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The use of farm wastes or organic fertilizers

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1. Introduction

Many soils in the Mediterranean regions show low soil organic matter (SOM) contents (Zdruli et al., 2004). This can be considered as a result of natural conditions, but it can be often due to badagricultural practices, leading to loss of soil fertility and decrease of soils' water holding capacity. The decrease of soil organic matter will be higher when on-farm produced organic wastes are exported from the farm. As a consequence, recycling of organic wastes on farms contributes to slow down the process of SOM decline (Delgado, 2010). Sometimes it can even increase SOM, notably when elsewhere-produced organic wastes are applied.

2. Organic fertilization vs. water and air pollution

Excessive application of organic wastes (also called organic fertilizers) as well as mineral fertilizers has led to nitrate pollution of groundwater and surface waters in many European regions. The European Union has therefore set limits to the amounts of animal manures that may be applied on agricultural soils (The Nitrate Directive and the Water Framework Directive).

When organic fertilizers are applied, also volatilisation of ammonia has to be considered, a gas that can contribute to rain acidification. For this reasonstorage tanks should be covered and spreading systems should avoid ammonia emission to the atmosphere as much as possible (injection or incorporation into soil).

3. Types of organic fertilizers

There are many different animal manures and their composition may vary largely, depending on the animal species, the production system and also the country. In the scientific literature, data on average nutrient composition (N, P, K, Mg, etc.) and organic matter content of organic fertilizers are available, at least, for, e.g., Emilia Romagna (Italy) and The Netherlands (Tables 1 and 2). The values presented differ to some extent as a result of differences in production systems. Where animal production is an important economic activity and where animal manures are extensively applied to agricultural soils, more data are available on the composition of the manures.

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The main objective of this paper, however, is not to review the contents and effects of the organic fertilizers, but to analyse and review the opportunities to increase SOM contents in Mediterranean countries.

4. Solutions/possibilities/opportunities

On-farm produced wastes such as animal manures contain nutrients and organic matter (Tables 1 and 2). When organic fertilizers are recycled on farms by applying the materials to agricultural fields, they not only contribute to closing nutrient and carbon cycles, but they also provide nutrients to crops and maintain or improve soil organic matter contents (Johnston et al., 2009; Morrone & Sieglinde, 2011).
The effectiveness of the application of recycled organic wastes to retard or prevent SOM decline depends on factors such as the quality and composition of the materials, the method of field application and the climate. For this reason, preferably all crop residues should be returned to soil to contribute to maintain SOM content. Sometimes, when specific market conditions occur, residues are exported from fields to be sold and to provide an extra income for farmers (e.g., straw of wheat, barley and corn).
With respect to SOM the effectiveness of animal manures is higher when the dry-matter content of the manure is higher. Solid manures are thus more effective than slurries (see also below in the examples of research projects). The organic resources can best be incorporated into the top layers of the soil.
In practice, when organic fertilizers are applied, account should be taken of the nitrogen and phosphorus content of the organic fertilizers and crop nitrogen demand. This is necessary to reduce the risk of nitrogen pollution of freshwaters, common where animal density is high. The balance between farm area and animal stock is based on nitrogen as driving nutrient, and as a consequence the quantity of organic matter applied to soils depends on the C/N ratio of the specific fertilizer, the stability of fertilizer itself, the availability of nutrients, the timing of application, and crop nutrient demand.

However, there are several questions that cannot be fully answered yet and require further research:

- Optimum SOM content related to C-sequestration potential in different areas (soil types and climate). Site-specific threshold values of SOM contents. Cost-efficient ways to enhance the stability and transportability of organic fertilizers (e.g., composting, fractioning solid/liquid).
- Types and rates of the organic resources that should be applied to have the desired effect on SOM. Effectiveness of organic resources. Practitioners often experienced difficulties to match crops' demand with the availability of nutrients. Possible solutions to be implemented are

toachievelow nitrate contents in the soil at the end of cropping season, split fertilization, use of catch crops, crop rotation design, let the soil be covered by cover crops/vegetation/residues as long as possible.Reduction of nitrate leaching risks in each zone, considering variability of leaching period due to climate change.Reduction of ammonia, methane, NOx and bad odours emissions.Soil tillage effects on SOM.There is also a need for the development of a decision support system for the application of organic resources to support farmers.

5. Examples of existing or recently completed research projects

- ### Pig manure application

Pig slurry (PS) applications could help to increase soil fertility in the semiarid Mediterranean conditions of many areas of the Ebro Valley (Spain). However, at the same time, special management attention is required to accomplish the nitrate regulations in order to minimize the environmental impact of N in nitrate sensitive areas.

However, studies of the long term organic fertilization with PS show only a slight improvement in soil quality if the allowed amounts (to follow the nitrate regulations and directives) of PS are applied. Even if the amounts of PS applied were much higher than the amounts allowed by the EU directives in nitrate sensitive areas (50 Mg ha^{-1} yr^{-1}), they were not sufficient to obtain clear effects in soil quality and SOM contents.

In these irrigated areas where the 'normal' corn grain productions are about 14 to 16 Mg ha^{-1}. Under sprinkler irrigation, the application of 3.4 Mg of organic matter ha^{-1} $year^{-1}$ (about 25-30 m^3 ha^{-1} of slurry manure) over ten years as a PS manure, was not sufficient to produce a clear increase in soil quality parameters, except for earthworm abundance. The slurry was applied before seeding and buried, less than 24 after the application. Higher rates of PS than those allowed with the Nitrate directives can be necessary to increase SOM (Biau et al., 2012).

- ### Milk Cow Manure

Dairy cattle and maize production are important economic activities in many different areas of the world. It has been known for years, that the application of dairy cattle manure is beneficial because, next to reducing fertilization costs, it can improve the soil chemical, physical and biological properties (Eghball et al., 2004).

In general, crop supply of N from manure is lower than from inorganic fertilizers due to the slow release of organically bound N and the volatilization of ammonia from surface-applied manure (Jokela, 1992). This slow release of the manure ends in a residual effect of increased nutrients and SOM that can last for

several years (Lund & Doss, 1980; Eghball et al., 2004). Residual effects can also maintain corn yield level for several years after manure applications.

Mid–term studies (seven years) (Martinez et al., submitted for publication) with the use of dairy cattle manure (0, 30 and 60 Mg ha^{-1} of fresh manure) combined with side-dress mineral N fertilization in maize have been conducted in irrigated areas of north-east Spain. In these areas corn yields of about 13-15 Mg ha^{-1} of maize grain are normally obtained.

The final results show that at the end of the trail the highest grain yields of 15300 to 15700 kg ha^{-1} were obtained with 30 Mg ha^{-1} of fresh manure (amounts allowed by the nitrate directive) plus 200 or 300 kg ha^{-1} of inorganic fertilizer N or just with 60 Mg ha^{-1} of manures with 100 Kg ha^{-1} of inorganic fertilizer N. However, at the same time, there was a clear increase of SOM at the end of 7 year period. At the end of the trail, the average of four inorganic fertilizer N rates (0, 100, 200 and 300 kg N ha^{-1}) for each dairy manure rate, the soil OM was 1.2, 1.5 and 1.7% for the application of 0, 30 and 60 Mg ha^{-1} yr^{-1}, of fresh manure, respectively. The Initial SOM content was 1.3%. The results show the dairy cow manure can be an effective way to increase the SOM contents in Mediterranean areas, although larger amounts of manure than those allowed by the EU nitrate directives are needed. It took seven years to raise the SOM contents from 1.3 % to 1.7% with the application of 60 Mg ha^{-1} yr^{-1} of fresh manure.

- CATCH-C.

The Catch-C project assessed the farm-compatibility of 'Best Management Practices' (BMPs) that aim to promote productivity, climate change mitigation, and soil quality.

Information collected on current management is spatially organised with the help of a typology of the main farm types and agro-ecological zones across Europe. Biophysical impacts of management practices are assessed from a large set of current field experiments by the partners. BMPs are formulated, along with their trade-offs and synergies between productivity, climate change mitigation, and soil quality. The project identified barriers against adoption of BMPs and formulated ways to remove them. In interaction with policy makers, Catch-C will develop guidelines for policies that will support the adoption of BMPs and that are consistent with regional, agro-ecological and farming contexts.

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- ## Organic fertilizer application and fruit trees

Organic fertilizers can also be applied to fruit trees. With this idea in mind, some experiments have been conducted in Italy.

The objectives of this experiment were to evaluate the long term (10 years) effects of organic fertilization on soil fertility, tree performance and fruit quality in a commercial peach orchard. Since planting in 2001, trees were subjected to the following treatments: Unfertilized controls, mineral fertilization including P and K at planting (250 kg P_2O_5 ha^{-1}; 300 kg K_2O ha^{-1}) and N split in two applications per year (at the flowering stage and at the green pruning, ranging yearly between 100-130 kg N ha^{-1}, depending on fall-winter rain amount), cow manure (5 Mg DM ha^{-1} yr^{-1} in spring), compost low dose (5 Mg DM ha^{-1} yr^{-1} in spring); compost low dose split (5 Mg DM ha^{-1} yr^{-1}); compost high dose split(10 Mg DM ha^{-1} yr^{-1}).

During 10 consecutive years the commercial peach orchard was permanently covered by grass, between rows. Grass has been cut twice a year and left on the field. Wooden pruning residues were exported off the field, while leaves and green pruning were left there.

After 10 years, SOM content increased significantly in treatments receiving compost, whilst treatments "mineral fertilization" and "cow manure" did not result in significant differences. The maximum increase of SOM content, starting from an average value of 1.6 % at the beginning of the experiment, was achieved by "compost high dose" treatment with SOM content (0-30 cm depth) of 3.9 %, averaged over the last 3 years.

Nitrate-N soil concentration was increased by the application of compost at 10 Mg ha^{-1} and mineral fertilizer; ammonium-N soil concentration was increased by the application of compost at the highest rate only at the beginning of the season, when soil moisture is higher.

Microbial C was increased by application of compost, but not by cow manure. Tree yield was not affected by treatments; however, fruit size was increased by mineral and high rate compost fertilizations. Leaf concentrations of chlorophyll and N were increased by the application of compost at the highest rate and mineral fertilizer (Baldi et al., 2014).

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6. Solutions and conclusions

Manures can be an effective way to increase SOM, but as it is known the increase of SOM contents is a slow process. It can therefore take more than five to ten years before it will become apparent that the application of organic manures has a positive effect on SOM contents.

There is no doubt that animal wastes can be a valuable way to recycle nutrients and to add OM to the soil. This has to be performed in a sustainable way. However, its use is limited to regions with intensive

livestock systems and mixed farming systems, since transport costs set a limit to a cost-effective use in more distant regions unless highly concentrated OM fractions of these animal wastes are produced.

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Table 1.Inventory of sources of exogenous OC in Emilia-Romagna region (Italy).

Type of OC source	OC content (%)	Nutrient content (%)	C/N	Dry matter (%)
Cattle slurry	3 – 8	0,1-0,4 N 0,1-0,2 P	5-10	4-10
Cattle manure	6-20	0,3-0,5 N 0,05-0,3 P	10-15	15-30
Pig slurry	1-4	0,1-0,5 N 0,05-0,2 P	2 -8	3-6
Broilers' manure	20-40	2,0-4,0 N 0,2-0,8 P	8-12	70-85
Laying hens manure (dehydrated)	15-30	3-5 N 1,5-2,5 P	5 -8	50-60

CRPA (Animal Production Research Centre). Map of agricultural sources of Organic Biomass in Emilia-Romagna. 2006. Modified. (Source: CRPA,2006. www.crpa.it)

Table 2. Nutrient composition of organic materials in the Netherlands. Source: Den Boer et al., 2012).

Manuretype	Dry matter (%)	Organic matter (%)	Total N (kg/Mg)	Inorganic N (kg/Mg)	Organic N (kg/Mg)	P_2O_5 (kg/Mg)	K_2O (kg/Mg)
Liquidmanure							
Cattle	2.5	1.0	4.0	3.8	0.2	0.2	8.0
Pigs	2.0	0.5	6.5	6.1	0.4	0.9	4.5
Poultry	1.0	1.0	2.0	1.9	0.1	0.9	2.5
Slurry							
Cattle	8.5	6.4	4.1	2.0	2.1	1.5	5.8
Meatpigs	9.3	4.3	7.1	4.6	2.5	4.6	5.8
Sows	6.7	2.5	5.0	3.3	1.7	3.5	4.9
Calves (red meat)	9.4	7.1	5.6	3.0	2.6	2.6	5.0
Calves (whitemeat)	2.2	1.7	2.6	2.1	0.5	1.1	4.5
Solid manure							
Cattle	19.4	15.2	5.3	0.9	4.4	2.8	6.1
Pigs	26.0	15.3	7.9	2.6	5.3	7.9	8.5
Layinghens	57.3	41.6	25.6	2.5	23.1	19.6	15.5
Chicken	71.3	35.9	28.0	3.6	24.4	25.6	20.8
Turkeys	52.0	42.7	23.3	6.0	17.3	19.7	13.4
Horses	28.7	16.0	4.6	0.5	4.1	2.7	8.1
Sheep	27.6	19.5	8.8	2.0	6.8	4.5	15.6
Goats	29.1	17.4	9.9	2.4	7.5	5.3	12.8
Ducks	27.5	23.7	8.9	1.6	7.3	7.3	8.4
Rabbits	40.8	33.2	9.4	2.3	7.1	6.7	10.7

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