

Production and reuse of waste in rural area with high density of greenhouse

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Abstract

Agricultural activities cause the production of considerable amounts of waste sometimes dangerous that must be properly handled to avoid negative impacts on rural areas and on agroecosystems. The estimation of qualitative and quantitative characteristics of agricultural waste products and the capacity of rural land of transposing organic matter deriving from the processes of composting, is a key point for the planning and management of the waste integrated cycle. The aims of this study are the evaluation of the quantities of various types of agricultural waste on territorial scale, the amount of compost that can be used in rural areas affected by different cultures and the effectiveness of community composter in the treatment of vegetable agricultural waste for the production of green composted soil. These assessments were carried out in an area of study characterized by a high spatial density of greenhouses. The methodological procedure used is based on the use of agricultural waste production coefficients and maximum application rates of compost for cultivation. The results show the role and potential of the agricultural areas in the waste cycle from production to the potential reuse of recovered material.

Introduction

The rural areas plays a key role in the mitigation of environmental risks related to the management of urban and agricultural wastes. Besides the production of waste produced by farms, may be present in a rural area municipal or industrial wastes treatment plants that

increase the environmental risk. In addition, rural areas are the final delivery for many organic wastes.

The industrial waste treatment facilities in the rural areas can cause negative impacts on the ecological balance, landscape, degree of naturalness (Pivato *et al.*, 2012). The construction and operation of these plants is, however, necessary in order to reduce the environmental impact of the production of urban and special waste. These plants allow the recovery/recycling, volume reduction, mitigation of hazards, disposal in sanitary safety. The need to build and operate landfills, recycling and composting plants, waste to energy and waste collection centers must therefore be combined with the simultaneous target to protect the environment, the landscape, human health and quality of agricultural and livestock production. In this context is necessary mitigate the health and environmental risks determined by waste treatment plants. For the prevention and reduction of pollution caused by waste management activities, the European Directive 2008/1/EC identifies the measures to be adopted to reduce emissions to air, water and soil. According to this Directive, waste treatment plants must be built and operated by applying the "Best Available Techniques" in order to reduce the overall impact on the environment.

It's also necessary to act on the management of waste from the stage of production, collection and transport through proper planning and organization (Calabrò, 2009).

The management of agricultural waste in rural areas is a complex problem that must, therefore, be addressed in the context of proper coordination between land use, planning and integrated cycle of wastes (Dal Sasso *et al.*, 2009). Waste management plans are identified by Legislative Decree no. 152/06 as important tools to make sustainable waste cycle, in terms of environmental and economic possibilities. These plans should indicate the method of the collection and treatment of wastes at regional and provincial level on the basis of qualitative and quantitative characteristics.

In Italy, the evaluation of agricultural waste is uncertain because they are left in the environment, burned in an uncontrolled manner (Picuno and Scarascia Mugnozza, 1994) and transferred illegally in road bins for the collection of municipal waste. The above reasons prevent a proper evaluation of the amount of agricultural waste produced especially in rural areas characterized by the presence of small farms, this makes difficult the drafting of management plans for agricultural waste.

The agricultural waste management plans of the Abruzzo Region and the Florence Province have made a significant and concrete impulse to the proper management of national agricultural waste.

It is expected in them the selective collection of recyclable fraction of the waste (cardboard, plastic and wood, used oil, batteries and accumulators) by means of the operators of waste management services and the creation of centers of collection of separated waste in accordance with Ministerial Decree 08/04/2008 and Ministerial Decree of 13/05/2009. These collection centers may be used for the transfer of many different types of agricultural waste for recovery/recycling. In this way are increased the "indices of recovery/recycling" of agricultural waste and emissions are reduced due to transport with the ability to

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organize and plan the itineraries of collection vehicles in the area.

The environmental impacts associated with the management of agricultural organic waste can be further reduced through their treatment and recovery on site. Are in fact available small plants (community composters, biomass heating plants, bio-gas plants) that can be installed in the farm. These plants are used to treat organic waste and to obtain compost and/or energy for use in agro-industrial processes and in particular in greenhouse sector. In fact, the compost can be used as a component of growing media of ornamental potted plants to reduce the amount of peat (De Lucia *et al.*, 2009) and the renewable thermal energy can be used for greenhouse heating to reduce the consumption of fossil fuels (Scarascia Mugnozza *et al.*, 2012).

The assignment of agricultural waste collection service to the municipal waste management services and the installation of on-site organic waste treatment plants, can improve the financial statements of farms, the rural landscape and the environment. These aspects have significant importance because the agricultural sector in 2008 was responsible for the production of about 440,000 t year⁻¹ of waste on a national scale (ISPRA, 2011) and 9,000 t year⁻¹ in the Puglia Region (ARPA Puglia, 2010). In Italy, in recent years, have been reduced environmental burdens connected to the waste cycle and has been improved the human/environment interaction thanks to the increase of the recovery of agricultural waste and a simultaneous reduction in the use of landfills (Atrigna *et al.* 2011).

A large quantity of agricultural waste consists of plastics (Scarascia Mugnozza *et al.*, 1999) due to the increasing use of plastic films in agriculture for greenhouses covering, mulching and crop protection (Scarascia Mugnozza *et al.*, 2007). During their use, the plastic films are subject to the reduction of mechanical strength (modulus of elasticity and elongation % at break) and radiometric characteristics (reduction of transmissivity in PAR) due to the action of external climatic factors and therefore are periodically replaced (Picuno *et al.*, 2009). In fact, we can estimate the production of agricultural waste plastic films consist of about 110,000 t year⁻¹ in Italy (Dal Sasso *et al.*, 2009) equal to 25% of total agricultural waste. These plastic wastes are often used in cement industries, however, their qualitative characteristics and the percentage of contaminants depend on the previous use (greenhouses, tunnels, mulching, etc.). (Briassoulis *et al.*, 2012). The other agricultural waste, are made by: agrochemicals containers, tires and batteries of agricultural vehicles, paper/cardboard packaging, wood, iron.

At the same time, in agricultural activities can be used plastic film, produced through recycling of plastic waste (Picuno *et al.*, 2009) and substrates products through composting of pruning and organic waste (De Lucia *et al.*, 2009).

The composting process reproduces, under controlled conditions, the natural decomposition and humification of organic substances (Zorzi *et al.*, 2010) by the combined action of microorganisms and chemical-physical reactions. The correct evolution of biological and biochemical reactions that characterize the composting process is related to chemical - physical parameters such as: moisture, pH, carbon/nitrogen ratio in the treated waste (Atrigna *et al.*, 2011). The composting determines the mineralization of the organic substance, the production of humic acids and the production of a stable end-product defined by Italian legislation "composted soil". The composting process can be realized in industrial plants with high potential of treatment, in domestic composters and in the modern electromechanical composter plants for community with treatment capacity of about 25 waste tons year⁻¹ (Figure 1). Community composting is a intermediate level between home composting and industrial composting and may be able to provide a treatment of organic waste physically near the production site (Accotto, 2011). The large distance of the rural areas by industrial composting facilities makes this solution economically and ecologically

interesting (Silingardi, 2011) although the energy consumption is about 15 kWh t⁻¹ treated.

Depending on the type of organic waste that are subjected to composting, soil improvers are classified by Legislative Decree n. 75/2010 as "Mixed composted soil improvers" (MCSI) and "Green composted soil improvers." (GCSI). The GCSI is produced exclusively from vegetable organic wastes (crop residues, agricultural residues, pruning of urban green) while the MCSI is produced from the treatment of municipal organic waste, sludge from the treatment of urban waste water and agro-industrial wastes, cuttings and prunings.

The composting of organic waste and the use of MCSI or GCSI in different agricultural sectors can help to solve two problems at the planetary level: the disposal of organic waste and the reduction of the environmental burden of agricultural process.

The use of quality compost in agriculture can make a significant improvement for agricultural food production more environmentally friendly, and allows to increase the fertility of agricultural soil, reduce erosion and irrigation requirements of the crop (Favoino and Hogg, 2002). Furthermore, the application of compost improves the biological conditions of agricultural soil by increasing the level of organic matter and humus and ensuring an adequate supply of nutrients to maintain the crops in an appropriate vegetative state with repercussions on productivity (Baldi *et al.*, 2008).

In 2009, 3.715.302 tons of organic waste were transferred to national composting plants and 976,424 tons of soil improvements, which complies with the quality standards imposed by Legislative Decree no. 75/2010, were produced (ISPRA, 2011). The soil improvements have been used in agriculture, in open field cultivation (70%) and in gardening and landscaping sector (30%) (Centeremo, 2011). Landfill disposal of 3,715,302 tons of organic waste would have resulted in the consumption of useful volumes for other waste, leachate, emission of approximately 7,200,000 tonnes of biogenic CO₂. The qualitative and quantitative characteristics of the leachate and biogas produced in landfills are in fact strongly influenced by the mineralization of available organic matter and biokinetic (APAT, 2005). In landfills, the high moisture content of the organic wastes produces percolate with a high content of organic substances that together with the production of biogas results in sagging of the final cover.

The objective of this study was to determine a methodology for the evaluation of the quantity and typologies of agricultural waste and, at the same time, to quantify the amount of compost used in the agricultural sector in a particular rural area. In order to assess the role of the agricultural land in the integrated waste cycle, this methodology was applied to a rural sample area. The qualitative characteristics of an GCSI obtained from a community composter were determined using data from a greenhouse farm present in the area sample as standard. The proposed methodology allows to steer management of the collection, transport and treatment of agricultural waste to environmental sustainability.

Materials and methods

Within of the present study were evaluated potential production of agricultural waste in a rural area sample of the Puglia Region, the amount of soil improver that can be used in agriculture and the effectiveness of a community composting plant fueled by pruning .

In order to estimate the flows of waste and soil improvers used in a territory, a methodology based on the analysis of cartographic data and information relating to the production of waste was used (geographical information system - GIS). For each crop present in the analyzed area were acquired application rates of soil improver from reference data

(Agricultural Integrated Management Regulation of the Tuscany Region, 2004).

Sample area

The sample area analyzed is the Optimal Collection Area no. 1 (ARO 1) which includes the municipalities of Bitonto, Corato, Molfetta, Terlizzi, Ruvo di Puglia (Figure 2). This geographical area has been identified according to the Puglia Regional Law no. 24/2012 for improving the waste management in compliance with the principles of differentiation, adequacy and efficiency. The area object of study is characterized by a total surface of 69,470 ha, from a suburban area with a strong agricultural vocation, by the high presence of greenhouse and the absence of widespread abandonment cultivation

Community composter

The community composter has been installed in the Municipality of Molfetta within the greenhouse farm "Primavita Srl". In order to compost organic waste coming from: the farm's pruning, horticultural residues and olive pruning produced in the study area, an automatic composter "BEEBLE 50" (Comar Ecology) (Figure 3) was used. The plant consists of a cylindrical tank in insulated stainless steel, inside which there is a composting chamber characterized by a volume of 1.32 m³. The composting process is automatically controlled because turning over and the progress of the organic material is carried out by an electromechanical system with shovels. The heating of the composter is provided by n. 2 electric heaters and is thermostatically controlled. The aeration in the composted mass is realized by a geared motor that moves the waste at time intervals ensuring optimal oxygenation and reduction of the size of the particles produced by the process. The composter is equipped with an automatic ventilation system that draws air from the outside and feeds it into the composting chamber with recirculation. The waste water resulting from the composting process is collected in a tank of 10 lt. for subsequent treatment (reuse in community composter) or for disposal. The composter has been combined with a Honda GX340 shredder to ensure adequate and uniform size of the vegetable organic material to be composted.

Applied methodology

Analysis of the rural territory

Territorial analysis of the ARO 1 was conducted using geographical

information systems (GIS) with the support of the ESRI ArcMap software. The data provided by the software and analyzed were: land use, spatial distribution of crops, greenhouses, tunnels and tendone systems. Specifically, have been used the land use thematic map of the Puglia Region at 1:5000 scale according to standard European CORINE



Figure 1. Community composter.



Figure 2. Municipal Limits of ARO 1.

Table 1. Coefficients of agricultural waste production.

Type of waste products	Description of o waste	Type of ocultivation	Coefficient of production	Unit of measure	Bibliographic source
Plastic waste from primary production	Plastic films for greenhouse covering	Horticultural greenhouse Vineyards covered	1.25	t ha ⁻¹ year ⁻¹	ANPA, 2000
	Plastic films for mulching	Horticultural	0.3	t ha ⁻¹ year ⁻¹	Cadir - Lab, 1994
	Irrigation pipes	Irrigation crops	0.06	t ha ⁻¹ year ⁻¹	ANPA, 2000
	Nets storm and shade	Vineyards	0.04	t ha ⁻¹ year ⁻¹	ANPA, 2000
Plastic packaging	Packaging of fertilizers and soil improvers	Arable crops	0.0027	t ha ⁻¹ year ⁻¹	Cadir - Lab, 1994
		Fruit trees	0.0018	t ha ⁻¹ year ⁻¹	Cadir - Lab, 1994
		Horticultural	0.003	t ha ⁻¹ year ⁻¹	Cadir - Lab, 1994
Agrochemical waste	Empty agrochemicals containers	Arable crops	0.0005	t ha ⁻¹ year ⁻¹	Cadir - Lab, 1994
		Vineyards and olive trees	0.0012	t ha ⁻¹ year ⁻¹	Cadir - Lab, 1994
		Fruit trees	0.0028	t ha ⁻¹ year ⁻¹	Cadir - Lab, 1994
		Horticultural	0.0009	t ha ⁻¹ anno ⁻¹	Cadir - Lab, 1994
Vegetable waste from primary production	Cuttings and prunings	Vineyards	2.4	t ha ⁻¹ anno ⁻¹	ANPA, 2000
		Fruit trees	2.75	t ha ⁻¹ anno ⁻¹	ANPA, 2000
		Olive trees	1.7	t ha ⁻¹ anno ⁻¹	Cotana e Cavalaglio, 2008

Land Cover and regional digital color orthophoto with a ground pixel resolution of 50 cm. In order to extract information on the area: occupied by the different agricultural crops (olive groves, vineyards, orchards, crops, vegetables), covered by greenhouses and screenhouse, mulched with plastic film areas, were realized photo-interpretation and geo-processing on the cartographic bases employed.

Calculation of agricultural waste production on a regional scale

The quantitative and qualitative evaluation of the typologies of agricultural waste in the study area was carried out by applying the factors of production that combine the spatial extent of the different cultivated areas to the quantities of waste produced. The coefficients of production of agricultural waste typologies that characterize the different cultivations (Table 1) were thus extrapolated from literature sources.

Evaluation of the amount of MCSI that can be used in the agricultural areas

The evaluation of the amount of MCSI that can be used in the area was made on the basis of maximum doses of nutrients (N, P, K) that can be applied to the soil. These quantities are given in the Agricultural Integrated Management Regulation of the Tuscany Region (2004) for

each crop and take into account the expected normal fertilization. The maximum amount by weight of MCSI that can be applied annually to different crops is shown in Table 2.

These collected data have allowed to calculate the mass of organic wastes from urban and agricultural areas required for the production of MCSI that can be applied within the study area. This calculation was performed assuming the hypothesis that 1 kg of organic waste produces 0.3 kg of MCSI. It was also verified whether the amount of municipal organic waste in the ARO 1 may be entirely destined for composting and reused in the provenance rural areas.

Assessment of the community composter effectiveness

For the assessing the effectiveness of the composter are ongoing experimental composting tests by different agricultural organic matrices. Were carried out chemical - physical analysis of composted organic matrices and produced GCSI. In the composter were conferred: pruning olive trees, and horticultural and floricultural organic waste. In order to enter in the chamber of composting a mixture with particle size between 1-10 cm, low percentage of impurity, moisture content of between 50-70% and a C/N ratio between 20 and 30, the organic material was triturated in Honda GX340 shredder. The analysis carried out (Table 5) On organic matrices showed a reduced nitrogen content. For this reason, in the composting chamber was introduced Urea for ensuring an adequate ratio C/N needed to start the process. This additive is permitted by the legislation on the environment and fertilizers.



Figure 3. Beetle community composter.

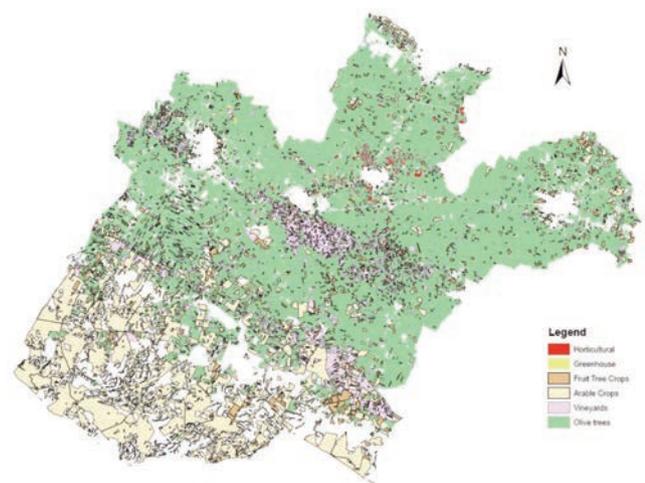


Figure 4. Land use in rural areas of ARO.

Results and discussion

Characteristics of the rural territory of ARO 1

The utilized agricultural area (UAA) in the ARO 1 is about 54,990 ha and is being used for the cultivation of: horticultural crops (330 ha) and flower (700 ha) in the open field and greenhouse, cereal (13730 ha), grapes (3760 ha), olive trees (34850 ha) and fruit trees (1620) (Table 3 - Figure 4). The cultivated area is partially characterized by the presence of greenhouse and tunnels (about 338 ha), plastic film (about 81.0 ha) and plastic nets (about 564.0 ha) for "tendone systems" used for grapefruit cultivation.

Table 2. Maximum application rate of compost.

Type of cultivation	Maximum application rate of compost	Unit of measure
Arable crops	7.3	t ha ⁻¹ anno ⁻¹
Horticultural	14.3	t ha ⁻¹ anno ⁻¹
Fruit trees and vineyards	7.1	t ha ⁻¹ anno ⁻¹

Table 3. Agricultural use of land.

Type of cultivation	Surface [ha]	%
Horticultural crops	330	0.6
Flower	700	1.3
Arable crops	13,730	24.9
Olive trees	34,850	63.5
Vineyards	3,760	6.8
Fruit trees	1,620	2.9
Total	54,990	10

Table 4. Production of agricultural waste in ARO 1.

Type of waste	Description of waste	Amount of waste produced	Unità di misura
Plastic waste from primary production	Plastic films for greenhouse covering	523.75	t year ⁻¹
	Film plastici per la pacciamatura	99.0	t year ⁻¹
	Plastic films for mulching	384.6	t year ⁻¹
	Irrigation pipes	22.56	t year ⁻¹
Plastic packaging	Packaging of fertilizers and soil improvers	110.47	t year ⁻¹
Agrochemical waste	Agrochemicals empty containers	58.03	t year ⁻¹
Vegetable waste from primary production	Cuttings and prunings	72724.0	t year ⁻¹

Table 5. Chemical properties of the organic matrices.

Chemical element	Value for olive pruning	Value for horticultural vegetable waste	Unit of measure
Nitrogen	0.45	0.49	g/100g of dry matter
Organic carbon	42.4	40.5	g/100g of dry matter
Rate Organic carbon/Nitrogen	94	83	
Phosphorus	0.04	<0.01	g/100g of dry matter
Potassium	0.51	0.51	g/100g of dry matter
Sodium	0.188	0.063	g/100g of dry matter
Calcium	1.58	1.16	g/100g of dry matter
Magnesium	0.27	0.09	g/100g of dry matter
Iron	258	227	g/100g of dry matter
Copper	266	5	g/100g of dry matter
Zinc	47	17	g/100g of dry matter

Production and management of agricultural waste

In the rural area of the ARO no. 1 are produced about 1,030 t year⁻¹ of plastic waste annually, 73,000 t year⁻¹ of cuttings and prunings and 58 t year⁻¹ of pesticides used containers. In Table 4 are specified the quantities of each type of waste products estimated through the production coefficients extrapolated from the literature and shown in Table 1.

Plastic wastes, mainly composed of film for covering greenhouses and plastic nets for tendone system, represent the fraction of agricultural waste that creates more environmental and landscape issues. The organization of the collection of this waste for delivery to collection centers may represent a useful solution economically and environmentally.

The collection of plastic waste can have an economic benefit to be distributed among the municipal authority and the service provider for the collection and, to confer this waste to recycling facilities thus avoiding mismanagement of plastic waste by farmers (eg. uncontrolled burning, abandonment, illegal dumping).

A particularly dangerous agricultural waste are used containers of agrochemicals that may have a significant environmental and health risks both. These containers must be disposed of as special waste (Legislative Decree 152/2006) for the serious damage to the environment and persons that substances contained are likely to cause. The collection of these containers from the waste management urban services could allow a correct treatment thus avoiding illegal disposal. Are widespread in northern Europe washing plants for empty containers of agrochemicals which allows to reduce the hazardous properties and to promote recycling as plastic. The washing procedure allows the removal of agrochemicals inside the containers and purification of wastewater deriving from the washing. The wastewater is then treated in bio-filters that are made from organic material called "bio-beds".

Table 6. Amount of MCSI usable in the ARO 1.

Type of cultivation	Maximum application of compost	Unit of measure
Cereal crops	100229	t year ⁻¹
Horticultural crops	4719	t year ⁻¹
Fruit trees and vineyard	38198	t year ⁻¹

The organic matter present in the bio-bed absorb pollutants and facilitate their biodegradation due to metabolic activity of the microbial component.

The cuttings and prunings are in some cases re-used in farms (green manure, fuel, etc.) and it is therefore necessary to provide for collection in composting plants, only for farms that want this service. An interesting solution for the recycling of organic waste produced in rural areas far from composting plants is represented by the composter community. At community composting plant installed in the greenhouse company "Primavita Srl" were introduced the pruning of olive tree and horticultural and floricultural residues. The organic matrices treated were analyzed for their chemical and physical characterization (Table 5) as well as the product compost. The compost was used to replace in whole or in part the peat used in the substrates. This practice reduces the environmental load because the peat comes from Northern Europe and is being depleted.

Compost usable in ARO 1

The application of MCSI on agricultural soil of the ARO 1 must not exceed 143,146 t year⁻¹. This amount is allocated to the agricultural areas used for cultivation of different crop types as specified in Table 6. The application of these quantities can improve the chemical - physical

and microbiological soil property thus avoiding nitrate leaching and, therefore, without compromising the groundwater quality.

The amount of organic waste required for the production of MCSI is about 429,438 tonnes. In the ARO 1 in the year 2012 were produced 102,263.2 tons of municipal solid waste (MSW) which are composed by 35% of organic material (www.rifiutibonifica.puglia.it). The municipal organic waste produced by domestic users and non-domestic (schools, offices, commercial activities) in the in the ARO 1 are approximately about 108,516 tons and can therefore be entirely destined for composting and be used in local agriculture. To achieve high levels of use in agriculture of GCSI and MCSI are needed adequate awareness and incentives for farmers. The use of MCSI and GCSI is, in fact, a complementary activity to the recycling of organic waste that needs adequate support through Measure 214 "Payment Agro - Environmental" of the Rural Development regarding the adoption of sustainable methods of agricultural production and land management.

Conclusions

The carried out work provides an appropriate methodology for evaluating the amount of agricultural waste generated and the calculation of the maximum amount MCSI applicable on agricultural soil on a territorial scale.

The evaluation of the maximum utilization rate of MCSI on a territorial scale, and the drafting of appropriate fertilization plans can improve the characteristics of the soil and of agricultural production without damaging the quality of the environmental matrices.

The ability to obtain information on the production of agricultural waste, divided by type, allowing both rapid quantitative estimate, and the correct programming of the collection, transport and disposal/reuse. In this context, the activation of the collection service of plastics waste (plastic films for greenhouses and tendone system, mulching films, agrochemicals empty containers) can increase separate plastic waste collection and their recycling. This collection service may be entrusted to the manager of waste management services or to farmers. The use of GIS can provide valuable support to the organization of the routes and frequencies of collection of agricultural waste as it allows to identify the spatial distribution of production.

The organic vegetable waste, can be transferred and processed in community composters placed in rural areas for the production of GMSI, to be used then for the crops, thus reducing transport for disposal. In order to reduce emissions due to uncontrolled burning or transport, this use permits reuse for agricultural purposes with clear environmental benefits.

The present study thus shows that the rural areas can play an important role in the waste cycle from production to recycling.

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