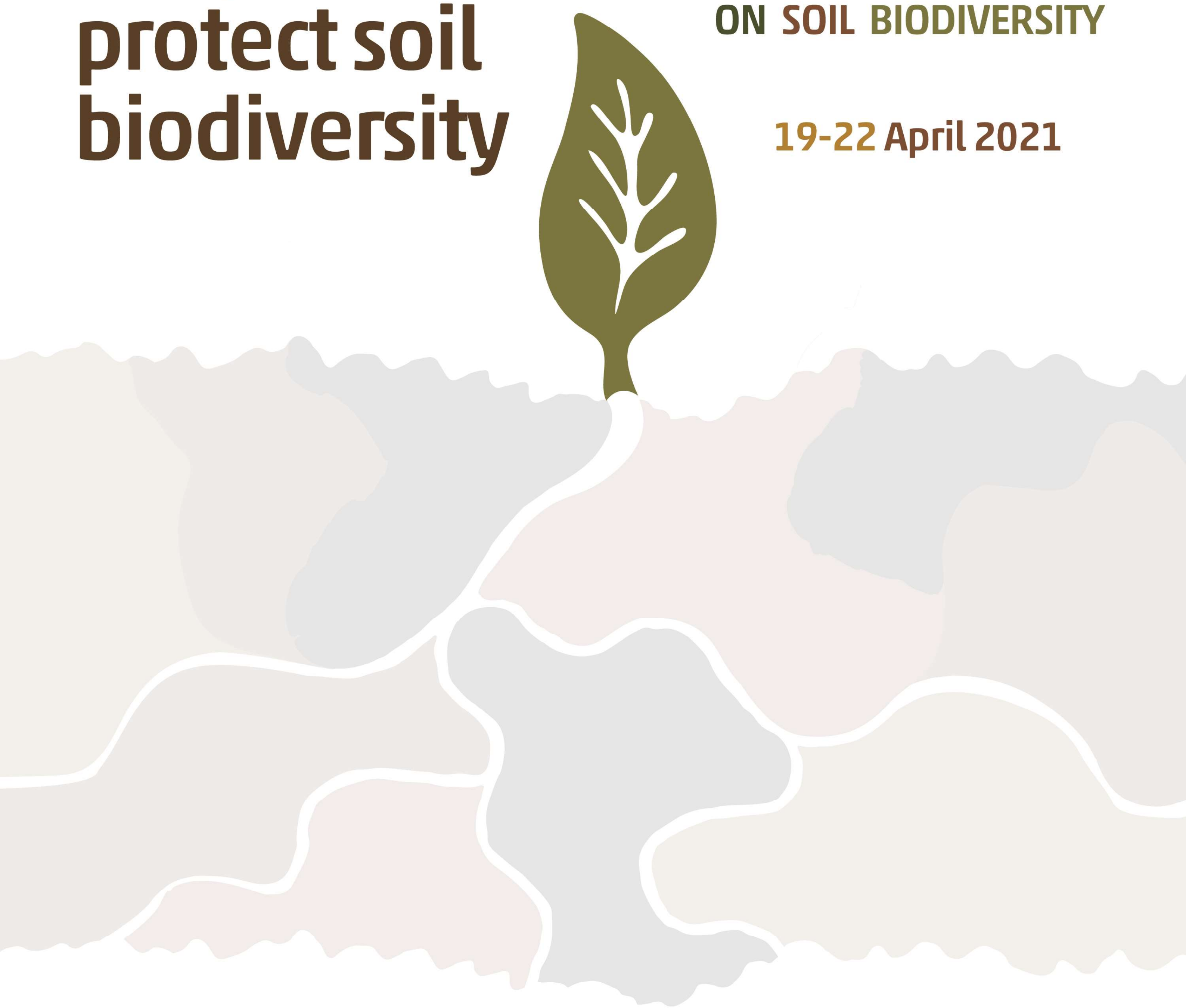

Food and Agriculture Organization of the United Nations
Rome, 2021

Required citation:
FAO. 2021. *Keep soil alive, protect soil biodiversity – Global Symposium on Soil Biodiversity 19–22 April 2021. Proceedings*. Rome. https://doi.org/10.4060/cb7374en

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ISBN [978-92-5-135218-2]
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Litter decomposition and organic matter turnover by soil fauna in a sustainably managed olive grove

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Abstract summary

In Mediterranean orchards, soil organic matter (SOM) plays a crucial role and its level is principally determined by the continuous physical and chemical action of soil fauna. The aim of this study was to characterize and compare C/N dynamics and other soil physico-chemical parameters, soil macrofauna abundance, bioturbation and litter/SOM decomposition indices in a Mediterranean olive (*Olea europaea* L.) orchard subjected to two different soil management systems (namely sustainable, S_{mng}, and conventional, C_{mng}) for 18 years. The adoption of the S_{mng} system significantly increased almost three times the abundance of earthworms and two times that of other macrofauna. Bioturbation due to soil fauna and roots was significantly higher in the S_{mng} system, and this caused a significantly faster SOM decomposition measured both in local litter bags and in tea bags. The results highlighted that a great part of the soil quality and fertility of the S_{mng} system could be due to the bioturbation activity of soil fauna, together with its interaction with decomposing microorganisms. It emerged that the role of soil fauna should be seriously taken into account in future land management strategies not exclusively focused on fruit yield and quality.

Keywords: bioturbation; litter decomposition; olive orchards; soil fauna; sustainable land use; tea bags.

Introduction, scope and main objectives

Soils and crops in Mediterranean agro-ecosystems are particularly vulnerable to climate change and environmental stresses, and they will be more and more in the next future (IPCC, 2019). Particularly, Mediterranean fruit orchards are endangered by an increasing water shortage often due to changes in rainfall frequency and distribution, and rise of soil aridity and desertification, with resulting critically low levels of soil organic matter (SOM) and contents of macro- and micronutrients, all of which essential for water storage and plant growth (Palese *et al.*, 2009; Pascazio *et al.*, 2018; Sofo *et al.*, 2019). In order to 'break' this vicious circle, nature-based solutions based on increased carbon inputs are required to facilitate sustainable use and conservation of soils.

The amount and types of SOM are principally determined by the continuous physical and chemical action of soil organisms, as soil fauna participates to SOM shredding, transformation and decomposition, in cooperation with microorganisms (Matson *et al.,* 1997; Six *et al.,* 2004). Moreover, Soil fauna-SOM interactions are of particular relevance in determining soil physical, chemical and microbiological fertility (Giller *et al.,* 1997; FAO, 2017; Totsche *et al.,* 2018).

In this research, olive (*Olea europaea* L.), a typical and widely-spread Mediterranean fruit crop, has been chosen for its multifunctional role. On this basis, the aim of this study was to characterize and compare C/N dynamics and other soil physico-chemical parameters, soil macrofauna abundance, bioturbation and litter/SOM decomposition indices in a mature Mediterranean olive orchard subjected to two different soil management systems (namely sustainable, S_{mng}, and conventional, C_{mng}) over a long term period of 18 years.

Methodology

The trial was carried out in a 2-ha olive orchard (*Olea europaea* L., cv. 'Maiatica'; 70-year.old plants with a distance of 8 x 8 m; NE orientation) located in Ferrandina (Southern Italy, Basilicata region; N 40° 29′; E 16° 28′). Half of the orchard (1 ha) has been managed using sustainable/conservation agricultural practices for 18 years (2000-2018) (sustainable management, S_{mng}), while the other half (1 ha) was kept as 'control' plot and was conducted with a locally conventional management (C_{mng}) (Table 1). In June 2018, soil sampling was performed in the inter-row area of both the systems (S_{mng} and C_{mng}). For both the soil management systems, five composite samples (n = 5) were prepared.

On soil composite samples (soil depths of 0-5, 5-10 and 15-20 cm), total organic carbon (TOC), total carbonates, total N (TN), pH and bulk density were determined according to Pansu and Gautheyrou (2006).

Soil macrofauna was hand-sorted and chemically expelled in the field using mustard oil solution. In order to evaluate soil bioturbation, mesh bags were prepared, installed for one year in the field and then recovered for evaluating biogenic structures due to macrofauna presence. An experiment using tea and and local litter was also carried out. Tea bags and local litter bags were buried for 90 days in the soil. After that, their decomposition indices were calculated according to Keuskamp *et al.* (2013) and Harmon, Nadelhoffer & Blair (1999).

Table 1: Agricultural practices adopted in the sustainable system (S_{mng}) and in the conventional system (C_{mng})

Practice	S_{mng}	C_{mng}
Soil tillage	No tillage. Spontaneous weeds and grasses mowed at least twice a year. Crop residues were cut and left on the ground as mulch.	Tillage (milling at 10 cm soil depth) performed 2-3 times per year in order to keep the soil bare.
Fertilization	Guided fertilization: fertigation based on a nutrient balance approach which takes into account nutrient input (by wastewater), output (by yield), and recycling/immobilisation in the grove system (by pruned material, senescent leaves, cover crops). The average values of organic C, N, P and K contained in the treated wastewater were 124, 54, 3 and 50 kg ha^{-1} $year^{-1}$. An integrative amount of 40 kg ha^{-1} $year^{-1}$ of N-NO_3^- was distributed in the early spring.	Mineral fertilization carried out empirically once per year in early spring by using granular product applied to the soil (NPK 20-10-10 fertilizer at doses ranging from 300 to 500 kg ha^{-1} $year^{-1}$).
Irrigation	Guided drip irrigation (6 self-compensating drippers per tree delivering 8 L h^{-1}) with treated municipal wastewater. The irrigation was based on crop evapotranspiration, calculated according to FAO equation: $ET_c = K_r \times K_c \times ET_o$ (K_r = reduction coefficient; K_c = crop coefficient; ET_o = potential evapotranspiration).	No irrigation (about 35 m^3 rainfall $plant^{-1}$ $year^{-1}$).
Pruning	Light winter pruning was performed each year in order to reach vegetative-reproductive balance of trees. Pruning material was cut and left on the ground as mulch.	Heavy pruning carried out every two years. Pruned residues burned out of the olive grove.

Results

The profiles of soil total organic carbon (SOC) and soil total nitrogen (STN) in the two management systems, and particularly in the topsoil (0-5 cm), were considerably different. Here, SOC levels were significantly higher ($p \leq 0.05$) in the S_{mng} system, compared to the C_{mng} one, while the differences in SOC levels were not significant in 5-10 cm layer, and reversed in the 10-20 cm one. The contribution of soil inorganic carbon (SIC) as fraction of soil total carbon (STC) was higher with increasing soil depths, but no significant differences were found between the two soil systems. The levels of STN were significantly higher in the S_{mng} system at 0-5 cm, while the differences in the remaining soil depths and soil systems were not statistically significant. The SOC/STN ratios in the both the soil systems were significantly different between the 0-5 cm soil layer and the other two depths, and were statistically higher in the S_{mng} system. In the litter of the S_{mng} system, the values of SOC and STN were 43.38 g kg^{-1} and 5.90 g kg^{-1}, while no litter was found in the C_{mng} system due to the soil management adopted. In the S_{mng} system, the values of soil pH and bulk density increased with rising soil depth and were significantly lower from those of the C_{mng} system.

Both the number (7 ± 1 specimens) and total weight (4.011 ± 0.702 g) of the collected earthworms were higher in the S_{mng} system, compared to the C_{mng} values (3 ± 1 specimens and 1.397 ± 0.334 g, respectively). Similar trends were found for other macrofauna specimens' number and total weight. The mean weight of earthworms was not statistically different between the two soil management systems, while that of other macrofauna was higher in the S_{mng} system.

The weight of the biogenic structures in the mesh bags with holes (access to macrofauna) were significantly higher in the S_{mng} system than in the C_{mng} one, with differences marked in the 0-5 cm soil depth (10.058 and 3.952 g in the S_{mng} and C_{mng} systems, respectively). The same trend was found in the mesh bags without holes (access to smaller fauna only) (3.710 and 1.392 g in the S_{mng} and C_{mng} systems, respectively, at 0-5 cm soil depth). At the deepest soil depths (5-10 and 10-20 cm) bioturbation was very low compared to the 0-5 cm soil layer.

The weight differences of the tea inside the two types of the tea bags (green and red), allowed to calculate the decomposition indices. Among these, the fraction of remaining green and red tea (Wr_{t} and Wr_{t}, respectively) were lower in the S_{mng} system. The stabilisation factor (S) resulted to be significantly higher in the C_{mng} system (0.670 vs 0.585), while the decomposition rate constant (k) showed a reverse trend (0.018 in the S_{mng} system and 0.010 in the C_{mng} one).

The fraction of remaining local litter (Xl_{t}) in the bags kept in the soil for one year was significantly higher in the C_{mng} system (0.847) than in the S_{mng} one (0.626). Regarding the litter decomposition constant (z), it resulted to be 0.515 in the S_{mng} system and 0.168 in the C_{mng} system, being significantly different at $p \leq 0.05$. Similar trends of local litter bags decomposition parameters, but with higher remaining litter and lower z values were found in the bags kept in the soil for 90 days.

Figure 1: (a) Earthworms, (b) mesh bags, (c) local litter bags, and (d) tea bags recovered from the soils studied in the experiment

Discussion

A great part of the soil quality and fertility in the S_{mng} system could be due to the bioturbation activity of soil macrofauna, together with its interaction with decomposing microorganisms and roots. From the general analysis of the data obtained, it appears that a S_{mng} system increased macrofauna abundance and bioturbation, with repercussions on SOC decomposition determined both in litter and tea bags. Generally, higher microbial and faunal biodiversity in agro-ecosystems leads to greater stability and multifunctionality (Giller *et al.*, 1997; Sofo *et al.*, 2019; Wu and Wang, 2019). From a productive point of view, in soil fauna-plant interactions both the animal and the plant profit from each other, and these interactions could play an important role in fruit growing, positively affecting plant status, water and nutrient uptake and improving product quality (Brussard *et al.*, 2007).

On this basis, the role of soil fauna should be seriously taken into account in future land management strategies focused not only to fruit yield and quality but also to multifunctionality of agro-ecosystems. From an ecological point of view, understanding the relationship between local changes (e.g., soil fauna/microorganisms, soil quality and fertility, soil carbon storage capacity, nutrient cycling and soil water retention) and global effects (e.g., soil quality/fertility, soil environmental importance, climate change mitigation and adaptation) can be particularly important in fruit orchards, whose products are a relevant source of income for many farmers operating in the Mediterranean area and have a potential role for climate change mitigation (Pergola *et al.*, 2013).

Conclusions

In view of circular economy principles and to capitalize on natural potential of soils, strategies have to be developed for sustainable land use practices that optimize nutrient and energy use. This will reduce SOM decline, soil erosion and soil degradation but also promote ecosystem services and foster biodiversity, with consequent benefits to the whole agro-ecosystem stability and its resilience against biotic and abiotic factors.

Acknowledgements

Part of this research (mesh bags) has been inspired and supported by the COST Action ES1406: Soil fauna - Key to Soil Organic Matter Dynamics and Modelling (KEYSOM).

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19–22 April 2021

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The Global Soil Partnership (GSP) is a globally recognized mechanism established in 2012. Our mission is to position soils in the Global Agenda through collective action. Our key objectives are to promote Sustainable Soil Management (SSM) and improve soil governance to guarantee healthy and productive soils, and support the provision of essential ecosystem services towards food security and improved nutrition, climate change adaptation and mitigation, and sustainable development.

Thanks to the financial support of

European Commission

Ministry of Economic Affairs of the Netherlands

Ministry of Finance of the Russian Federation

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Confédération suisse
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ISBN 978-92-5-135218-2

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CB7374EN/1/11.21