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# Thirteen years of continued application of composted organic wastes in a vineyard modify soil quality characteristics

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ABSTRACT

A solution for environmentally wiser agriculture is the use of composted organic wastes as soil amendments. Just as this alleviates the problem of recycling organic residues, it provides necessary nutrient input for food production. The objective of this work was to study the effect that 13 years of applying three different composted organic wastes or organic amendments have had on soil quality, GHG emissions and the dynamics of its microbial communities 15 days after the annual application. For this purpose, in 1996 a field trial was set up in a Tempranillo vineyard. Since 1998, the applied organic amendments have been as follows: 1. a pelletized organic compost (PEL) made from plant, animal and sewage sludge residues; 2. a compost made from the organic fraction of municipal solid waste (OF-MSW); 3. a compost made of stabilized sheep manure (SMC); 4. a mineral fertilizer (NPK); and 5. an unaltered control. The mean annual doses applied since 1998 have been 3700 kg ha$^{-1}$ fresh weight (FW) of PEL, 4075 kg ha$^{-1}$ FW of OF-MSW, 4630 kg ha$^{-1}$ FW of SMC, and 340 kg ha$^{-1}$ of NPK treatment. Soil quality was consistently enhanced by amendment application over the 13 years. Total nitrogen was significantly increased in PEL (0.1%), OF-MSW (0.09%) and SMC (0.1%) compared to control (0.06%). Nutrient content was also improved in a similar way, e.g. the most significant increase in P Olsen (80.7 mg kg$^{-1}$) and $K_2O$ (473.8 mg kg$^{-1}$) was found on SMC. The overall enzyme activity was also increased 15 days after the annual application and OF-MSW had the highest rate (95.9) compared to control (51.3). This increase in metabolic activity was also recorded in GHG emissions. $CO_2$ equivalents per hectare were 1745 kg for OF-MSW and it was the only significant difference found. PEL with 1598 kg and SMC with 1591 kg were not different from the Control (1104 kg). Even though GHG emissions in the soil increased because of the application, soil organic matter content increased significantly (at least 35% more in all organic treatments compared to control) and this rise in organic matter was consistent over the years. According to the results, 85% of the sequences corresponded to 5 main phyla: Proteobacteria, Actinobacteria, Bacteroidetes, Acidobacteria and Gemmatimonadetes, with unclassified material making up for 10.9% (average) of the sequences. Bacterial diversity by Shannon and Chao1 indices was not affected 15 days after the application. However, slight changes in the bacterial community were recorded 15 days after application only in OF-MSW treatment. Assessing soil quality using these three factors allows the relevant agronomical capabilities of the soil to be integrated with the potential effect of this practise on global warming.



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## 1. Introduction

Climate change poses an important challenge for food production. Agricultural systems must meet the goal of ensuring productivity by effectively adapting to changing climatic conditions and enabling mitigation practices, in other words, agriculture has to be more resilient (Steenwerth et al., 2014).

To achieve the goal of a wiser agriculture, the quality of the soil that is being used must be preserved or enhanced through fertilization. Soil quality has been described as the degree of fitness of a soil for a specific purpose (Gregorich et al., 1994). Also, soil quality is understood as a series of ecological functions, such as nutrient cycling, energy and water storage, and biological transformations (Doran and Zeiss, 2000; Havlicek, 2012). Moreover, the ability of soil to function as a viable component in food production, according to the requirements of each crop and its surrounding environment, has to be the central focus for evaluating soil quality.

The assessment of soil quality should consider the purpose of each particular soil. In this case, as previously stated by Aranda et al. (2011) soil management practices in traditional Spanish viticulture neglect soil quality and lead to its deterioration. One reason is the frequent ploughing to keep the land bare for the majority of the time. This practice is aimed at reducing competition with weeds and suppressing pathogens (Francia Martínez et al., 2006). Additionally, large quantities of phyto-sanitary products are applied to the vines, which seriously erode and degrade soil (Milgroom et al., 2007). These practices deplete the organic matter content, noticeably affecting firstly soil quality and eventually the quality of the grapes, as well as the sustainability of the vineyard (Morlat and Symoneaux, 2008).

An interesting alternative to traditional mineral fertilization, which improves soil quality in vineyards, is the application of composted organic wastes. Residues and surplus materials from different stages of food production, such as organic waste and manure, provide agricultural systems with nutrient resources that would otherwise be discarded (Westerman and Bicudo, 2005). These residues already cause an important management problem as disposal options are limited and not necessarily environmentally-friendly (i.e., landfills and incineration) (Kumar et al., 2012). Moreover, after composting, these materials are rich in nutrients, and contain an important quantity of organic matter. Compost performance in soil is closely linked to the composting process (Ceustermans et al., 2010). A mature compost increases the possibility of preventing or reducing the greenhouse gas emission potential of waste, and a beneficial feedback loop is generated as resources are used more efficiently (with less losses). More importantly, composted organic wastes prevent the deterioration of soil functions. Previous studies on the effect of composted organic-residues in vineyard soils have demonstrated that significant changes are observed from the 6th year of trial onwards (Morlat and Chaussod, 2008). Also, previous research into the physical properties of soil revealed that the addition of compost, from the organic fraction of municipal waste, improved the organic matter content without posing a risk of heavy metal phyto-toxicity (Pinamonti, 1998).

In the case of long-term application of compost from organic wastes, soil quality should be studied in addition to other parameters. A good starting point is the traditional soil quality measurement that includes indicators such as enzyme activity, nitrogen mineralization, nitrification rates, total nitrification and denitrification. All these processes depend greatly on microorganisms and their community structure. Also, as incorporating composted organic-residues into soil fosters intense short-term microbial activity (Zaccardelli et al., 2013), an examination of the soil's microbial structure is also an appropriate addition to soil assessments. This latter can be analysed through the use of novel techniques based on the abundance of the 16s gene through the extraction of microbial DNA (Robe et al., 2003). The advantage of this technique is that a high proportion of the bacterial community can be recovered (Vega-Avila et al., 2015).

Lastly, greenhouse gas emissions ($CO_2$, $CH_4$, and $N_2O$) from soils are important, as, for example, fertilization is the origin of 35% of global $N_2O$ emissions (Isermann, 1994). Gaseous emissions are usually researched and used as the sole indicator of how a fertilization practice influences climate change. The rationale behind climate change mitigation is bound to the idea of reduction (or even removal) of greenhouse gas emissions (Shcherbak et al., 2014) within a context of mineral and short-term fertilization. Where composted organic residues are applied this objective is not fulfilled because the practice itself is an emissions' trigger. Conversely, over some years, long-term carbon sequestration is achieved by maintaining and even increasing C stocks in soils (Gattinger et al., 2012) as a consequence of applying a fully mature compost (Johnson et al., 2007). For this reason, the application of composted organic residues offers a new mitigation opportunity and this indicator should also be analysed.

North-western Spain has a long tradition of viticulture and wineries. From ancient times, these industries have been considered one of the most important economic activities in the Navarra region (Unwin, 1996). The extensive vineyards in the area cover approximately 27,447 ha, and more importantly, wine making represents around 8.8% of the total agro-related income (INE, 2009). The economic importance of wine production is much more far reaching than just the area covered by vineyards: the Protected Designation of Origin (P.D.O.) *D.O.C. La Rioja* in Navarra, establishes a quota per hectare of produced grape. However, the focus of this study is not efficiency in terms of yield, but rather a comparison of the effects long term (at least 10 years) application of various fertilization practices have on soil quality.

In this context, the aim of this work is to characterize the quality of the soil after 13 years of continued treatment using organic amendments. In addition, we have analysed the effect of this application in the microbial activity and the GHG emissions. We were particularly interested in observing the composition of bacterial communities 15 days after amendment's last application. Additionally, this study sought to understand if these fertilization practices serve as sources or sink for carbon.

## 2. Materials and methods

### 2.1. Site description

In accordance with the aforementioned objectives, this research was carried out at a long-term experimental site established in 1996 in Bargota, which is situated within the P.D.O. *La Rioja*, in Navarra, Spain. The area is located on a 5% slope in the catchment area of the Ebro River. The climate, according to the classification system of Papadakis (1961), is Mediterranean, with hot summers and annual rainfalls of between 450 mm and 490 mm; the mean annual temperature is 13.8 °C. Fig. 1 shows the precipitation levels and air temperatures recorded during the assayed period. Soil texture in this area is loamy-clay and it is classified as a typical Calcixerept. The characteristics of the control soil for the year 2011 are found in Table 1.

In the year 1996, grapevines (*Vitis vinifera* L c.v. Tempranillo) were planted over a Richter 110 rootstock at a density of 0.3 stocks $m^{-2}$ (3 × 1.15 m). The vines were trained using a midway bilateral cordon system (*Cordon de Royat*) to a height of 0.8 m. Each