Developing an integrated approach to enhance soil fertility and favour recarbonization of Mediterranean agricultural soils: a case study from Valencian Region in Spain

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Mediterranean countries are the most sensitive to climate emergency in terms of the sustainability of agri-food sector, being in addition one of the most oxidable environment for the soil organic matter. In this line, IPCC highlighted the increase of organic matter in soils and waste management as the main drive forces/measures to mitigate climate change. Agriculture, livestock and agri-food sectors in Mediterranean countries have a wide amount of waste fluxes including significant waste-diversity to produce balanced and high-quality composts not only to reconstruct C stock, but also to rebuilt soil properties to increase resilience of agricultural soils against erosion, water shortages and others. A wide range of organic materials, in raw or stabilized forms (named as amendments, fertilizers or biofertilizers) are available nowadays in the market with a projection of growth considering the upcoming EU legislation package on circular economy (EU, 2016) that promote and harmonize the use of fertilizing products from organic sources or secondary raw material (Vico *et al*., 2020). Pardo *et al.* (2017) estimated 121.955 Kton/year of exogenous organic matter from waste fluxes in Spain, being 82% from food production. However, a significant rethink of the existing management of some of these wastes in Spain must be developed, using controlled and uncontrolled agricultural fires. In this line Agrocompostaje project is been developed in Valencia Region (2017-active now) to generate the driving forces to produce this model change oriented to recarbonization of agricultural soils using several approaches but especially mulching and co-composting. Valencia Region includes 656.000 has of agricultural land with average soil organic matter below of 1.3%, being significant at Spanish and European scale in citrus, fruit orchards, winery, almond and horticultural crops.

Agrocompostaje project includes i) monitoring, quantification and analysis of organic waste fluxes (>300 different sources); ii) development of co-composting pilots with actors (>95 pilots into the region); iii) optimizing of co-composting mixtures in km 0 and low cost scenarios (>160 different combinations; iv) monitoring of the process and quality assessment of final compost, including agronomic advisement.

The analyses of more than 300 different sources of organic wastes from agriculture, livestock and agri-food sectors in the Valencian Region produced a very powerful database to identify the opportunities for managing these organic matter pools and especially the nutrients included into these mass fluxes to be reoriented to agricultural soils. Agricultural and agri-food wastes are slightly acidic and mainly organic (>80%), quite similar in several properties, being the most significant differences the higher density and NPK contents in agri-food wastes (table 1). Livestock wastes in Valencia are alkaline, salty and rich in P. The average composition of these wastes is shown in Table 1S, detecting a significant presence of water-soluble polyphenols in all the samples.

In each actor scenario, own waste fluxes and surrounded waste options have been mapped, analysed and used to develop co-composting pilots (>95 pilots into the region) to produce optimized co-composting mixtures oriented to obtain balanced compost near to km 0 using low-cost approaches including bartering, co-use of co-composting areas between actors etc. developing more than 160 different combinations of ingredients. In Table 2 are summarized all these co-composting processes in an averaged/ideal compost produced into our region, able to be used to calculate the re-carbonization and nutrient recovery capacities

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Table 1. Average composition of theValencian Region wastes.

Property	Agricultural origin (n=151)	Livestock origin (n=114)	Agri-food origin (n=90)
Water content (%)	39.7 (1.0-94.6)	39.4 (11.2-71.8)	50.9 (7.9-93.8)
Bulk density (t/m^3)	0.249 (0.015-0.88)	0.37 (0.12-0.83)	0.523 (0.05-1.25)
pH (1:10 extract w/v)	6.6 (4.3-9.3)	7.7 (6.1-9.4)	6.5 (5.0-8.4)
Electrical conductivity (1:10 extract w/v)	4.01 (1.0-36)	5.85 (2.1-16.7)	4.34 (1.16-12.3)
Organic matter (%)	81.7 (40.5-97.1)	70.3 (28.9-89.9)	82.7 (48.6-96.7)
Organic C (%)	42.2 (25.1-66.1)	36.5 (18.5-46.9)	45.4 (29.1-61.5)
C/N ratio	37.5 (10.5-115)	24.0 (7.8-122)	33.0 (9.0-110)
Total N (%)	1.55 (0.5-3.7)	2.12 (0.79-4.29)	1.90 (0.56-4.78)
Total P (g/kg)	2.88 (0.25-16.9)	6.1 (1.1-25.8)	3.87 (0.19-21.9)
Total K (g/kg)	18 (3.9-57)	26.3 (6.4-81)	21 (5.1-49)
Total Na (g/kg)	6.9 (0.21-111)	7.8 (0.3-19.3)	4.21 (0.4-13.8)
Water-soluble polyphenols (mg/kg)	8541 (572-66826)	5695 (768-16644)	5951 (1116-12455)

Table 2. Average composition of developed composts in Agrocompostaje program in the Valencian Region.

Property	Nº samples	Average (range)
Water content (%)	89	43.0 (8.0-80.5)
Bulk density (t/m^3)	89	0.488 (0.196-0.842)
pH (1:10 extract w/v)	95	8.3 (6.7-9.8)
Electrical conductivity (1:10 extract w/v)	95	3.98 (1.08-17.2)
Organic matter (%)	95	49.2 (21.4-86.2)
Organic C (%)	95	28.4 (9.92-45.2)
C/N ratio	95	14.9 (6.77-41.3)
Total N (%)	95	2,07 (0.66-4.32)
Total P (g/kg)	94	7.50 (0.92-27.0)
Total K (g/kg)	95	18.4 (2.6-74.7)
Total Na (g/kg)	95	7.04 (0.44-22.5)
Water-soluble polyphenols (mg/kg)	95	1396 (149-4867)

The averaged N and K values in the ideal compost were close to those in the start-up ingredients; P showed the concentration effect of the composting processes. Co-composting produced significant losses of organic matter as CO_2 but the impact of these procedures in organic waste value chain can be considered neutral or positive depending on each scenario and actor if we consider the emissions depleted as agricultural fires, C sequestration as organic matter input in Valencian soils and the nutrients recovered. In accordance to Vico *et al* (2017), the economic equivalent value of NPK nutrients can be estimated in 33.6 euro/ton. The results of the project include sectorial solutions (wine, olive oil and horticrops sectors), with validated recipes to produce and use advanced compost. Finally, a powerful knowledge platform (www.agrocompostaje.edu.umh.es) has been developed including a composting calculator as an open access app, ©CompostCalculator by UMH.

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