Multifunctional peri-urban agriculture: some ecosystem services of a sustainable olive grove

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Abstract

This study reports the influence of a sustainable management model which entails the recycling of urban wastewater and distribution by drip irrigation, recycling of polygenic carbon sources internal to the olive orchard (cover crops, pruning material) on yield, soil water holding capacity, soil biodiversity. Sustainable management practices were applied for a 15-year period in a 2-ha olive orchard located in an hilly peri-urban zone of southern Italy, where olive tree represents the dominant crop and has a key role inside the traditional landscape. A comparison between sustainable and conventional management (soil tillage, burning of the pruning residues, mineral fertilization, empirical irrigation) was carried out. This study suggests some guidelines of a sustainable management of peri-urban olive groves, with benefits to the whole agro-ecosystem stability and to the near town, recognizing the multifunctional role of agriculture that enhances the creation of synergies between urban and rural areas.

Keywords: C capture, wastewater reuse, sustainable soil management, cultural heritage, local food

INTRODUCTION

Currently, more than 50% of the global population lives in cities and urban areas and this share is continuing to increase (UNDESA, 2014). By 2050, the world population is also expected to increase by 33% and agriculture will need to produce 60% more food globally (Alexandratos and Bruinsma, 2012). However, the most important natural resources (soil and water) are not renewable and are subjected to high pressure of anthropogenic activities and climate change. The agricultural sector is the largest user of water resources, accounting for roughly 70% of all freshwater withdrawals globally (WWAP, 2014). Treated municipal wastewater could be an alternative and sustainable source of water and nutrients, a solution to address water growing scarcity, becoming a central issue inside the context of a circular economy (WWAP, 2017). Soil restoration is another important challenge of the 21st century, facing increasing soil degradation, characterized by decline in quality and decrease in ecosystem goods and services (Lal, 2015). Several studies confirmed that farming systems could affect the type, rate and severity of soil degradation by altering the SOC pool, structural morphology and other properties (Autret et al., 2016). Nowadays, there are evidences that sustainable orchard management practices (e.g., no-tillage, cover crops, shredding of pruning material) might sequester atmospheric CO_2 into soil, tree biomass and litter, enhancing soil organic carbon (SOC) stock and biodiversity (Montanaro et al., 2017a).

To deal with water scarcity and soil degradation, peri-urban agriculture could link urban and rural areas and increase their resilience, enhancing ecosystems in their regulation. This study presents a sustainable model applied in an olive grove located in the peri-urban hilly area in southern Italy, under a Mediterranean semi-arid environment. In Italy, no less than 61% of olive crops are still located in hilly areas (ISTAT, 2010) and the traditional olive landscape keeps a mediating role between man and nature, and represents a major result of long-term relationships between communities. Olive tree has a high symbolic value related to the cultural heritage and the identity of Mediterranean areas

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(Palazzo and Aristone, 2017).

The proposed guidelines in peri-urban agriculture could be used as example by policy makers and water managers, through a multifunctional approach aimed at increasing benefits for the community.

MATERIALS AND METHODS

Experimental design

At an approximately 80-year-old hilly olive grove ('Maiatica', 8×8 m planting density) located in southern Italy, near the hill town of Ferrandina, two blocks (1 ha each) were identified and managed according to sustainable agricultural practices (S) and conventional ones (C) for 15 years. Trees of the S plot were drip-irrigated by treated urban wastewater and pruned every year and residues shredded and left on the ground as mulch, soil was not tilled and covered by spontaneous self-seeding weeds mowed twice a year. Urban wastewater was treated by a pilot unit located at less than 1 km from the town according to simplified schemes and channelled to the orchard at 1.5 km distance from Ferrandina (Palese et al., 2013). The treated irrigation water was supplied from May to October by drip irrigation. The plant is placed on the top of the hill allowing water distribution to the olive grove on the hill slopes by gravity. The seasonal irrigation volume was of 3,425 m^3 ha^{-1} $year^{-1}$, in accordance with the seasonal irrigation need of an olive orchard (Palese et al., 2013).

The C plot was grown under rain-fed conditions and managed according to conventional practices: soil tillage usually performed 2-3 times a year, empirical soil fertilization, heavy pruning every two years and burning of pruning residues.

Different parameters were evaluated and compared between the two managements: soil organic carbon (SOC), soil water infiltration rate and storage capacity, microbial biodiversity, yield and fruit quality.

RESULTS AND DISCUSSION

The sustainable model of peri-urban agriculture presented in this paper is aimed at the delivering of different ecosystem services: from provisioning (local food, olive and oil) to regulating (water cycle, soil erosion, land degradation, drought), supporting (nutrient cycling), cultural (maintenance of cultural heritage and tradition) and social (new jobs) services.

Results revealed a positive effect of sustainable agricultural practices and municipal wastewater irrigation on soil quality, with benefits to the stability of the whole agro-ecosystem.

SOC stock and CO_2 sequestration

Results revealed that a 15-year period of sustainable management significantly increased SOC concentration from 0.8 to 1.56% (from 2000 to 2015), that equals a C accumulation rate of approximately 2.2 t C ha^{-1} $year^{-1}$ (top 30 cm soil layer) and that is twice the amount of the conventional management, highlighting the potential role of that orchards for carbon capture. In particular, the S system was able to fix a higher total amount of CO_2 than the C system (more than double), acting as a sink of carbon (Palese et al., 2013). This is due to the fact that S plot was irrigated with urban wastewater and S plants had a higher vegetation growth and higher yield compared to C ones (Figure 1). Due to the composition of the polygenic carbon sources added to soil under sustainable management practices (cover crops, pruning material) and to the irrigation with municipal treated wastewater, a huge amount of nutrients was released to the extent that external supply of mineral fertilizers could successfully be reduced. For example, the reduction of the applied N fertilisers (about 67% less than the total plant need) allowed to save money and to limit environmental pollution (Table 1).

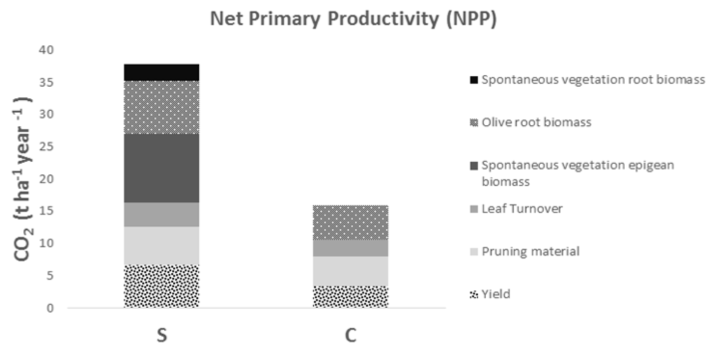

Figure 1. Mean (2001-2008) annual net primary productivity (CO_2, t ha^{-1} year^{-1}) in the two olive plots under sustainable management (S) and conventional one (C) for different orchard items (re-drawn from Palese et al., 2013).

Table 1. Amount of nutrients supplied with municipal wastewater, plant needs for each nutrient and amount needed as external input with fertigation.

Nutrient	Quantities supplied with 3000 m^3 ha^{-1} of municipal treated wastewater (kg ha^{-1} year^{-1})	Plant need (kg ha^{-1} year^{-1})	External input (kg ha^{-1} year^{-1})
N	55	130	75
P	3	5	0
K	51	50	0

Soil water holding capacity

Increased SOC is generally associated with improved soil quality traits (e.g., soil porosity, soil water infiltration rate, water-holding capacity, storage and availability of plant nutrients, reduced soil erosion) (Montanaro et al., 2017a, b), this may be beneficial for dry environments and contribute to save water. The vertical soil water infiltration rate measured at the S plot (at about 12 cm depth) was about 10-fold higher than that of C one, allowing a storage of water of 4,250 m^3 ha^{-1} (at 2 m depth) under S management, while at C plot it was 2,934 m^3 ha^{-1} at the end of the rain season (Palese et al., 2009). On the contrary, a tilled soil is characterized by a reduced infiltration of water, a consequent runoff and increased soil erosion, that leads to a loss of capacity of the near dam and floodings. The sustainable management could be a solution to this huge economic problem, enhancing benefits for the community.

Microbial biodiversity

Soil fertility is mainly related to the variability, abundance and richness of microorganisms (Zornoza et al., 2015). They are responsible for the cycling of organic matter and the generation of nutrients for plants through enzymatic processes (Nannipieri et al., 1990). The S plot showed a higher total number of soil bacteria and fungal amount, with a more genetic, functional and metabolic diversity of soil micro-organisms (Sofo et al., 2010, 2014). The positive effects of minimum tillage and organic carbon input on soil bacteria are due to increased soil aeration, cooler and wetter conditions, temperature and moisture buffering capacity of the soil, as well as higher carbon content in surface soil (Brady and Weil, 2008).

Recently, the effect of S management has been evaluated in the olive grove on diversity of microbial communities in the phyllosphere and carposphere (Pascazio et al., 2015) and in xylem sap (data not published), revealing an higher richness and biodiversity of micro-organisms under S management compared to C one.

Yield and fruit quality

Olive trees under S management showed on average an annual yield 2.3 times higher (62.6 vs. 27.0 kg $plant^{-1}$) than C tree. Similarly, S drupes showed better fruit quality parameters compared to C ones (Palese et al., 2013). In particular, irrigation positively affected fruit characteristics like the mean fresh fruit weight (a very important parameter for table olives), compared to rain-fed ones (Palese et al., 2009).

The scaling up of the pilot unit of the plant presented above could irrigate the surrounding olive groves around approximately 200 ha near the Ferrandina town (Table 2). For this reason, it is necessary to sensitize the policy makers and water managers in order to implement actions related to climate change adaptation and mitigation.

Table 2. Project values.

	Unit of measurement	Value
Equivalent population	E. P.	10,000
Daily water supply	m^3	0.25
Effluent flow rate	$m^3\ d^{-1}$	2,000
Irrigable hectares	ha	180

CONCLUSIONS

The study summarised the positive effects of sustainable agricultural practices and treated municipal wastewater irrigation including some soil quality traits, nutrient use efficiency, with benefits to the whole agro-ecosystem.

This study presented a sustainable model of peri-urban agriculture aimed at the delivering of different ecosystem services. The use of treated municipal wastewater and the application of sustainable practices can increase resource efficiency, avoid further costs for sewage sludge disposal and provide benefits to ecosystems through reducing freshwater consumption, recycling and reusing nutrients, creating new jobs, providing local food, preserving traditional landscape and cultural heritage.

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