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D2.1 INVENTORY OF ALL AVAILABLE TECHNOLOGIES FOR OA AMENDMENTS

(1st edition)

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Summary

This deliverable summarises the existing literature concerning the variety of organic amendment (OA) production from agricultural waste residues (raw, composted or pyrolysed) and application methods with special emphasis on valorisation of date palm residues and the influence of their application to soil quality. The existing scientific, technical and professional literature concerning the OA production and application was reviewed, not restricted to the project's interest zone or to composting and pyrolysis. In addition, the collection of the up-to-now funded related projects were performed by searching in European databases and in literature, by visiting projects' web sites.

1. Introduction

Agricultural residues are carbon-based materials generated as a by-product during the harvesting and processing of agricultural crops. Agricultural residues which are produced during harvesting are primary or field-based residues while those produced along with the product during processing are secondary or processed based residues.

1.1 Tree residues in Europe and in Mediterranean countries

Crop residue management has a very important focus of concern among various stakeholders. Fruit tree growing in Europe is practiced on ca. 50 million of ha. Woody residues from tree crops are among the major sources of biomass, with annual pruning yields ranging between 1 and 5 tons of fresh matter/ha, with an estimate production in EU28 exceeding 13 million tons every year. It is estimated that in Mediterranean Countries, pruning from orchards produce more than 2.5 tons of pruning residues /ha/year. Some areas in Europe face an excess of crop residues and the allelopathic problems that are observed have not been well described and analysed. Management of agricultural pruning residues can offer benefits in case or reuse or environmental problems where it is not reused and need disposal. While the EC has suggested and supported an increase of use of prunings as biomass fuel or through composting, these specific uses are still marginal either due to technical limitations or legislative issues, and low remuneration of the reuse chain, and currently most of the pruning residues are still outside of the bioenergy supply chain.

Although there are clear figures about the impact caused by lack of management of pruning residues in the EU, their re-use is in line with the need of increase renewable energy to meet the 2020 climate and energy targets. Notwithstanding the most recent EU Directives 2015/1185 and Regulation 2015/1189 (Directive 2009/125/EC) also encourage the use of pruning residues for energy producing. Also, at European level, the DIRECTIVE 2008/98/EC of the European parliament and of the council excluded straw and pruning from the waste directive (chapter 1, art. 2). According to the art. 185 of LG.D. n. 152/2006 modified by art. 41 L n. 154/2016 the straw and pruning residues are not considered wastes, nor by products ruled by the arts 183 and 184 of the LG.D. n. 152/2006, and they can be used directly without specific permits

Most prunings generated within the EU are either burnt in open-air fires or are shredded as a soil amendment Whilst the former entails no net-environmental benefits, the latter can improve soil conditions, but can also be a vector for disease. As a result, some regions ban or strongly recommend against mulching of biomass and use as a fertiliser, whilst others recommend it, often accompanied by pesticides. When farmers integrate prunings into the soil, frequently they do so not because it is the best use of the material, but because it is the simplest waste management method (EuroPruning project, www.europruning.eu). The main driving force that determines whether burning or soil amendment is predominant is whether there is a regional or national ban on burning prunings in open-air fires.
According to the EuroPruning project results the removal of prunings from orchards (Peach, Almonds, Apples, Cherries, Vineguards) did not affect the content of soil organic carbon at the study sites except for the tree row in the cherry orchard (Brandenburg/ Germany). Grass cover in the interrow can be regarded as an alternative carbon source for soil microorganisms. Consequently, pruning effects can be more pronounced in herbicide treated and therefore grass-free tree rows. The effects increased with increasing amounts of pruning left on the soil.
However a general recommendation about the removal of pruning was that prunings should not be removed, if vegetation cover > 80 % between trees (interrows) cannot be established and (a) soil structure is weak and tends to compaction / silting / surface runoff or (b) the orchards are prone to erosion and there are no alternative erosion protection measures or (c) top soil tends to water logging / anoxic conditions or vegetation cover with > 15 t ha^{-1} $year^{-1}$ fresh biomass (3 t ha^{-1} $year^{-1}$ dry mass) cannot be established and soil carbon content is low.
If one or more of the cases (a) – (c) apply, the dominant problem should be treated as follows: If (a) or (b): Prunings should be chipped and used as cover mulch. If (c): Prunings should be chipped and worked into the soil. This general advice may be modified according to local environmental characteristics.
Based on the above, there is no suitable large-scale value chain for pruning residues across EU, which are commonly managed across multiple collection sites at local scale, mainly composted or landfilled. On the other hand, the main biological treatment for reuse wood pruning in agriculture is their composting followed by mechanical fractionation to obtain an homogeneous green material to be used as soil amendment or for other admitted uses such as landfill cover and revegetation. One of the most important soil management strategies that aim to increase the carbon pool in soil is the addition of organic matter. Pruning waste composting performed in Europe is currently quite primitive, as they are mainly collected and piled in authorized composting plants, without specific treatments or devised end uses

2. Date palm

2.1 Date palm cultivation

The date palm is among the oldest cultivated tree crops in the Mesopotamian region, more than 7,000 years. The origin of the date palm (*Phoenix dactylifera* L.) is supposed to be in North Africa or Middle East. There are very few and local reports on the origin and ancient history of oasis agrosystems in the MENA region (Middle Eastern and North African region) (Mlih et al 2015) which is one of the most water-scarce regions in the world. Tengberg (2012) reported that the origin of oasis agriculture likely dates can back to the prehistoric times around the Persian Gulf. From its homeland, the date palm was dispersed to North Africa, the Arabian Peninsula and to South Asia, southern Africa, the America and Australia, wherever suitable climatic conditions were found to enable commercial fruit production (Johnson 2012).

Date palm represents a good cash crop for many farmers. Date palm is marketed all over the world as a high-value fruit crop and is an extremely important subsistence crop in most of the desert-like regions (Mlih et al 2015). In the Mediterranean basin, date palm is largely cultivated and plays an important economic role. The major constituents of date palm biomass are cellulose, hemicelluloses and lignin. In addition, date palm has high volatile solids content and low moisture content. These factors make date palm residues an excellent biomass resource in date-palm producing nations.

2.2 Date palm wastes

According to FAO statistics, approximately 120 million date palm trees are existing in the world. Date palm (*Phoenix dactylifera* L.) is an essential component of farming systems in arid and semi-arid regions of the world (Fatima et al. 2016) Middle East and North African countries climate is an ideal situation for date palm plantation (Barreveld 1993). The palm date trees offer a large agricultural by-product and date palm residues that could be used for many purposes (feeding of livestock, composting, etc.) (Dhehibi et al 2020). The large amounts of palm wastes produced every crop season constitute a big charge for the farmers who are mainly trying to burn, or transport them outside of oasis. Every year after date palm harvesting, large quantities of residues (frond and leaves) accumulated in agricultural lands (Jonoobi et al. 2019). A typical date tree can generate as much as 20 kilograms of dry leaves per annum while date pits account for almost 10 percent of date fruits (Aola et al. 2020). Each date palm tree produces about 20 and 40 kg dry organic waste annually in Saudi Arabia (Alkoaik et al., 2011) and in Iran, (Mallaki and Fatehi, 2014) respectively.

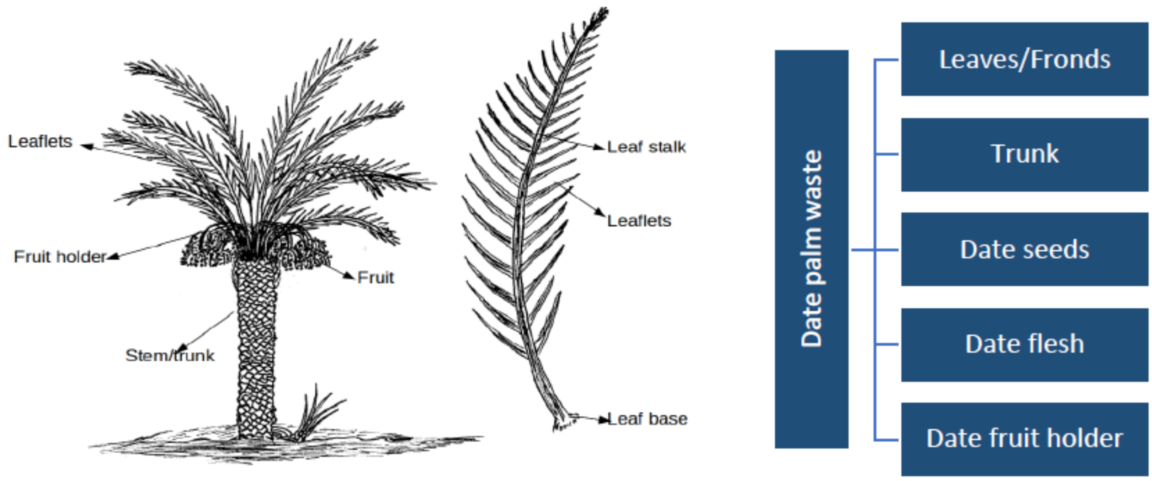


Figure 1. A date palm tree with its different components (Aola et al. 2020)

Under modern plantation practices, field operations generate quantities of empty fruit bunches, cull fruits and pruned leaves. Commonly these residues are left in the field as mulch and fertilizer (Johnson 2012). Ben Salah (2014) reported that in Tunisia approximately 4.5 million trees produce dates and their management generates significant amounts of wastes, essentially palm leaf waste (16 kg/tree/year). In fact date palm leaves are the most residues, which are produced by date palm trees annually; other parts of date palm such as seed and trunk are utilizable too (Jonoobi et al. 2019). These wastes mostly are left in agricultural lands or they burned, which can be an environmental and health issue (Torigoe et al. 2000). According to evidence, leaving raw materials from date palm waste for a long time are prone to be highly flammable [Bashah, 1996]. Habchi et al 2020 reported that the date palm wastes are a serius environmental problem in many cities in Algeria where it is produced in large amounts and mostly disposed of through burning. Moreover, the accumulation of date palm residues is generating harmful effects such us proliferation of insects and parasites, causing infection to date palm trees yield losses and decline in the quality of dates. (El-Shafie et al. 2017).

2.3 Soil climatic conditions

Date palm trees plays a key role in achieving environmental balance because it grows in a harsh climatic environment and even in highly saline sand (Sharif et al, 2010). The date palm absorbs carbon dioxide to a significantly greater extent than other trees, due to its large size. This makes the date palm an important tool against global warming, which is mainly caused by carbon dioxide emissions. The date palm can be produced easily under unfavourable natural and economic conditions. Date palm trees can bear air temperatures of up to 50 °C for short periods and low air humidity for fruiting as long as water is available in the subsoil (Qureshi and Barrett-Lennard, 1998). Date palm cultivation is mostly found in dry land soils of low plant productivity yielding low organic matter inputs (El-Juhany, 2010). These soils are inlow organic matter content (Dregne, 2002) and due to the sandy texture its potential to sequester carbon is limited (Kösters et al., 2013), and its potential water-holding capacity is also low. Therefore, high amounts of irrigation water resources are wasted due to poor soil properties (Blanchart et al., 2007). Since date palm farming is located in the arid zone, the growth of date palms has relatively high demand for basic cations and other nutrients in proper balance which must be substituted annually (El Mardi et al. 2006). Tolerance to salinity depends on the genetic potential of the date palm variety, the climate, as well as soil drainage and texture (Maas, 1986). Ideal soil conditions for date palm are sandy to clay loamy soils while it is moderately tolerant to alkaline soils, and needs good aeration and drainage (Chao and Krueger, 2007). Date palm can tolerate soil salt concentrations of up to 4.0 dS m^{-1} (Ayers and Westcot, 1985). On the other hand, an electrical conductivity of 17.9 dS m^{-1} in soil and 12.0 dS m^{-1} in water reduces yields up to 50%. Fruit production usually stops at about 15.6 dS m^{-1} (Marcar et al. 1995).

3. Sustainable utilization of Date palm biomass

A wide range of physico-chemical, thermal and biochemical technologies exists for sustainable utilization of date palm biomass. The low moisture content in date palm wastes makes it well-suited to thermochemical conversion technologies like combustion, gasification and pyrolysis which may yield steam, syngas, bio oil etc. Indeed, the date palm wastes can be converted to fuel pellets or briquettes, energy-rich products (biochar, bio-oil and gases including methane, hydrogen, carbon monoxide, and carbon dioxide) and to biofertilizers. In fact the highly organic nature of date palm waste makes it highly suitable for compost production which can be used to replace chemical fertilizers in date palm plantations. Thus, abundance of date palm trees in the MENA and the Mediterranean region, can catalyze the development of biomass and biofuels sector in the region. Below the biochar and composting process and for the sustainable use of agricultural residues including date palm residues is reviewed

3.1 Energy-rich products-Biochars

Incineration and composting are the typical processes used, but still, it is not proper to process these organic wastes, this is due to the nitrogen concentrations and a significant amount of solid grains and smoke that is released during the process (Tsai et al., 2007)

Biochar is produced from thermal conversion of unstable carbon-enriched materials into stable carbon-enriched charred materials. More specifically biochar is a relatively stable carbonaceous material derived from pyrolysis of wastewater sludge and agricultural waste. Currently more and more attention and efforts are being given worldwide for the development of technologies to convert agricultural waste into biochar, due to the rising energy demands and concerns over greenhouse gas emissions, as well as soil degradation (Hossain et al. 2010; Hossain et al. 2011). Pyrolysis is the thermal decomposition of date palm biomass occurring in the absence of oxygen. The products of biomass pyrolysis include biochar, bio-oil and gases including methane, hydrogen, carbon monoxide, and carbon dioxide. Pyrolysis proceeds in three steps: in the initial step moisture and some volatile loss. In the secondary step occurred primary bio-char. The last fast step follows by a slower step including some chemical rearrangement of the bio-char. During the third step, the bio-char decomposes at a very slow rate and carbon-rich residual solid forms. The formation of secondary charring makes the char less reactive. Depending on the thermal environment and the final temperature, pyrolysis will yield mainly biochar at low temperatures, less than 450 ^{0}C, when the heating rate is quite slow, and mainly gases at high temperatures, greater than 800 ^{0}C, with rapid heating rates. At an intermediate temperature and under relatively high heating rates, the main product is bio-oil. Usman et al. (2015) noted that there is limited information about the date on the production and characterization of biochar produced from date palm waste along a wide range of pyrolysis temperature in literature. They concluded that carbon sequestration biochar was found at a temperature > 500 ◦C. However, biochar produced at lower temperatures do contain more functional groups and has lower pH values, this makes this biochar more suitable for soil with poor fertility and high pH (Usman et al. 2015; Aloa et al. 2020)

The use of Date palm wastes as a low-cost adsorbent is a sustainable waste utilization solution because the date palm waste is abundant in many countries. Therefore, utilizing waste materials to produce biochar is a sustainable solution in terms of cost effectiveness and impact on global warming potential (Sizirici et al. 2021). Bassyouni et al. (2014) showed the date palm waste can be pyrolyzed to produce activated carbon and liquid phenolic products.

Biochar appears to be a new potential low-cost and effective material that has a wide range of characteristics transfusing unique properties. Its properties include high water-holding capacity, large specific surface area, enriched surface functional groups, cation exchange capacity, porous structure similar to that of activated carbons, impact especially on microbial communities (Tan et al. 2015). The above properties are in correlation with the biochars' production factors and are used in agriculture, composting, and land remediation/restoration. The molecular structure of biochars shows a high degree of chemical and microbial stability. A key physical feature of most biochars is their highly porous structure and large surface area. This structure can provide refugia for beneficial soil micro-organisms such as mycorrhizae and bacteria, and influences the binding of important nutritive cations and anions. The quantities of key mineral elements in biochars are directly related to the levels of these components in the raw feedstock (Hina et al. 2010; Pan et al. 2010).

3.1.1 Conditions affecting Biochar production

Number of factors influence biochars' production such as heating temperature and time, type of gas and probably the use of catalyst (Wahi et al., 2017). Many studies considered the temperature as a factor where the biochar characteristics depended highly on it. Stability of the biochar carbons was affected directly by the pyrolysis temperature. Chemical changes are introduced to biochar during the pyrolysis at various temperatures. As the biomass gets dehydrated, aliphatic bonds are converted into aromatic bonds which are consolidated into stable graphene structures (Zama et al 2017). Sun et al. (2014) have shown that the pyrolysis temperature and the type of feedstock are influential factors on the production rate, thermal stability, carbon content and elemental composition of biochar. Slow pyrolysis is often associated with the formation of higher contents of N, S, Ca, Mg, P in addition to greater surface areas and enhanced CEC. This is due to the fact that easily decomposable and volatile components of biochar such as oxygen, hydrogen, nitrogen, total phosphorus and sulfur are lost during the slow pyrolysis (Lehmann and Joseph 2015). At higher pyrolysis temperatures, the surface area and porosity increase along with the concentration of minerals including P,K,Ca Mg on the surface of the adsorbent which in turn would allow ion exchange with metals and result in higher adsorption capacities (Chen et al. 2014). Also, as the pyrolysis temperature increases, some physical and chemical changes occur in biochar such as a decrease in cell pore diameter and an increase in the specific surface area (Lehmann et al 2015). Sizirici et al (2021) used leaf and frond date palm waste as feedstock to derive biochars. The effects of pH, feedstock type, and pyrolysis temperature at 400, 500 and 600 °C on the capacity of date palm waste derived biochar to remove copper, iron, nickel and zinc in single and mixed metal solutions were investigated. Biochar obtained from different feedstock at different pyrolysis temperature did not show any statistically significant improvements on the removal of single or mixed metals from aqueous solutions. The date palm leaf or frond biochar obtained at low pyrolysis temperature was as effective to remove metals as the ones obtained at high pyrolysis temperatures.

A project titled EuroChar was funded by the European Commission under its Seventh Framework Programme (FP7). EuroChar used various feedstocks, ranging from wheat straw to olive residues and poplar, as feedstocks for biochar production and focus on two conversion technologies, Hydrothermal Carbonization (HTC) and Thermochemical Carbonization (TC). Large differences were observed in the elemental as well as chemical composition of biochar obtained by pyrolysis, pyrogassification and hydrochars. The final carbon content, in particular, varied significantly depending on the feedstock considered while Policyclic Aromatic Hydrocarbons (PAH) as well as dioxin concentrations were below the limits given by the international and European biochar standard definitions. Moreover Rack and Woods (2012) concluded that biochar is more stable than hydrochar and has a higher C sequestration potential taking into account weathering effects and priming effects on soil organic matter.

3.1.2 Biochar process

The conversion process includes pyrolysis, gasification, torrefaction and hydrothermal carbonization. Pyrolysis includes the heat of the organic material (e.g. biomass) in the absence of oxygen conditions while gasification includes the heat of the organic material in higher temperatures than pyrolysis but in limited oxygen conditions. Torrefaction is a process where biomass is heated in an inert atmosphere at temperatures around 200-300 ^{o}C, while hydrothermal carbonization is a heating process at lower temperatures than torrefaction but in high pressure (2-6 MPa) (Kambo and Dutta, 2015). A new method that alternatively can be

used for biochar production is microwave pyrolysis which offers rapid, uniform and selective heating of biochar compared to the previous processes (Wahi et al. 2017).
The different thermal conversion technologies and their products are described in the following figure:

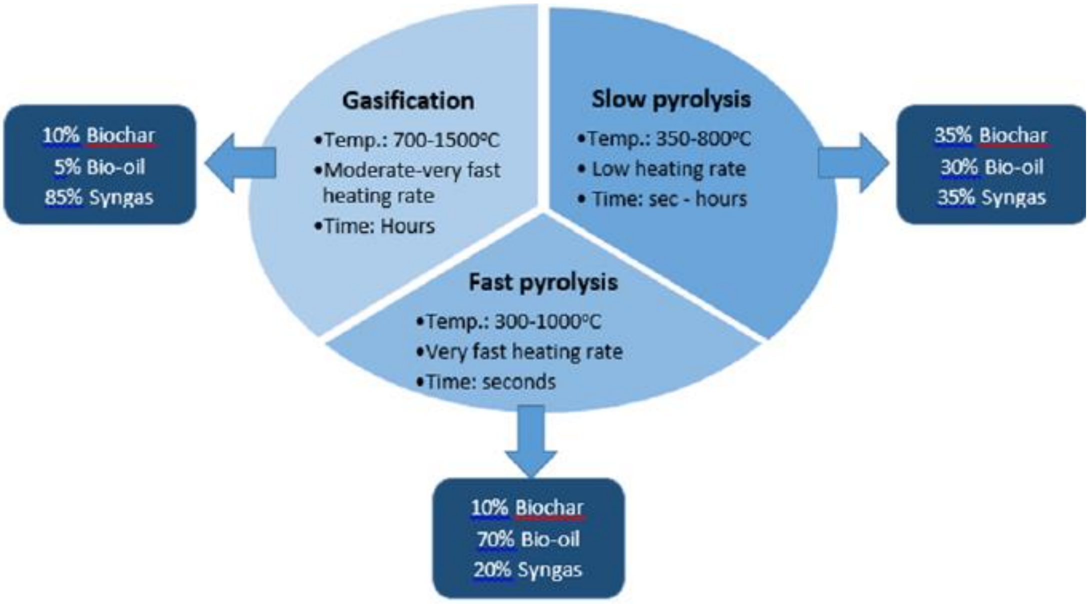


Figure 2: Biochar production methods and different biochar yields obtained (Aola et al. 2020 modified from Igalavithana et al. 2017)

The raw organic materials vary according to the physical and chemical properties and the final particle size of biochar. Different types of agricultural residues, algal biomass, forest residues, manures, activated sludge, energy crops and polymers can be used as organic precursors (Oliveira et al. 2017; Simitzis and Ioannou, 2012).
A 30-day incubation experiment was conducted using a heavy metal-contaminated mined soil amended with date palm feedstock and its derivative biochars (Al-Wabel et al. 2019). The biochars produced at different charring temperatures were left to cool inside the furnace overnight, and then, kept in desiccator for 60 min. Date palm waste was collected, dried, chopped, and put in an airtight stainless-steel container that has a height of 22 cm and a diameter of 7 cm. After that, it pyrolyzed in an electrical muffle furnace at 300, 500, and 700oC (at the rate of 5oC min-1) for 4 h (Al- Wabel et al. 2013; Usman et al. 2015). EUROCHAR project scientists (FP7-ENV-2010) tested two different methods to create biochar: gasification or thermal carbonisation (TC), and hydrothermal carbonisation (HTC). The different biochars were analysed and tested as soil amendments in fields across Europe. The project noted major differences in the composition of the biochars depending on the source of biomass as well as the treatment method. Biochars made by TC are more stable and have a better sequestration potential than those made by HTC.

3.1.3 Effects of biochar application to soil properties

Biochar incorporation into the soils can be considered as a mean for agronomic or environmental management (Lehmann et al 2011). The biochar application in soil achieves not only soil remediation from organic and inorganic pollutants but also ameliorates soil properties (Oliveira et al., 2017).

The existing literature on using the date palm biochar as fertilizer is few but it seems it can be used and improve soil quality (Jonoobi et al. 2019). Biochar derived from organic wastes and incorporated in soils offers multiple environmental and financial benefits (Maraseni et al., 2010). Biochar application has several benefits including carbon sequestration to soil, enhancing soil fertility by improving nutrients and moisture retention and microbial activity increasing consequently crop productivity (Tang et al. 2013; Lone et al. 2015). It influences soil structure, texture, porosity, particle size distribution and density. This binding can raise soil pH (acidic), enhance availability of macro-nutrients such as N and P, and increase its electrical conductivity and cation exchange capacity.

Biochar affects soil macronutrient status of soils. According to Zhang et al. (2017), twelve biochars of different origin, i.e. walnut shells, corn cobs, corn straws, rice straws, at different pyrolyzed temperatures were applied to soil in pot experiment. They showed that biochars decreased the available N, increased the available P, K and increased also the ryegrass biomass. The addition of biochar improved soil properties and reduced the hazards caused by soil acidification and natural acidic soils (Dai et al, 2017). Biochar surface contains many functional groups, e.g. $–COO^-$, $-O^-$, which react with metals such as aluminum and manganese ions and H^+ from the soil solution, alleviating partially soil acidity. Moreover, the nature of biochar is alkaline indicating the increase of soil pH values with its addition to soil. The amelioration of soil parameters such as pH, C:N ration, dissolved organic carbon, total carbon and K concentrations affected the microbial communities

Addition of biochar is also useful for decreasing net nitrification rate (DeLuca et al. 2006), N leaching as ammonium and nitrate (Ippolito et al. 2012, Steiner et al. 2008) ammonia volatilization (Steiner et al. 2010) stimulates N immobilization (Rondon et al. 2007). Ammonium leaching has been shown to be reduced, along with N_2O soil emissions. There may also be reductions in soil mechanical impedance (Atkinson et al. 2010). The biochar can increase N retention onto soil and the N reduction rate (Lehmann et al 2003). Another study examines the use of biochars produced from different biomasses as absorbents to evaluate their efficiency in nitrate fixation (Yang et al. 2017). The nitrate behavior did not significantly alter after the application of biomass except for biochars derived from bamboo pyrolyzed at high temperatures, which presented relatively high sorption to nitrate. Moreover, biochars ameliorated soil nutrient content, affecting the N transformation process.

In addition, incorporation of biochars into soils has been reported to have a positive impact on soil carbon sequestration and improving soil fertility (Nartey and Zhao 2014). In recent years, many studies have shown that biochar incorporation into soil can reduce greenhouse gas emission, sequester carbon and improve soil quality (Glaser 2006, Lal 2008, Lehmann et al. 2009, Sohi et al. 2010, Vacari et al. 2011) when considering the fact that soil amendments reach in organic decomposable materials could cause an increase in carbon dioxide efflux from soil. The results of EuroChar project confirmed that biochar produced by a commercial method (AGT) is sufficiently stable in the soil environment for it to have potential use in carbon sequestration. Al-Wabel et al (2019) reported the date palm biochars exhibited much lower cumulative CO_2–C efflux than date palm feedstock, even with low-temperature biochar, indicating that BCs have C sequestration potential. Morever date palm feedstock and biochar (300^{o}C) with increasing addition rate significantly reduced soil pH, whereas SOC, CO_2–C efflux, and soil MBC were increased compared to the control.

In addition, remediation of contaminated soil has been also reported by several studies [EL-Mahrouky et al 2015, Al-Wabel et al 2014). Biochars have been reported to be an effective immobilizing agent for a wide range of inorganic and organic pollutants (Nartey and Zhao 2014; Al-Wabel et al. 2015; Rizwan et al. 2016) Many studies showed that biochars can be used as alternative sorbents to remove different types of organic and inorganic contaminants from aqueous solutions (Inyang et al 2012, Tan et al 2015).

Date palm feedstock and its derivate biochars were applied to heavy metal-contaminated soil in order to investigate their effect on different parameters such as; different types of carbon in the soil, a mobile fraction of heavy metals, pH and electrical conductivity (Al-Wabel et al. 2017). Generally, it was found that changeable factors (temperature, rate, metal type) affect the reduction of metal availability. Al-Wabel et al (2019) also reported that that low-temperature date palm biochar significantly reduced the mobile content of Cd, Cu, Pb, and Zn in mining contaminated soil in addition to minimize soil CO_2–C efflux. They concluded that the efficiency of biochars in reducing metal availability may be depending upon varying factors including pyrolysis temperature, application rate, and metal type. In addition, activated carbon from the date seed was perhaps one of the most widely used adsorbents since its adsorption capability has been determined and proven while it is a low-cost raw material (Girgis and El–Hendawy, 2002).

The capability of date stone/seed as activated carbon studies was again reviewed by (Ahmed 2016). They concluded that the surface areas of date stone-carbons ranged between 490 to 1282 m^2/g and yields from 17 to 47% with highest values obtained by chemical activation. Activated carbon derived from date seeds were applied to different contaminated media. The capability for removing heavy metals, dyes, pesticides, and phenols showed the following adsorption concentrations 1594.0, 612.1, 238.1 and 359.1 mg/g, respectively. This represents a promising option for solving environmental problems. Therefore, enhancing metal phytostabilization of contaminated soils and plant growth should be considered in future researches.

Biochar influences microbial biomass and composition due to its unique properties. Biochar porous structure functions as the appropriate environment for microbes' development and colonization. Rack, and Woods, (2012) showed that Biochar application resulted in a significant shift in microbial communities present in 2 of the 3 core sites. Understanding these shifts may help in future to elucidate the mechanisms through which biochar contributes to soil fertility. Zhu et al. (2017) reported that the addition of biochars in soils changed soil properties leading to the modification of microbial activity while certain reactive organic substances and heavy metals contained in biochar may influence negatively soil microorganisms due to toxicity. Liao et al. (2016) reported the influence of cotton straw biochar on soil microbial community composition and activity in drip-irrigated desert soil planted to cotton. The results have shown an increase in soil microbial biomass, carbon substrate utilization, and enzyme activity related to C and N transformation. Ming et al. (2016) studied various biochars derived from straw residues and wood chips, and added separately to a paddy soil. Biochars' amendment can alter soil microbial properties and more specifically, increase the number of general bacteria and consequently increase the concentration of phospholipid fatty acids. Khadem et al. (2017). examined how the addition of corn stalk biochar in two calcareous soils influences the activity of several cellular enzymes involved in C and N cycling and microbial metabolism Biochar may improve the enzyme activities to arid soils and consequently soil quality, carbon sequestration and biogeochemical cycles. Zhu et al., (2017) also examined the changes in soil microbial biomass carbon, nitrogen, phosphorus, urease and alkaline phosphatase activities with biochar addition. Biochar increased microbial biomass carbon in most cases, microbial biomass nitrogen in the shallower soil layer and alkaline phosphate activities. Moreover, there were fluctuations in enzyme activities during the growth periods and depths. Finaly, Al-Wabel et al (2019) showed that date palm feedstock and biochar with increasing addition rate significantly increased soil MBC compared to the control.

3.2 Composting

Composting is the most popular method for biological decomposition of organic wastes. Composting is the process through which raw organic matter (such as tree residues from pruning, cereal straws, animal manures or the organic fraction of solid urban waste) is progressively decomposed and partially converted into stabilized humus (Libutti et al 2021). Composting could provide an economical and environmentally significant method to reduce date palm wastes (Benabderrahim et al. 2018). Date palm waste has around 80% organic content which makes it very well-suited for the composting process. Commercial-scale composting of date palm wastes can be carried out by using the traditional windrow method or a more advanced method like vermicomposting**.** The windrow forming a natural slope was packed at the top and it was approximately at one-meter high. The final shape of the windrows is depended on the configuration of the available land. The waste recycling process of date palm is not a new technology, yet it is considered the most important biological process within the environmental system that aims to keep the environmental balance (Safwat et al. 2007). They concluded that instead of burning date palm branches, they can be utilized to produce a good quality of compost

3.2.1 Composting methods

Dhehibi et al (2020) described the following composting methods:

Composting in trench

This is the simplest method consisting of infield deposits of organic waste either households or vegetation. It often incorporates manure for enhancing microbial activity and is watering to maintain a humidity of organic matter in transformation. The trench is covered with sand to keep the Interior moisture and avoid odors. The problem with this type of composting is that the returning and airing composted wastes is impossible. On the other hand, advantage, you can mix lots of green wastes and even dry by-products if they are not woody.

In stack composting

This is the system used in the open composting stations. In stack composting is a long process. Composting of the waste lasts from 6 months to a year. It is common to mix shredded plants to manure (2/3, 1/3 or 3/4, 1/4) to balance the compost and help its decomposition. The advantage of this mode is that you can easily stir the compost to aerate it and easily control the temperature of the compost

Composter composting

The composter is a cylinder placed in a bathing area. This system accelerates the composting process. There is a less easy mixing and volume constraint.

3.2.2 Composting prosses

Composting is considered as an effective biological, economical and sustainable technique to reuse the organic wastes. During composting the organic wastes stabilizes by their conversion into humic substances while inactivates pathogen flora, allowing compost use for soil amendment (Zhang and Sun, 2015; Dona-Grimaldia et al. 2019) The composting process generally needs more than 3 months to have a good quality product (Karbout et al. 2019). There are two types of composting procedures (Misra et al. 2003):

Aerobic: Composting is most commonly an aerobic process, that is, the biological breakdown of the materials takes place in the presence of oxygen (air). The main byproducts of the breakdown are carbon dioxide, water and heat.

Anaerobic: Composting can also be an anaerobic process, where breakdown occurs in the absence of oxygen. In this case, the main byproducts are methane, carbon dioxide, and various low organic acids and alcohols.

The biodegradable process during composting can be depicted in many ways, but, basically, it consists of two major stages: activate composting phase (thermophilic phase) and curing phase. During the active composting phase, easily decomposable compounds are break down quickly, and pathogen can be eliminated by high temperature up to 60 bacteria community to activate in the dynamics of succession. At this phase, the quick short decline of pH is shown due to formation of organic acids, meanwhile the reduction of C/N and the increasing of fulvic acids content are observed. In contrast, during the curing phase the compounds less susceptible to carbon mineralization (i.e., transformation of C to CO_2) are broken down along with fatty acids, which can be phytotoxic hazard against plant growth, and humic acids are produced as a form of p ring. All parameters of temperature, pH, C/N ratio tend to be gradually stable until the end, and form the optimum condition for growth of fungi in composting pile

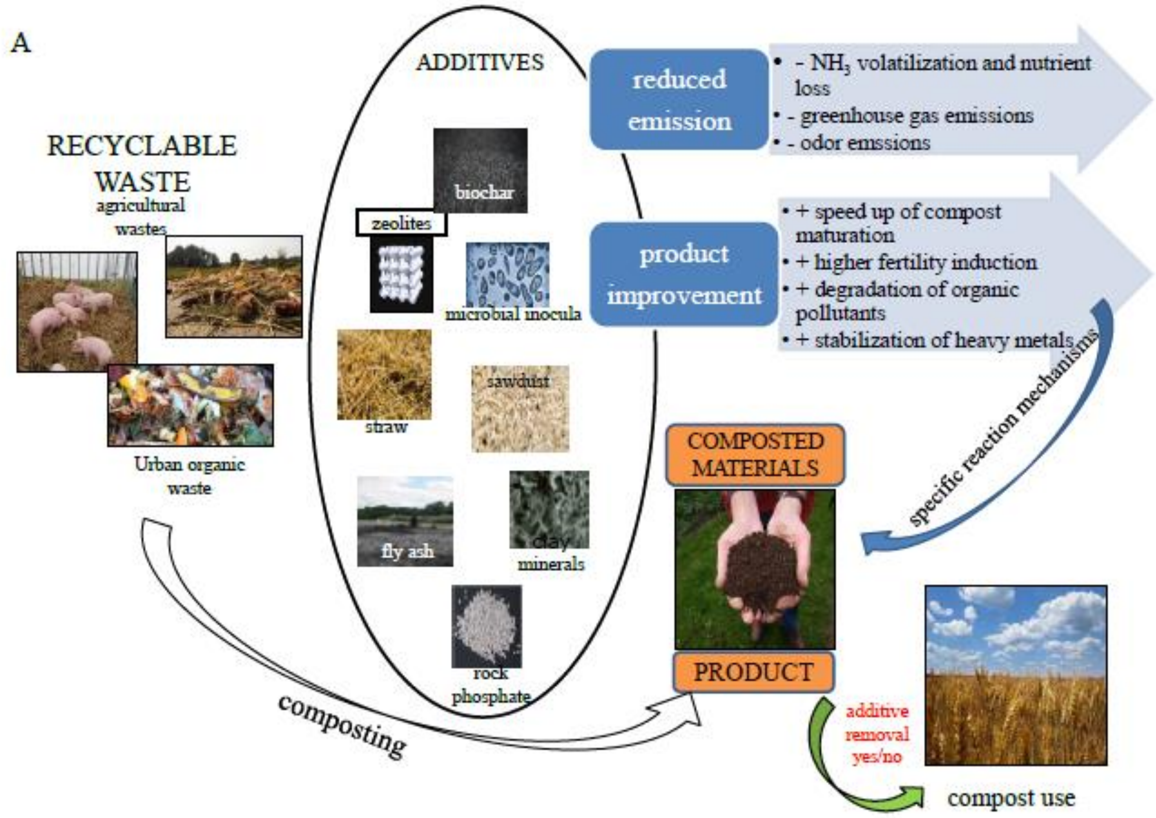
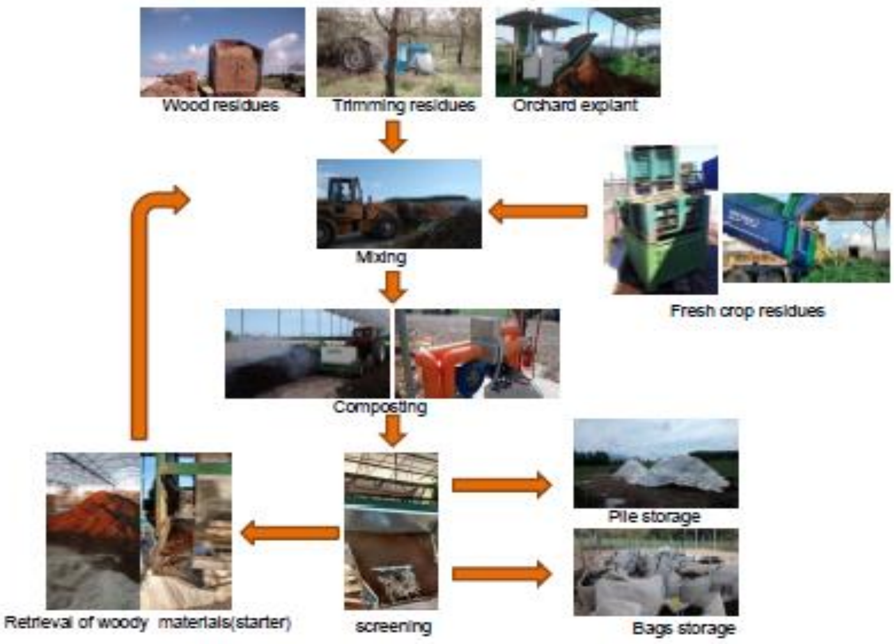


Figure 3: Composting process (Giagnoni et al. 2019)

According to LIFE10 ENV/ES/000469, AGROWASTE project results more than 20 composting piles have been made using mixtures of fruit and vegetable wastes, taking into account the needs required for the composting process such as: the relation between carbon and nitrogen (C/N) 25/35, humidity 50- 60% and pH values 5-8. The wastes and byproducts were chosen according to their temporary nature, their complimentarity and analytic characteristics. Special effort was made to use all the materials which could confer an added value to compost and could improve its fertility and biopesticide effect (ex. Garlic, broccoli, tomato). The process of composting in all cases lasted 5-7 months, with an inital phase, followed by a termophilic phase, to finish with phase characterized by room temperature (maturation phase). In most cases, the quality and maturity were determined by chemical, physic-chemical, biological parameters as well as through pathogen analysis and insecticide

products during all the process. One of the parameter which best indicative maturity was the C/N relation, with levels of 14- 17, and the organic matter soluble content, with levels < 3 g kg^{-1} in most of composts.
CarbOnFarm project (LIFE12 ENV/IT/000719) promoted the on-farm composting technique under Mediterranean conditions (Figure 4). The mixed biomass was translocated in the composting lines in a trapezoidal pile with a longitudinal extension of 40 m and positioned on to the specific forced aeration network system, for a duration of about 60 days. In the initial thermic step or active phase, the forced oxygenation and the maintenance of an adequate moisture level produce intense biological and biochemical transformation with a raising of the temperature around the 65°C that allow the sanitization of the bulk biomass and the removal of pathogens. The final stabilization was obtained with the curing phase, which last about 4 weeks, and is characterized by the progressive temperature decrease and slower biochemical modification with the increase of humus fraction. The stable mature compost undergoes to a sieving procedure to obtain a uniform and homogeneous organic material, thereby removing and recovering the undecomposed woody fragments that will be reused in the subsequent composting cycles acting also as useful starter of the active phase. The final step regards the storing of compost either into bags or bulk piles before the distribution to the farmers

The standard composting procedure is represented by the following flow chart:



Wood residues, trimming residues, orchard explants: sources of structuring materials

Fresh crop residues: sources of nutritional materials.

Mixing: mixing of matrices with nutritional and structuring functions.

Composting: application of the standard composting procedure under controlled moisture and temperature conditions (50-70 days): active phase (20/30-days)+ curing phase (30/40 days)

Screening: separation of the coarser undecomposed woody material from compost and its recovery. This material can be used in another composting cycle.

Storage: in piles or in bags.

Figure 4: Standard on-farm composting procedure

3.2.3 Basic rules of composting

The secret to a healthy compost pile is to maintain a working balance between C and N. As composting proceeds, the C/N ratio gradually decreases from 30:1 to 10–15:1 for the finished product ready to be used (USDA, 1990, Brust, 2019). This is due to the "condensation" of humified substances while carbon is partially converted to CO_2 through mineralization. Safwat et al (2007) also recommended an optimum C:N ratio is around 10 -12 to obtain a good microbial growth, Therefore, considering green material that is rich in nitrogen is important. (Dhehibi et al 2020). Composting needs water that is important for compost development. break down the organic matter. Plant material should be down sized to at least 7-10 cm. Safwat et al. (2007) recommended shredding or grinding the raw materials where the best size is less than 5 cm; critical oxygen concentration is around 15%; The pile will compost in 4 to 6 months, till it become a dark and crumbly material (Dhehibi et al 2020). Moisture content between 50% - 60% seems the optimal and finaly optimal pH values vary between 6 and 8 (Safwat et al. 2007). The first composting rule is to mix different organic wastes. the 2nd rule of composting is to maintain the organic product to compost sufficiently moist as known that decomposition of organic waste can be done in the presence of water. The 3rd and last rule are to return and regularly aerate compost (ideally every 15 days) in order to work properly, micro-organisms which require oxygen and therefore air. It's also possible to help ventilation by integrating fibrous elements (cut branches of approximately 5 cm in length).

According to the Misra et al (2003) the following factors influence the on-farm composting:

Aeration: Aerobic composting requires large amounts of O, particularly at the initial stage. Where the supply of O is not sufficient, the growth of aerobic micro-organisms is limited, resulting in slower decomposition. Moreover, aeration removes excessive heat, water vapour and other gases trapped in the pile.

Moisture: Moisture is necessary to support the metabolic activity of the micro-organisms. Composting materials should maintain a moisture content of 40–65%. Where the pile is too dry, composting occurs more slowly, while a moisture content in excess of 65 percent develops anaerobic conditions.

Nutrients: Micro-organisms require C, N, P and K as the primary nutrients. Of particular importance is the C:N ratio of raw materials. The optimal C:N ratio of raw materials is between 25:1 and 30:1 although ratios between 20:1 and 40:1 are also acceptable.

Temperature: While the ideal temperature for the initial composting stage is 20–45 °C, at subsequent stages with the thermophilic organisms taking over, a temperature range of 50–70 °C may be ideal. Turnings and aeration can be used to regulate temperature.

Lignin content: This nature of lignin has two implications. One is that lignin reduces the bioavailability of the other cell-wall constituents, making the actual C:N ratio lower than the one normally cited. The other is that lignin serves as a porosity enhancer, which creates favourable conditions for aerobic composting

Polyphenols: Insoluble condensed tannins bind the cell walls and proteins and make them physically or chemically less accessible to decomposers

pH value: The pH level should not exceed eight. At higher pH levels, more ammonia gas is generated and may be lost to the atmosphere

Dhehibi et al (2020) concluded that the monitoring process of composting is based on the control of three key factors: humidity, oxygenation, and temperature. The selection of the composting site inside the oasis farm is crucial as it can contribute to reduce the risk of drying out by the sun. Regular watering and turning (moving the compost product) are recommended with the aim to compensate the evaporation and enhance oxygenation. M

3.2.4 Composting and Date palm wastes

The generated huge amounts of date palm wastes are either buried in landfills or burned directly in open fields causing serious threat to the environment and human health. (Usman et al. 2015). Significant amounts of wastes mainly fallen date fruits, date fruit seeds (pits), and date press cakes are being generated by the date palm agro-industry. These wastes pose serious environmental problems besides contributing to a great loss of raw materials (Chandrasekaran and Bahkali 2013). Moreover, date palm fruit harvesting is often accompanied by substantial fruit losses that occur during the picking, storage and conditioning processes.

Palm wastes have high organic matter content but suffers from a significant lack of nitrogen ratio compared to another wastes. This makes a long time to decompose automatically in nature (Habchi et al. 2020). However, animal manure has been used for composting date palm residues. It is well known that animal manures contribute significantly to the soil fertilization and the sustainable use of manures can improve organic matter and structure of soils.

Date palm wastes compost were mechanically produced (Benabderrahim et al 2018) according to the following steps: 1. collect of palm tree wastes 2. grinding residues 3. transmission of ground product to the steeping basins 4. soaking the ground material in water (7–10 days) 5 drying and mixing with cow manure in a 3:1 ratio 6. preparation of Andean and fortnightly mixing of amount water and aged 6 months prior to its use to eliminate any potential pathogen. The characteristics of palm compost and cow manure are shown in the following Table 1.

Table 1. Characteristics of palm compost and cow manure

Parameter	P-compost (6 months)	Cow manure
pH (H_2O)	7.6 ± 0.3^a	7.8 ± 0.6^a
EC (dS/m)	3.2 ± 0.4^a	4.1 ± 0.5^b
N (g kg^{-1})	12 ± 2^a	21 ± 3^b
C (g kg^{-1})	320.5 ± 32^a	350.6 ± 24^a
C/N	27.08	16.1
P (%)	0.37 ± 0.01^a	0.41 ± 0.02^b
K (%)	0.42 ± 0.03^a	0.57 ± 0.01^b

In addition, goat manure is usually available and it is reach in total nitrogen (1.01%). Thus, it can be this co-composted with the palm leaf waste to decrease its high carbon/nitrogen ratio. Abid et al. (2020) noted the fact that the goat waste is seldom used before, and date palm waste composting is mixed at low rate (32%) in the previous scarce published works. The above authors introduced a new waste soaking step before managing the windrow to improve crushed date palm biodegradability. This stimulated the activity of microorganisms and consequently reduced the duration of composting process.

On the other hand, Habchi et al (2020) used different amounts of alfalfa (*Medicago sativa* L) plant as a nitrogen source (20%, 30%, 40%, 50%, DM), in order to facilitate the degradation of Date palm wastes and to accelerate the composting process. The major differences in physicochemical properties of composts obtained are mainly related to the change in their contents from date palm waste and *Medicago sativa* L used.

All organic waste materials derived from date processing could be used for compost preparation. A composting mixture consisting of 70% date palm wastes and date palm pits and 30% shrimp and crab shell wastes was reported to take about 13 weeks to mature and at the end of maturation the compost had all the quality of a good fertilizer marked by its various constituents (Khiyami et al., 2008a, b). The final product has a considerable fertilization value. It was found to have 57.1% moisture content with a pH of 7.9 and organic matter of 891 g/kg dry matter with significant amounts of 2.2, 0.82, 14.3, and 1.3 g/kg calcium, phosphorus, potassium, and sodium, respectively. Dhehibi et al (2020) added treated biosolid sludge to the crushed material date palm in order to initiate and promote the composting process. This treated biosolid sludge comes from the treatment plants of the neighboring localities and their transport to the site.

3.2.5 Compost quality

Composting process and the final product quality depend on many factors including the raw materials typology and their formulation while composted, the material's water content, returning frequency of the windrow, temperature, and the microbial activity (Masmoudi et al., 2013; Cesaro et al. 2015; Harindintwali et al. 2020).

Compost quality is especially related to its stability and maturity (Hachicha et al. 2009; Cesaro et al. 2019; Nikaeen et al. 2015). This is assessed by different physico-chemical (pH, EC, temperature, moisture and C/N) and biological (microbial flora, respiration, germination index, solvita test) parameters, associated to spectroscopic techniques (Masmoudi et al., 2013; Song et al., 2015).

The C/N ratio is one among the main parameters affecting the composting process judging the degree of evolution of organic matter (i.e. its ability to quickly break down in the soil) and kind of compost (Michel et al. 1996). The evaluation of the balance between carbon and nitrogen, shows that if the ratio is less than 20, mineral N is released in the early of decomposition process (Aitkenhead et al. 2000). The C/N ratio is considered at 25–30 as the initial optimum ratio (Fong et al 1999). Dhehibi et al (2020) reported that the nutritional balance of microorganisms is located at C/N ratio of 24. Below this ratio, nitrogen is in excess and therefore will be released, the availability of plants. Above, the nitrogen will be collected in the soil solution to meet the needs of microorganisms. Moreover, it is commonly accepted that the ratio C/N of a product is high, more it slowly decomposes in the soil, but most got humus is stable. Indeed, if the mixture to compost is too low in nitrogen, it will not be degraded. If the proportion of nitrogen is too high, the compost can overheat and kill microorganisms in the compost (Dhehibi et al 2020).

The effect of the incorporation of residues on the dynamics of nitrogen in the soil can be described by three parameters: the assimilation efficiency (proportion of carbon decomposed by microorganisms which is assimilated), the ratio of residues and microbial biomass C/N ratio. Used alone, this criterion of quality has its limits: two products with the same C/N can have different actions on the evolution of the content of soil microorganisms. The C:N ratio must therefore be regarded as an indicator of quality to be supplemented by other information (Mustin, 1987).

Recently, Giagnoni et al. (2019), defined the co-composting as a designed technique that allows the aerobic degradation of organic waste mixtures, primarily aiming at obtaining a product with specific characteristics. As compared to the typical composting activity, the main difference is that the waste admixture not merely constituted to initiate and sustain the biodegradation process, but also the possibility of combine various wastes to obtain 'tailored' products with designed properties, or to reclaim and valorize natural resources such as degraded soils or polluted soils and sediments, through the setup of appropriate co-composting protocols.

Abid et al. (2020) confirmed the good quality of the compost issued from water-soaked mixed date palm waste and goat manure aerated windrow in order to produce an organic amendment for soils. The results showed a rapid temperature increase during the first week, and a relatively long compost maturity phase. The compost didn't exhibit any phytotoxicity effects on indicator plants while the index exceeded 80%. Their results also showed that considering its total nitrogen content and OM was lower to 3% and 55% respectively, the produced compost could be further classified as green waste compost (French standards NF U 44–051, 1981). It was concluded that Date palm waste and goat manure co-composting is an efficient environmentally-friendly and economically viable solution for the treatment of date palm wastes, providing OM for a sustainable agriculture.

3.2.6 Effects of compost application to soil properties

Sustainable soil management is focused on improving its organic fraction, i.e., maintaining, protecting and possibly increasing the SOM content by applying the best agronomic decisions. Such operations can be the following: Supply organic fertilizers, manure, compost or soil improvers to increase the SOM level, counteracting its mineralization rate and also conferring better physical and structural properties to soil (Libutti, et al 2021). Recycling of plant residue biomass combined with compost addition for many years increased soil organic carbon in other Mediterranean tree crops such as peach, kiwifruit and apricot (Montanaro et al. 2010, 2012). The farming operations of organic fertilizing and/or compost supply are generally very effective in establishing a rapid and progressive increase in the SOM content and boosting soil fertility because of a large array of benefits (Smith et al. 2013, Montanaro et al. 2012, Celano et al. 1998). For this reason, manuring or compost application are highly recommended, not only considering the supply of organic matter to the soil, but also because considered an even better alternative to pruning incorporation into the soil. Positive effects of compost amendment on nutrient elements recycling and soil fertility are obvious through intense vegetative weed growth around the trees where compost was applied (oLIVE-CLIMA, LIFE 11/ENV/000942). Benabderrahim et al (2018) showed that the application of palm waste compost at 30 t ha^{-1} increased significantly the principal soil properties (organic matter and water retention capacity) and decreased their electric conductivity. They concluded that the P-compost at appropriate dose could be used as a good organic fertilizer for other crops surrounded date palm trees and could replace chemical fertilization with satisfactory results.

On the other hand, Kavvadias et al. (2018) reported that addition of compost from shredded pruning residues or olive mill by-products did not have a significant effect on SOM, total and inorganic nitrogen and soil microbial properties. This was attributed to the relatively low amount of organic matter applied to soil each year and the addition of fresh organic matter, which was poor in nutrients and thus could result in poor response of the microbial biomass to form new biomass. Ferrara et al. (2015) and Jokela et al. (2009) registered limited changes in SOM and other chemical parameters after a soil amendment with various organic materials. They concluded that it may take many years before some soil quality indicators fully respond. When compared to a similar N fertilization level supplied using mineral fertilizers, compost additions showed a good supplying capacity of nutrients (CATCH-C project, 7th Framework Programme for Research, Technological Development and Demonstration). Among all practices, the application of external C-sources, such as compost, farm yard manure (FYM) and slurry resulted in the highest overall increases of SOC concentrations. Increments due to these external C inputs ranged between factor 1.37 and 1.21 compared to similar mineral N fertilisation rates.

The compost maturity and stability are important criteria for its safe use in agriculture immature compost may produce phytotoxic compounds damaging seed germination as well as plant growth (Abid et al 2020). On the other hand, the compost product can be used as a conditioner and an ameliorated for soil structure, increasing soil organic matter, suppressing plant pathogens, and enhancing plant growth (Hoitink et al, 1986). Compost application can increase SOM and water reserve and reduce runoff and soil erosion from the typical hilly, terrain characteristic of the Mediterranean region (Manios, 2004, Zorpas, 2009). Compost applications improve soil fertility over time (Zorpas, 2009). The transition period between conventional and organic composted practices is often marked by a decrease in N availability and in yields due to a shift in biological activity and N sources that are not immediately available for plant use (Zorpas 2009). Moreover, among the benefits of composting is an increase in soil microbial activity and improved soil physical conditions such as increasing water-holding capacity (Wander et al. 1994; Gunapala and Scow, 1998). Lower increments of N_2O emission occurred with the application of the following BMPs (ranked in order of increasing emission): compost > slurry > (high) mineral N fertilization > No-Till (NT) > catch crops/cover crops (CATCH-C project). Moreover, farmyard manure and compost amendment emerged as the best management practices for increasing both earthworm abundance and MBC content.

4. Related research projects

Research projects related to the valorization of agricultural wastes and residues through thermal and biological conversion for soil application are described below:

FP4-FAIR - Specific research, technological development and demonstration programme in the field of agriculture and fisheries (including agro-industry, food technologies, forestry, aquaculture and rural development), (1994-1998)
IMPROLIVE-Improvements of Treatments and Validation of the Liquid-Solid Waste from the Two-Phase Olive Oil Extraction
Website: *http://www.fiw.rwth-aachen.de/cms/index.php?id=281*
The aim of the project was to create a comprehensive package of treatments for wastes from the two-phases olive oil extraction. The targets were to develop a catalogue and a data-base for processing technical and economic information, to improve the recovery of orujo oil and alpeorujo drying to obtain better oil quality and reduce costs, to validate alpeorujo by protein optimisation to obtain animal feeding, by aerobic bioremediation of liquid and solid phases, to obtain plant growth promoters, and by combustion/gasification to recover energy and combustible gases. The objectives of this project are to define feasible alternatives for the validation of alpeorujo. Several procedures will be investigated: balanced-protein enrichment to produce animal feed; bioremediation and composting for plant and mushroom cultivation; fluidized bed and spray drying; combustion/gasification for energy recovery; and anaerobic digestion for the production of biogas. The results will allow to develop industrial standards and methods for the treatment of alpeorujo in an economical, feasible and environmentally sound approach.

LIFE95 ENV/GR/001092, Biotransformation of solid and liquid waste of olives
Website: https://webgate.ec.europa.eu/life/publicWebsite/project/details/1375
The purpose of the project concerns the biological treatment of the liquid wastes of olive mills through the use of a biowheel, mixing of the liquid wastes with the extracted press cake from olives (solid waste of olives) and the production of organic fertilizers through the co-composting process. The final product should be free of toxic substances, should enrich the soil and should constitute a good quality fertilizer for plants in general. The project begins with the preparation of studies and designs regarding the technical specifications of the proposed installations. The particular needs of each olive oil mill are taken into consideration and a

selection is made of sub-contractors and test fields. Following the selection, construction began on the units¿ sites and tests. Once it was completed, improvements were made on the operation of units. At this point, cultivation began using the produced fertilizers. Subsequently an evaluation was conducted on technical, environmental and economic aspects. The project ended by disseminating the results, during the entire project. It is hope that this project will lead to an optimal waste re-use method for the liquid wastes of olive mills.

LIFE96ENV-E-000269 Demonstration plant of recycling for vegetable wastes and algae
Website: https://cordis.europa.eu/project/id/LIFE96ENV-E-000269
The purpose of the project is to construct a demonstration plant for open-air composting using algae and other plant residues (pruning, parks and garden cuttings), fine-tuning the process to obtain a high-quality product that is easily applied to organic farming, household gardening, plant nurseries and tree plantations.

FAIR (CT96-1420), IMPROLIVE: Improvements of Treatments and Validation of the Liquid-Solid Waste from the Two-Phase Olive Oil Extraction
Website: http://www.ucm.es/info/improliv/index.htm
The aim of the IMPROLIVE project was to create a comprehensive package of treatments for wastes generated from the two-phases olive oil mills. The targets were to develop a catalogue and a database for processing technical and economic data, improve the recovery of orujo oil and dry alpeorujo (sludge) and thus oil quality, validate alpeorujo by protein optimization to obtain animal feeding, aerobic bioremediation of liquid and solid phases to obtain plant growth promoters as well as apply combustion/gasification to recover energy and combustible gases.
The project is multidisciplinary and the overall methodology integrates several procedures: computerized integration of data and results, wastewater treatments, balanced-protein enrichment, aerobic bioremediation and nitrogen fixation, extraction by decanter centrifuge, fluidized bed, spray or similar drying and combustion/gasification.

- The composting procedure for alpeorujo anaerobic-aerobic treatment for liquid fractions seems to be the most favoured treatment. By combined use of both methods the disadvantages resulting from separate application are nearly compensated.
- A composting process has been developed to enable transformation of alpeorujo under thermophilic conditions into a humidified organic substrate suitable for agricultural use. Bulky material is only required for the initiation of the process. The process is greatly enhanced by treating the pile with dilute solution of hydrogen peroxide.
- The mature alpeorujo compost is suitable as soil fertiliser and has been used in large scale trials over a variety of plants.

LIFE97 TCY/IL/047, The Galicomp project: centralized treatment of organic waste
Website: https://webgate.ec.europa.eu/life/publicWebsite/project/details/1561
The project aimed to provide: · A technological solution for a suitable strategy for organic farm and municipal fibrous waste. The project would implement the technology using a representative proportion of waste generated in the region. The proposed site for the composting facility is in the experimental station in the Hula Valley. An overall treatment strategy to handle all the organic waste in the region. The infrastructure for the centralised collection, handling and treatment of waste and for the disposal of compost. Implementation of the Galicomp facility was expected to prevent environmental pollution, reduce the amount of material for land filling and enhance the sustainable development of the area.

LIFE98 ENV/E/000370 Development and implementation of a centralized plant for the re-use and valorization of agricultural waste from intensive cultivation and handling of fruits and vegetables.

Website: http://www.serconet.com/ayto.t.pacheco

The project aimed to develop a centralized plant suitable for the treatment of agricultural wastes from intensive cultivation and handling of fruits and vegetables. The plant was designed to produce four sub-products by using agricultural wastes as raw materials, namely biogas; organic fertilizer; liquid fertilizer; and water. The designed technical solution was a five-step process which integrates three different waste treatment technologies. The steps and technologies involved were: (1) Initial methanization through mesophilic anaerobic digestion (2) Phase separation (3) Secondary methanization through mesophilic anaerobic digestion (4) Production of organic fertilizer through accelerated composting and (5) Production of liquid fertile through reverse osmosis.

LIFE98 ENV/F/000331, QUALORG: Development of a quality management for the organic valorization of biowastes from household refuse – Qualorg

Website: https://webgate.ec.europa.eu/life/publicWebsite/project/details/942

,Eight French communities together with a German community would host the 9 pilot sites of the QUALORG programme. The main activities of the project would focus on setting up the quality approach and the establishment of guidelines to perpetuate recycling procedures, while controlling management costs. The QUALORG approach would prioritise customer satisfaction: from the citizen who sorts his waste, to the compost user and all other potential customers, farmers, fertilizers producers, landscapers, etc. It would draw its aspiration from the ISO 9001 quality systems: planned actions, on-site implementation, performance analysis and corrective measures, combined with consultation. The tasks planned were as follows: 1) The definition and validation of the quality chart. 2) Test the chart according to a 'quality system' over a period of 2 years and implementation in the pilot sites provided by the municipalities.

LIFE99 ENV/P/000658, WASTE: Treatment and management of green residues by a process of composting

Website: http://www.cm-penafiel@penafiel.pt

This project set out to optimise the composting process through the regulation of variables like temperature, the C/N ratio and the degree of shredding of the material, in such a way that it would be possible to deal with 20 tons of waste cuttings' daily. The project's objectives were: - To reduce the amount of waste deposited in the district dump. - To produce natural compost that could be used in the district's public spaces and in agricultural fields, as a substitute for traditional chemical manure.

LIFE00 ENV/E/000555, BIOCOMPOST: Demonstration Plant for composting municipal sewage sludges and rice straw, and evaluation the agronomic quality of the produced compost

Website: www.biocompost.org

The project developed a new system to collect rice straw from muddy plots and a composting process using a mixture of rice straw and sludge from wastewater treatment has been tested and improved, and has shown good results. This has demonstrated the potential for recycling rice straw resulting from harvesting, as compared to the practice of burning it. As far as the produced compost is concerned, the project concluded that the product as an organic

emendation in agriculture, is a significant option as a suitable end use. The beneficiaries evaluated the effect of the compost on a series of species characteristic of the Natural Park's ecosystems (psamofilas) and also they used it to amend a franco clayey ground used in the cultivation of citrus fruits. Results revealed an increase in organic matter but not in humic acids nor in other analysed properties of the soil.
The rice stalk was used in two different treatment lines:

a) Composting in heaps: 9,700 t of green matter (resulting from the separation of the organic fraction from Urban Solid Waste (USW) from 45 municipalities) were mixed with 970 t of rice stalks, in the ratio of 1:10 with the organic material. The process consisted of leaving the mixture in heaps for 10 weeks, carrying out approximately 45 turns on the rows of material, for which a self-propelled tumbler was used. The mixture of more than 10,000 t resulted in a significant loss of mass during the composting process; 35% of the mass was lost in the refining processes and further losses occurred during the decomposing process. Finally, approximately 2,900 t of compost were produced. This compost was sent mainly to vineyards in the regions of Utiel, Requena and Godelleta.
b) Composting in silos: The rice stalks (102 t) were mixed with 102 t of sludge from sewage purifying plants, 100 t of pruning waste and 36 t of green matter. Two silos were built for the purposes of the BIOCOMPOST project using reinforced concrete with a lower channel for air distribution and the evacuation of lixiviates. After grinding of the rice stalks and mixing it with the sludge, green matter and pruning waste, the material is lined up into heaps and composting begins. The mixture remains for 6-8 days with the rows being turned practically on a daily basis. After this first step, it is transported to the silos where it remains for 6-8 days and the moisture is constantly adjusted by irrigation. The next step consists of further grinding in lengths of 30 mm and leaving it to mature for 6-8 weeks. After a final refinement the quantity of high quality compost produced in this alternative process line was 85 t, due to the reduction in mass during composting.

LIFE00 ENV/E/000543, COMPOSTDISSEMINATION Co-composting procedures and its use on afforestation, landscaping and forestry and agricultural crops in the Andalusian region

Website: http://www.cma.junta-andalucia.es

The project's objective was to demonstrate that organic waste from human activity, such as household rubbish, bio-solids from urban waste water treatment plants and plant remains from parks and gardens, could be a valid resource from the technical, economic and environmental points of view for co-composting or joint composting. In the first phase compost would be processed in two composting plants that initially did not carry out co-composting. In the second phase the compost obtained would be tested as humus in gardening, landscaping and forestation, like an organic fertilizer in forest and agricultural cultivation, and as substratum in forest, ornamental and horticultural greenhouses. In the third and last phase the results would be widely disseminated, concentrating efforts in the project area, and a 'LIFE Compost Office' would be created in Andalusia as a permanent two way feed-back point and permanent source of information about co-composting technology and the application of compost. Also to be promoted was a 'LIFE Compost Forum' in which the technical, economic and environmental aspects could be debated.

LIFE 00 ENV/IT/000223, TIRSAV: New technologies for husks and waste waters recycling

Website: www.tirsavplus.eu

The aim of the TIRSAV project is to significantly reduce the environmental impact of the disposal of olive mill industry by-products. The project focuses on developing a co-blending strategy to combine, in a recycling plant, olive oil wastewaters, fresh olive pomace and other natural organic by-products, into an 'improved' waste mixture for agricultural land application. The project has been completed successfully satisfying all the criteria from an environmental and socio-economic point of view. The final products allow integrated use of different bio-wastes from the agro-food industry and agricultural production, while the experimental mixes produced comply with the reference limits set by Italian regulations for simple vegetal non-composted amendments or for mixed composted amendments (Law 748/84), with characteristics that also make them suitable for Organic Agriculture (Reg 2092/91 and MiPAF Circular n. 8 of 13 September 1999).

LIFE00 ENV/GR/000671, MINOS: Process development for an integrated olive oil mill waste management recovering natural antioxidants and producing organic fertilizer

Website: www.pharm.uoa.gr/minos

The objective of the project was to establish a demonstration process for the integrated utilization of waste produced by olive oil press factories. The produced wastewater contains chemical compounds with significant pharmacological, biological and chemical properties of high added value.

This project involved the development of a viable high-technology process for the recovery of natural antioxidants from olive oil mill wastewater. The system is integrated with the composting of the wastewater sludge for the production of a natural organic fertilizer. Another target of the project was the reduction of the water consumption by recycling it and reducing the energy demand of the process using the olive oil mill solid waste as solid fuels.

The approach was expected to provide an integrated and viable solution concerning the management of the specific olive oil mill waste.

Treatment technology

The integrated system developed consists of the following main steps:

- Successive wastewater filtration stages
- Capture of polyphenols by specialised adsorbance resin
- Treatment of the resin outflow in a nanofiltration/reverse osmosis system
- Recovery of polyphenols captured in the resin media by using organic solvent
- Delivery of polyphenols mixture through thermal recovery of the organic solvent
- Chromatographic separation and purification of polyphenols
- Composting of the sludge produced by the filtration stages and the olive leaves which are rejected as solid waste from the mills producing soil fertilizer
- Composition of the final treated waste

LIFE00 ENV/GR/000723, Elaiocycle: Establishment, operation and demonstration of an innovative closed−cycle system of oil milling waste water using the Fenton method in Sitia−Crete, and reuse of treated water and by−products in agriculture

Website:https://webgate.ec.europa.eu/life/publicWebsite/index.cfm?fuseaction=search.dspPage&n_proj_id=1875

During this project, a pilot plant was designed and constructed in Eastern Crete with the purpose of fully treating the effluent from olive oil milling plants. The effluent from the adjacent oil mill is channeled to a treatment plant. At the plant, the effluent is processed through the Fenton method in combination with a dissolved air flotation device to extract the solid contents form the effluent. The subsequent solid component in the form of non−toxic sludge

cake is further processed through a closed in vessel co−composting reactor in conjunction with locally available agricultural waste. From this process, stabilized compost free of pathogens was obtained and allowed to mature into a high quality organic fertilizer available for distribution.
The scientific team was further developed the technology and they produced compost with increased quality characteristics. The developed methodology of composting is mainly adopted by Agricultural associations in Greece, which further pack and trade the product.
Tests carried out in crops and trees revealed a positive effect of compost in plant growth, however, no tests and studies have been performed until now regarding the potential effect on soil quality during cultivation.
A pilot plant will be designed and constructed in Eastern Crete with the purpose of fully treating the effluent, also known as 'blackwater' from olive oil−milling plants. The effluent from the adjacent oil −mill will be channeled to the treatment plant. At the plant, the effluent will be processed through the Fenton method in combination with a dissolved air flotation device to extract the solid contents form the effluent. The subsequent solid component in the form of non−toxic sludge cake will be further processed through a closed in vessel sin−composting reactor in conjunction with locally available agricultural waste. From this process, stabilized compost free of pathogens will be obtained and allowed to mature into a high quality organic fertilizer available for distribution. It is anticipated that this fertilizer will meet EU 2092/91 standards for organic agriculture. The developed methodology of composting was mainly adopted by Agricultural associations in Greece (pack and trade the product).

LIFE02 ENV/IT/000089, fertiLIFE: Sustainable fertilisation of an intensive horticultural basin through an innovative management system of the local vegetal waste bio-mass utilising an existing composting plant and supporting a permanent info-structure
Website: www.arsial.it/portalearsial/FertiLIFE/index.html
The fertiLIFE project aimed to conduct a survey of all green waste produced locally and to develop an information system which allows for the utilisation of the compost in the same fields where it originated. Its specific aims were to: Create a pilot rationalisation system of bio-mass waste recycling; Produce a high-quality compost to be used as a fertiliser; Demonstrate the feasibility of a self-sustainable fertilisation system; and Disseminate the methodology and results among target groups. Demonstration of the effectiveness of the local bio-masses system would include an economic analysis of costs and benefits taking into account profits, chemical fertilisation and waste disposal cost reduction and the potential for greater intakes from the sale of an organic production with a specific label of origin. The benefits for the environment were also to be evaluated. Cost and benefits analysis would be carried out taking into account the effect that the proposed management system combined with the specific realisation of small territorial composting plants would have on similar environmentally rich areas with intensive agriculture use.

LIFE02 ENV/E/000187, ENERWASTE: Implementation of an anaerobic digestion facility at a Spanish slaughterhouse for a sustainably closed energy and waste
Website: www.enerwaste.info
The objective of the ENERWASTE project was to improve the management of slaughterhouse wastes, which is a serious environmental and economical problem for the industry. An integral solution to the management of slaughterhouse wastes is anaerobic digestion which is a process very similar to the natural one taking place in the digestive track of the animals. After treatment a renewable energy (biogas) and a new resource (fertilizer) are generated.

LIFE03 ENV/GR/000223, DIONYSOS: Development of an economically viable process for the integrated management via utilization of winemaking industry waste; production of high added value natural products and organic fertilizer

Website: https://webgate.ec.europa.eu/life/publicWebsite/project/details/2105

The overall goal of this project was the development of an economically feasible process for the integrated management of the waste generated by the winemaking industry in Greece. Specifically, the project wanted to demonstrate and prove that the development of a unit (at a pilot-plant scale) that would process winery solid waste to recover the high added-value polyphenols and use the remaining waste for the production of high nutritional value animal food or natural organic fertiliser was financially viable for SMEs.

The project succeeded to recover natural polyphenols, substances of high added value and wide applications by industries as food supplements and active ingredients of cosmetics, while promoted the use of the remaining slurry wastes and sludgy wastewater for the production of high nutritional value animal feed and also transformation of the remaining sludge to natural organic fertilizer by composting. The waste grape pomace mixed with the sludge are used for the production of high nutritional value animal food or were composted to produce natural organic fertilizer. The composting system developed in the framework of the DIONYSOS project is a "static pile" – "invessel" system, mechanically aerated, which is equipped with a control system of the waste humidity content. The maturing of the compost is implemented in open windrows, mechanically aerated. The produced compost was tested in small scale experiments for the cultivation of two vegetables on a sandy and on a loamy soil, showing very satisfactory results, as far as plant development is concerned. However, no other soil type and cultivated plants were tested, while the effect of compost addition on soil was not identified, at least during the project duration.

LIFE03 TCY/CY/000021, PIGWASTEMAN: Guidelines to the Cyprus Competent Authorities for Policy Formulation for Sustainable Management of pig-farming wastes in Compliance with EU Practice

Website: http://pigwasteman.ari.gov.cy/

The overall aim of the project was to support the competent authorities of Cyprus to formulate a waste disposal policy for sustainable management of the pig-farming wastes. In order to obtain comparable operational data and to minimize operational cost two pilot systems were installed at the same pig farm.

In the first pilot treatment scheme the following stages are seen:

1. Separation of liquid and solid fractions via mechanical separator.
2. Aerated lagoon followed by polishing lagoon for the treatment of the liquid manure fraction.
3. Composting of solid manure fraction and storage for a minimum of three months.
4. Land spreading of liquid manure fraction and of treated solid manure.

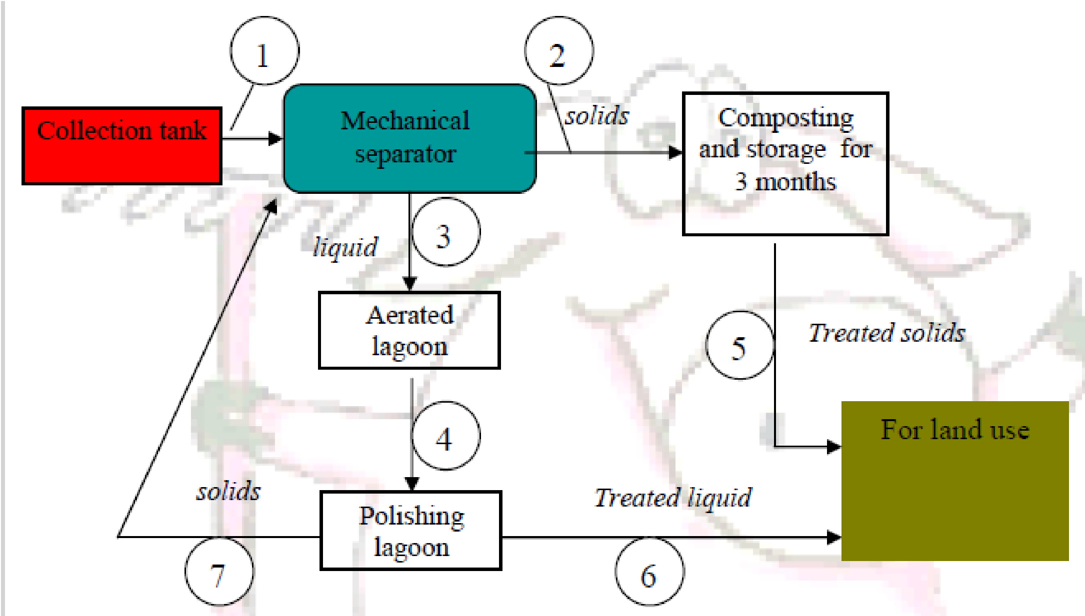


Figure 5: Pilot treatment scheme 1, PIGWASTEMAN project

LIFE04 ENV/HU/000372, ECOFILTER: Modern and environmentally friendly composting methods of agricultural waste

Website: https://webgate.ec.europa.eu/life/publicWebsite/project/details/2406

The project developed an environmentally sound clean technology for use in the composting agricultural sector. Presently, compost farms are aware of the urgency of addressing the ammonia emissions problem, but try to introduce solutions that have only a limited impact. Examples of these solutions include moving compost to other sites, using chimneys, and building bunkers or aerated floors. There is also a concern that compost quality will be affected if new technologies are introduced. The project will address these issues.

The first step of composting is the pre-wetting and pre-fermentation of the mixture. Then fermentation occurs in completely closed and floor aerated indoor tunnels and the mixture turns into phase I (green compost). Although it can be sold in this form (can be used for growing mushrooms), the composting process is continued to produce phase II and phase III compost. In the second stage, the compost is pasteurized in tunnels, thus all bacteria which could damage later the mycelium of the mushroom spawn are perished. For the production of 1 t of phase II pasteurized compost 1.4 t of green compost are needed; the yield of 1 t phase II compost is approximately 220-260 kg mushroom. Therefore, the European mushroom compost industry needs to produce ca. 4-5 billion t of phase II compost, which is equal with 5.6-7 billion t of green compost. According to customers’ needs, the spawn runs through the compost, resulting in phase III compost. By means of the spawn-run compost the growing period of the mushroom will be shorter meanwhile the yield will be higher.

LIFE04 ENV/GB/000820, TWIRLS: Treating Waste for Restoring Land Sustainability

Website: www.bangor.ac.uk/ies/TWIRLS/index.php.en

The aim of this project is to demonstrate that it is possible to safely compost many of the wastes produced by people, industry and agriculture, as a sustainable alternative to landfilling. During composting, pollutants contained in the wastes are destroyed or stabilised. The finished compost can then be used to restore derelict post-industrial sites or to return organic matter and nutrients to degraded agricultural land. In this area of our site you can read about the aims of our research, the different wastes we are using and how we are composting them.

The TWIRLS project began composting 1000 m3 of wastes at Shotton, Flintshire, Wales. Wastes (green waste, de-inking paper fibre and tertiary treated sewage sludge) were delivered to site, mixed according to six different combinations designed to give a target initial C:N ratio between 20 and 35, and composted for 80 days in EcoPOD® in-vessel composters.

The EcoPOD system

An enclosed vessel (EcoPOD) composting system is used (www.ag-bag.com) to turn waste into compost. In-vessel composting has some advantages over traditional windrow composting, including a high degree of process control, little odour or bio-aerosol production; it is self-contained with no waste/litter dispersal and little leachate production; it has a rapid cycle time, maximizing throughput on a smaller area; and is not dependent on external environmental conditions. In-vessel systems are more expensive to install and maintain than open windrows, but the containment makes them more suitable for co-composting contaminated soil from industrial sites. The EcoPOD system we are using has the added advantage of being portable, meaning that after obtaining proper regulatory approval, we can compost on-site instead of transporting soil using public highways. Recyclable HDPE bags are filled with shredded feedstock materials and each bag is aerated using fans connected to an aeration pipe running the length of each bag.

LIFE04 ENV/FR/000337, ZNP: Zero Nuisance Piggeries

Website: www.zeronuisancepiggeries.com

This project aimed to develop and demonstrate a holistic approach to pig slurry management via: applying flushing techniques to clear the fresh manure on a regular basis throughout the day to prevent anaerobic decomposition of the manure within the building and hence the major source of odour nuisance; using centrifuge systems to separate liquid and solid waste products within the manure for subsequent treatment; biological treatment of the waste products while using a membrane filtration; and creating an effective composting regime for the centrifuge manure residues. This holistic approach aimed to minimise negative environmental impacts from pig farms.

LIFE ZNP project team developed and tested an innovative prototype technology that provides effective treatment of pig manure and significantly reduces the risks of environmental pollution. Environmental benefits from the new treatment methodology includes 100% elimination of suspended solids and 95% elimination of total chemical oxygen demand (COD). Nitrogen is almost wholly transformed into nitrates (by 94%) and subsequently denitrified. Compared to the control pig units, the ZNP system reduced the outflow of ammonia and nitrous oxide by up to 70% and mitigated greenhouse gases and atmospheric pollution. ZNP staff predict that widespread use of the new holistic treatment technology in France could reduce national ammonia emissions from pig production, currently around 60,000 tonnes, by approximately 18,000 tonnes a year. Other important benefits include the reductions in water consumption linked to the integral recycling system, which provides savings up to 40% compared with conventional systems. From a technical perspective, ZNP's prototype technology is highly productive and relatively simple to install. As such, the technology is deemed to have good transferable benefits throughout Europe and for different livestock producers. This is evidenced by proposals to develop a similar holistic manure management system in Denmark and interest shown in the ZNP approach by poultry sector representatives.

LIFE05 ENV/IT/000845, TIRSAV PLUS: New technologies for husks and waste waters recycling plus

Website: http://www.tirsavplus.eu/

Building on the results of a previous LIFE project (LIFE 00 ENV/IT/000223, TIRSAV), the TIRSAV PLUS project addresses the issue of cost-effectiveness of an innovative technology at oil-mill level through the planning and construction of a centralized recycling plant. The unit will also be able to recycle other organic wastes to produce organic fertilizers that are easy to use and acceptable for farmers. Finally, the project will promote the harmonisation of legislation at European level regarding the oil-mill wastes.
Project actions focused on a composting procedure tackling both OMWW and OMSW via a three-phase extraction system. Wet OMSW was treated by a two-phase extraction technique within the same processing system. The combined effect results in high quality compost and flexible maturation systems allows the technology to be tailored to different needs of different oil mills.
Two main systems were demonstrated. The PCS (Passive Composting Simplified) approach consists of a pre-treatment step, followed by a slow maturation and a further treatment. The ACC (Active Composting Composite) approach involves a pre-treatment step, followed by active ripening and refining phases. The compost produced by both methods is in accordance with the criteria of traceability, environmental sustainability, and agronomic efficiency. The by-products satisfy high quality requirements, allowing their use even in organic vegetable production, and floriculture production.
If translated to the EU scale, the TIRSAV+ process system could produce about 3.6 million tonnes per year of high-quality compost for use in agricultural soils. Greater efficiency in terms of recycling of organic matter can also be achieved from the production process. 100% of the organic waste produced by the extraction process of the olive oil (olive pomace, vegetation water, leaves, branches, tank washings) is recycled.
New processes demonstrated by the project upgraded previous mixing systems, as well as plant for separating olive stone. The processes of loading and unloading from a processing step to another, and the automatic control system (PLC), have also been upgraded, improved and implemented. The whole process was conceived as a modular flexible system according to the quality and quantity of materials to be treated. A unique system of maturation of compost in small containers (Bins and Big bags) has also been developed.
Efforts to produce specially prepared composts succeeded. These can be designed to respond to specific cultivation requirements, such as the production in open field, protected crops, biological or out of the ground cultures. In addition, new perspectives were opened in terms of the characterization of compost quality, to better classify the soil conditioners produced by the different operators and define their best use.

LIFE05 TCY/MA/000141, MOROCOMP: Design and Application of an Innovative Composting Unit for the Effective Treatment of Sludge and other Biodegradable Organic Waste in Morocco

Website: https://webgate.ec.europa.eu/life/publicWebsite/project/details/2626

The project aimed to develop and establish an innovative composting system for the treatment of sludge generated by Urban Waste Water Treatment Plants (UWWTPs) and drinking water refineries and other biodegradable organic waste (BOW) in Morocco. This would enable the operators and national authorities to treat, control and use the sludge and other BOW effectively and in compliance with European environmental policy. The project implementation would protect the water-bodies and soil from untreated and uncontrolled sludge disposal in order to promote the protection of public health and the environment. At the same time, the use of treated sludge and other BOW as soil improver would prevent the use of chemical fertilizers and subsequently protect arable land from degradation and the surface and groundwater from contamination. The composting system would be used as a pilot demonstration unit for further applications in large-scale plants in Morocco and in the European geographical areas facing similar problems.

Designing a composting system: The project designed an innovative aerobic sludge composting system, taking into account local characteristics, proven technologies, environmental impacts, minimal risk to public health, compliance with EU legislation, sustainable market for the end product, flexibility and use of materials of the region. The system ensures minimisation of odours and process time.

LIFE07 ENV/GR/000280Strategies to improve and protect soil quality from the disposal of olive oil mills' wastes in the Mediterranean region (Prosodol)

Website: http://prosodol.gr

The Prosodol project aims to develop and implement protective/remedial technologies that can be used to remove or significantly limit the presence of pollutants or other stressing factors in soils and water bodies affected, directly or indirectly, by the disposal of olive oil mills' wastes. Technologies being tested/applied include bioremediation and use of low-cost porous materials as soil additives. Also, prior waste disposal, a waste pre-treatment methodology using low-cost additives, has been developed in order to reduce some of the toxic load and thus, enhance soil remedial/protective techniques that follow. Composting techniques with low operational and production cost, that can be applied by individuals in their own disposal lands are being developed and implemented in a small field scale.

The design and implementation of a monitoring system to assess soil and water quality at areas where disposal of untreated olive oil wastes takes place for many years, aims to develop methodologies and procedures, capable to identify soil/water quality parameters and extent of pollution over time as well as to provide national authorities with an effective monitoring tool for eliminating environmental risks.

LIFE08 ENV/GR/000578, INTEGRASTE: Development of integrated agroindustrial waste management politics maximizing materials recovery and energy exploitation

Website: www.integraste.gr

The overall objective of the INTEGRASTE project was to demonstrate the exploitation of mixed solid and liquid agro-industrial wastes (e.g. residues from agriculture, olive mills, piggeries, etc.) as a sustainable fuel source. This aimed both to provide an economically feasible solution to the problem of agro-industrial wastes and contribute to long-term energy sustainability.

The project planned to develop an optimised prototype facility for the integrated management of various agro-industrial wastes using anaerobic digestion, composting and wastewater treatment using membranes and electrolysis. It thus aimed to valorise the waste streams in the form of electrical and thermal energy, compost, and irrigation water, aiming towards a zero-discharge system.

The INTEGRASTE project successfully demonstrated a relatively simple technological infrastructure for the integrated management of agro-industrial wastes, which will present considerable energy benefits with a low carbon footprint.

The pilot plant was fed with various agro-industrial substrates with success and produced energy through the combined heat and power (CHP) unit. The project was able to demonstrate at pilot scale:

- An integrated approach to the management of several agro-industrial waste streams simultaneously to reduce the carbon footprint of the food supply chain;
- Novel process designs that helped overcome known problems of digester stability;
- The potential to recover electrical and thermal energy from agro-industrial wastes with greater efficiency than via incineration;

- Maximisation of the cost-effective production of biogas using decision-support systems;
- Production of composts for use in agriculture;
- Recycling and re-use of the treated aqueous effluent for irrigation, instead of relying on other sources of water. The project successfully tested the use of the plant effluent in Sorghum culture.

LIFE09 ENV/ES/000459, ECOREGA: Green (environmentally friendly) management of cattle farm waste and its repercussion on the GHG emissions

Website: https://webgate.ec.europa.eu/life/publicWebsite/project/details/3145

The aim of this project was to demonstrate good practices in the management of agricultural organic waste that can help to reduce the environmental impact of cattle farms and reduce their GHG emissions. Project actions would focus on using agricultural waste for composting and methane production. The project planned to demonstrate an innovative system that mixes liquid manure from cattle farms with other types of organic waste (such as that from pigs and poultry). The aim was to produce a natural fertilizer and methane for energy recovery. The ultimate goal was for farmers to adopt these waste management strategies and thus avoid the use of other external resources and reduce the transportation of waste. The project would also promote the recovery of deteriorated soil through the application of compost.

The engaged farmers provided livestock waste (and vegetable waste as a supporting material), along with facilities for making compost and crop farms to check the fertilising capacity of the obtained compost. After analysing the slurry and soil, compost was produced under the guidance of the department of agricultural science at the University of Santiago de Compostela (USC) and other companies responsible for the operation and maintenance of the compost piles. The only materials used were those available in the farms selected. Compost piles were monitored throughout the process and amended when needed. Once the process was completed, the compost was applied to plots in varying degrees. The end results were analysed in comparison to control crops.

The project demonstrated that adding compost improves crop yield though not to the extent that would have achieved through the use of an inorganic fertiliser. This result however can be explained by the already high organic content of the soils in the region. As a result, a single year is not sufficient to determine the benefits compost over other forms of fertilisation. A multi-year trial is required to effectively conclude that this method is better for the soil but still economically viable. The project concluded that higher profit margins or economic subsidies are necessary to compensate the work needed to produce compost. Increased soil biodiversity and reduction of GHG emissions are insufficient incentives for farmers to adopt a practice than adds to their workloa

LIFE10 ENV/ES/000469, AGROWASTE: Sustainable strategies for integrated management of agroindustrial fruit and vegetable wastes

Website:https://webgate.ec.europa.eu/life/publicWebsite/index.cfm?fuseaction=search.dspPage&n_proj_id=3919

The objective of the AGROWASTE project was to design an integrated management system for fruit and vegetable wastes (FVW) for the region of Murcia, Spain. The aim of this was to promote environmentally-friendly technologies that convert FVW into resources for subsequent use, and to demonstrate proposed technologies for delivering economically-useful end products for specific waste types. For this management system, the project developed a web-platform that includes a database of the main sustainable strategies for the valorisation of FVW

The project performed pilot-scale demonstrations of some of the best innovative technologies for FVW. These innovative technologies focused on valorising FVW in three main target areas:

food (by identifying and adding value to bioactive compounds extracted from FVW as multifunctional food ingredients); energy (by obtaining biogas through anaerobic digestion of industrial wastewater and organic solid wastes with high organic content); and agriculture (by obtaining mature organic soil amendments through an aerobic process that can be used both for improving soil quality and as a substitute for non-renewable peat)

FP7-ENV-2010 - Specific Programme "Cooperation": Environment (including Climate Change) EUROCHAR: Biochar for Carbon sequestration and large-scale removal of greenhouse gases (GHG) from the atmosphere

Website: https://cordis.europa.eu/project/id/265179

The EU-funded EUROCHAR project aimed to test the effectiveness of this approach. The project achieved this though testing different biochar production methods, conducting field trials and modelling the impact of applying this strategy worldwide.

EUROCHAR scientists tested two different methods to create biochar: gasification or thermal carbonisation (TC), and hydrothermal carbonisation (HTC).

The different biochars were analysed and tested as soil amendments in fields across Europe. The project noted major differences in the composition of the biochars depending on the source of biomass as well as the treatment method. Biochars made by TC are more stable and have a better sequestration potential than those made by HTC.

None of the biochars showed any toxicity to plants, and all hazardous chemical components were well below EU limits. In the field, the biochar products showed good stability, and researchers noted that biochar altered the microbial communities in the soil at several study sites.

EUROCHAR modelled the long-term impact of this strategy in the EU, and found that it could sequester carbon equivalent to 5 % of EU transport emissions. Biochar clearly holds promise as a carbon sequestration strategy in the EU and worldwide. The results of EUROCHAR will have a far-reaching impact on carbon sequestration efforts and climate change in general

LIFE10 ENV/DE/000126, AlternativeBiomass4Energy: Sustainable biomass production, processing and demonstration of alternative cropping and energy systems.

The project will investigate a new approach for converting digests from biogas plants and biowaste into biochar. The possible impacts on crop growth, cropping systems, carbon sequestration and carbon credits will be investigated. The main emphasis will be on demonstrating on a pilot scale a new carbonisation technology (BSP) for the conversion of different sources of waste and digests. This will then be put back into the biomass cropping systems and/or used for energy purposes.

The project will also assess the influence of crop management on the overall biogas yield and the economic and environmental impacts (including the impact on biodiversity) of the different crops. The project will screen multiple feedstocks of biowaste and alternative biomass production systems for large-scale production of biomass that does not compete with food production, and which also solve waste disposal problems in natural eco-systems.

LIFE10 ENV/PL/000661 Biorewit: New soil improvement products for reducing the pollution of soils and waters and revitalizing the soil system.

Website:https://webgate.ec.europa.eu/life/publicWebsite/index.cfm?fuseaction=search.dspPage&n_proj_id=3918

The main goal of the project is to develop innovative technologies for new soil improvers and soilless substrates for greenhouse cultivation. These will include a) the use of natural fibrous wastes e.g. straw, sawdust, wool, cotton for the production of soil improvers, b) the use of natural fibrous wastes for the production of biodegradable soilless substrates and c) the application of new fibrous soil bio-activators in the cultivation of vegetables on demonstration plots and on experimental fields for cultivation. Research on soilless cultivation of tomato and cucumbers will also be carried out on new fibrous substrates in greenhouses and plastic tunnels at coordinator premises.

LIFE10 ENV/GR/000594, WASTEREUSE: Best practices for agricultural wastes treatment and reuse in the Mediterranean countries

Website https://webgate.ec.europa.eu/life/publicWebsite/project/details/3336

The WASTEREUSE project addressed two significant environmental problems: the uncontrolled disposal of agricultural waste (e.g. olive oil mill wastes, waste from wine production) and the excess use of natural resources and nutrients (e.g. water, phosphate rocks used for the production of fertilisers). The project aimed to increase the recycling of water and nutrients, through the sustainable use of agricultural waste. It planned to achieve this by combining developed technologies in integrated methodologies. Specifically, the project's objectives included evaluating innovative and traditional technologies for agricultural waste treatment and its reuse in crop cultivation (irrigation and fertilisation); developing alternative cultivation practices for irrigated crops in the Mediterranean region by recycling water and nutrients from agricultural waste; protecting soil quality; reducing the carbon footprint of the agricultural sector; reducing natural resources and fertiliser use; and improving profit margins by reducing external inputs.

LIFE11 ENV/GR/000951, AgroStrat: Sustainable strategies for the improvement of seriously degraded agricultural areas: The example of Pistachia vera L.

Website: www.agrostrat.gr

The AgroStrat project will develop and demonstrate an integrated approach for the sustainable management of intensively cultivated areas in the Mediterranean, such as the pistachio producing areas on the island of Aegina. This approach will include the formulation of a sustainable management and monitoring plan at local/regional level, and the re-use of pistachio waste.

Specific objectives include:

- To identify and characterise practices that contribute to soil degradation
- To examine how pistachio waste could be processed to produce compost and low-cost activated carbon for the treatment of wastewater containing organic and inorganic contaminants

LIFE11 ENV/GR/000942, oLIVE-CLIMA: Introduction of new olive crop management practices focused on climate change mitigation and adaptation

Website: www.oliveclima.eu

The oLIVE-CLIMA project set out to test new cultivation practices for tree crops in order to find a cost-effective means of mitigating and adapting to climate change. Focusing specifically on olive-producing areas in Greece, it investigated the potential of these areas to capture more carbon in soils, and to reduce greenhouse gas emissions. To identify farming practices that lead to increased carbon dioxide uptake by plants it worked in partnership with farmers from 3 farming organisations, to cover the full range of socio-economic activity: from standard practices to innovative environmentally-sensitive farming. To reverse the trends of soil organic matter loss, soil erosion and desertification the project implemented measures that increase the rate of organic matter build-up. Measures to reduce greenhouse gas emissions and other environmental impacts during crop production included reducing dependence on inorganic fertilisers. The project provided farmers with methodologies that enhance biodiversity, reduce carbon dioxide emissions from soil and which are suitable for organic agriculture. The project demonstrated to farmers that environmentally-benign agriculture can be more efficient, with less cost, can lead to product differentiation and in the case of olive-oil production can result in self-sustaining crops. To link farming practices to quantifiable carbon storage in the soil, the project developed a set of easy-to-measure indicators. A final objective was the incorporation of the projects results into national environmental and agricultural policy and legislation.

FP7-KBBE-2011-5 - Specific Programme "Cooperation": Food, Agriculture and Biotechnology, REFERTIL Improvement of comprehensive bio-waste transformation and nutrient recovery treatment processes for production of combined natural products

Website: https://cordis.europa.eu/project/id/289785

The goal of the REFERTIL project was to convert local organic waste and food industrial by-product streams in economical industrial scale into safe biochar and compost products produced under competitive market and economic conditions in European dimension. The developed Animal bone bioChar "ABC" is a recovered organic P-fertiliser, made from food grade animal bone grist, having high nutrient density (30 % P_2O_5) and pure phosphorus content. ABC was designed to be economically affordable, environmentally sustainable, and in accordance with strict EU/MS policy and food safety regulations. The protection of human health and the environment primarily considered for the safe ABC product development. The high product quality was achieved by meeting stringent requirements on the quality and safety criteria while detailed analyses of compost and biochar feed material sustainability is considered as well. The efficiency of the ABC has been field demonstrated in several European countries. Moreover, the application of advanced 3R pyrolysis technology ensured zero emissions production and output product safety, efficiency and market competitiveness. All REFERTIL-developed ABC biochar products are therefore of high grade, fully quality controlled and completely safe under wide range and different climatic, soil and horticultural cultivation conditions, while also used as specific adsorbent In most agri application cases ABC is formulated into BIO-NPK

LIFE12 ENV/ES/000913, LIFE Eucalyptus: Energy Eucalyptus Integrated Wood Processing Project

Website: http://www.ingemas.com

The LIFE Eucalyptus Energy project aimed to increase the efficiency of the valorisation of eucalyptus biomass. By adding value to leaves and branches that would otherwise be treated as waste, it aimed to improve the sustainability of eucalyptus forests/plantations

Specific main objectives of the project was Specific objectives of the project included:

- developing intelligent pellets using biochar and studying their effectiveness asa carbon storage tool through a complete carbon balance of the project. It planned to test its reliability and examine the potential use of biochar as a biofuel;
- improving the recovery of valuable products from a pyrolysis plant which is used to produce charcoal from eucalyptus. Notably, it planned to demonstrate its potential as a biorefinery, by using the organic phase of the pyrolysis liquids as a biofuel and for producing valuable chemicals;
- exploring the potential of using other biomass sources, such as municipal green waste or agricultural residues, to supplement the eucalyptus material.

Additionally, although the beneficiaries also developed adequate demonstrations for showing the capacity of the biochar produced to improve the soil quality, they did not have sufficient time to produce significant results, given that at least two years are needed for observation the experiments were launched only six months before the project end. However, this aspect was outsourced to a technological centre, which is committed to monitoring results after LIFE.

LIFE12 ENV/IT/000356, Life RESAFE: Innovative fertilizer from urban waste, bio-char and farm residues as substitute of chemicals fertilizers

Website: http://ingchim.ing.uniroma1.it/

The main objective of the LIFE RESAFE project is to demonstrate the production and effective use of reduced salinity fertilisers (RSF) as a step towards replacing chemicals and mineral fertilisers through a technological route based on urban organic waste (UOW), bio-char and farm organic residues (FOR).

Based on this approach, it will be possible for farmers and urban waste managers to reduce costs and benefit economically from material recovery (e.g. reduced quantities of waste sent to landfill and the related costs saving). They will also benefit financially from the use of these organic fertilisers. The environmental impact will also be significant, due to the decrease in greenhouse gas emissions from landfills and to the benefits for soil structure and fertility.

The use of the RSF will have the following advantages:

- A significant reduction in the systematic use of chemical fertilisers;
- A consistent improvement in soil health and fertility;
- Increased availability of nitrogen and phosphorus for plants;
- Increased ?suppressive soil potential? against soil pathogens.

LIFE12 ENV/IT/000719, LIFE CarbOnFarm: Technologies to stabilize soil organic carbon and farm productivity, promote waste value and climate change mitigation

Website: http://www.nmr-cermanu.unina.it

The LIFE CarbOnFarm project intends to address the basic requirements concerning the sustainable use of agricultural soils through the restoration and preservation of soil functionalities. It will help to valorize the economic and environmental role of soil resource in the agro ecosystems and improve the recycling of agricultural biomasses.

Environmentally sustainable methods of SOM management were used that are tailored to non-livestock farms from Southern Europe. Target areas include those characterized by limited access to organic matter sources, the progressive decline of SOM content and the steady increase of soil erosion and desertification processes. On-farm composting facilities will be introduced to promote the productive and financially-viable valorisation of residual biomasses from local agricultural activities. Project monitoring actions will provide new and valuable data concerning soil organic carbon (SOC) quantity and quality, greenhouse gas (GHG) emissions from cultivated soils, soil stability and crop productivity, as well as the environmental, energetic and economic sustainability of the applied methodologies.

FP7-PEOPLE-2012-CIG - Specific programme "People" implementing the Seventh Framework Programme of the European Community for research, technological development and demonstration activities (2007 to 2013) BASE Biochar Application in a Natural Ecosystem

Website: https://cordis.europa.eu/project/id/333802

BASE is undertaking an in-depth investigation of the effects of biochar application to soil in a natural ecosystem. Working in partnership with world leading experts at Wageningen University and the Netherland Centre for Ecology, BASE will utilise multi-disciplinary techniques from soil physics, chemistry and biology and will investigate across scales, from genes up to landscape to obtain a full understanding of the impacts of biochar application to soils.

Biochar is supposed to increase the water holding capacity in sandy soils. But it was found that biochar produced from cuttings from grassland did not significantly improve the hydrological properties of sandy loam soil. Microtomography was used to show that the material was highly hydrophobic, thereby preventing water from entering the pore space of the biochar particles in the soil. Additional studies revealed that biochar's effect on crop productivity most likely results from the fertilisation effects of nutrients within the biochar. This can be in the form of potassium from the ash constituent in biochar or nitrogen. However, this fertilisation effect was found to be less than for the material the biochar was originally produced from. This result highlights the importance of rigorously applying controls for experiments investigating the effects of biochar application to soil.

FP7-PEOPLE-2012-CIG - Specific programme "People" implementing the Seventh Framework Programme of the European Community for research, technological development and demonstration activities (2007 to 2013). BIOCHARISMA: Sustainable use of Biochar in Mediterranean Agriculture

Website: https://cordis.europa.eu/project/id/333784

Biochar, or charcoal made from biomass waste, has the potential to greatly improve soils while also sequestering carbon waste. However, there is little evidence for the value of biochar for Mediterranean soils, and the effect of polyaromatic hydrocarbons (PAHs) in biochar is unknown. To answer these questions and promote use of biochar in the Mediterranean, the EU-funded BIOCHARISMA initiative assessed the effect of biochars on soil quality and plant growth, and measured the impact of PAHs in the soil. Researchers began by creating biochar from isotope-enriched sewage sludge and organic carbon waste, and comparing its properties with non-isotopically labelled biochar. They found that there were no differences, and thus the labelled biochar could be used to study its effects in the soil. At the same time, researchers showed that the method used to produce biochar had an effect on the chemical composition of the final product. Using biochar in greenhouses improved plant germination rates and soil fertility, with the best effects coming from biochar sourced from sewage. This is likely due to high concentrations of minerals, nitrogen and phosphorus. In field experiments, plants grown with biochar showed improved shoot development and were better able to resist arid conditions. Analysing biochar residue collected from the field showed that the method used to create biochars determined the concentration of PAHs present

UTF/NAM/004/NAM, Date Production Support Programme. Second Phase: Strengthening of the Namibian Date Palm knowledge base and introduction of Date Palm Cultivation into Communal Farming and Settlement Project (1998-2016)

Website: https://www.fao.org/partnerships/resource-partners/investing-for-results/news-article/en/c/1094316/

- Establishment of date production units initiated to investigate date palm adaptation, production and viability, and serve as a nucleus for further development.
- Four commercial date palm plantations set up, producing different varieties of dates.
- Practical on-farm research conducted to clarify issues that could affect date palm production in the country.
- Support provided to private date farmers through formal training activities and technical advice, to ensure long-term sustainability.
- Approximately 650 date palms distributed for planting in household gardens, for which the owners received assistance and guidance.

- Processing of date fruit not suitable for marketing as fresh fruit was investigated, and a distillery was established, within a public-private partnership framework, for the production of fine spirits, brandy and gin

7th Framework Programme for Research, Technological Development and Demonstration, Theme 2 – Biotechnologies, Agriculture & Food, CATCH-C (2012-2014)
Website: http://www.catch-c.eu
The CATCH-C project aims at identifying and improving the farm compatibility of sustainable soil management practices for farm productivity, climate-change mitigation, and soil quality.
The effects of soil management options were identified, as were the barriers to adopting BMPs in different types of farms. Data from over 300 long-term trials were used to quantify the effects of different soil management options on selected indicators for soil quality, crop productivity and climate change mitigation. Overall, BMPs did improve soil quality in a number of ways. CATCH-C observed that BMPs often came with trade-offs such as lower yield or increased emissions. Researchers also found that local conditions strongly affected BMP efficiency, and even the direction of impact.

KBBE.2012.1.2-01 – EUROPRUNING: Development of new or improved logistics for lignocellulosic biomass harvest, storage and transport (2013-2016)
Website: www.europruning.eu
EUROPRUNING began by defining the quality specifications of the materials to be produced and used as feedstock for energy production; it was essential to ensure quality adequacy to the final consumer needs and with it, the success of this type of resources in the market. The next step was developing innovative machinery and logistical tools to help farmers more easily convert their prunings into bioenergy supplies able to fulfil the quality requirements previously set.
These machines are accompanied by a 'SmartBoxTool' and an ICT platform for optimising collection and delivery logistics, as well as monitoring pruning quality. For example, when it comes to storage, the platform provides recommendations for how best to manage large storages of piled biomass. Once the prunings are ready for transport, a GIS-based decision-making tool allows logistic operators to reduce costs and optimise efficiency. The project also offers a truck-mounted GPS system to help drivers to find storage and delivery points matched by their quality requirements as well as calculating the best route between the two of them. A set of guidelines and best practices were also released to promote a cost-effective and sustainable pruning-to-energy strategy amongst all the market players: a good start of the business, biomass harvesting in the orchard, harvesting machine information, pruned biomass storage, pruned biomass logistics and transportation, fuel quality and its combustion in the boilers, environmental and social aspects.

LIFE17 CCM/ES/000051, LIGNOBIOLIFE: Development of high value-added bioproducts from forest waste through microwave technology
Website: https://www.fgua.es/
Specifically, the project will demonstrate, on an industrial scale, the efficient production of biochar and bio-asphalt from lignocellulose residues using microwave pyrolysis. The aim is to show the valuable qualities of biochar and the potential of wood vinegar for use as a green alternative to chemical herbicides. The project also plans to demonstrate the environmental, structural and economic viability of the use of bio-asphalt. Finally, the viability of installing

three bio-refineries (one in Spain and two in Portugal) will be assessed and possible business plans drawn up.

LIFE17 ENV/IT/000269, LIFE AGRISED: Use of dredged sediments for creating innovative growing media and technosols for plant nursery and soil rehabilitation

Website: http://www.agrivivai.it

The AGRISED project tackles three environmental problems: the management of dredged sediments and of pruning residues, replacement of peat and other high impact materials currently used from plant nursery growing media, and rehabilitation of degraded soils. The LIFE AGRISED project will demonstrate that dredged sediments can help reclaim degraded soils and create new growing media for plant nurseries. This will involve using sediments to restore soils through a physico-chemical process pioneered in an earlier LIFE project, New Life (LIFE10 ENV/IT/000400) and test results in land near industrial areas. Agri Vivai company will co-compost sediment with green waste to provide growing media for plants with high market value, including ornamental plants such as Frasers photinia (*Photinia fraseri*) and laurustinus (*Viburnum tinus*). The company will investigate the effectiveness of this new substrate by testing it alongside conventional alternatives. The project will then provide a life-cycle assessment, an economic evaluation and guidelines on the legislative barriers for bringing sediment-based products for growing plants to the market.

Expected results:

- Introduce technology and protocols to manage dredged sediments and green waste sustainably;
- Substitute 10% of largely peat-based growing media for ornamental plants with sustainable sediment-based alternatives, reducing the impact of the horticultural sector on peatlands and supporting the EU Habitats Directive;
- Produce plant growing media with better fertility, structure, water holding capacity, aeration and biological activity than conventionally used peat and coir pith;
- Evaluate the effectiveness of soils incorporating dredged sediments and green waste forproducing ornamental plants, maintaining green urban areas and improving degraded soils, thereby promoting the EU Soil Thematic Strategy;
- Assess potential risks for human health and ecosystems in using sediment in soils, and provide insight for a broader implementation of the European Waste Framework Directive;
- Define protocols for using co-composted sediment in agriculture and soil reclamation, addressing possible legal constraints and contributing to ongoing revisions of EU legislation on fertilisers.

Date Palm project International Center for Agricultural Research in the Dry Areas (ICARDA) (2004-2018)

Website: https://mel.cgiar.org/projects/236

The project goal is to develop data palm production systems in the GCC countries, utilizing available modern technology. The project structure is designed to comprise three components as follows: I. Problem-solving research (this will include research activities in crop management and protection, biotechnology and germplasm conservation) II. Technology transfer component (techniques and technology packages) III. Capacity Building [to strengthen the National Agricultural Research Systems (NARS)]

Increase efficiency and expedites production of offshoots in quantities needed by growers at a reduced cost; improve date palm productivity per unit of water and rationalize the use of the available resources so it becomes sustainable; define the nutritional requirements for optimal growth of date palm through leaf tissue and soil analysis to establish the need for use of macro

& micro nutrients; improve date palm head practices & management for a vigorous tree with high yield.

PRIMA, Thematic area: Agro-food Value Chain, Topic - Use and management of biodiversity as a major lever of sustainability in farming systems
GreenPalm - Development of sustainable date palm-based agro systems by preserving their biodiversity (Reference Number: 2019-SECTION2-15)
Website: https://www.era-learn.eu/network-information/networks/prima
The main objective of this proposal is to conserve the biodiversity and improve the sustainability of Mediterranean date-palm agrosystems by genetic, microbiological and technological approaches. GreenPalm focuses not only on conservation of genetic diversity of date palm cultivars with high added value, but also considers underexploited and neglected cultivars with culinary, cosmetics or medicinal roles
Specific objectives
To make a screening of P. dactilyfera varieties in southern Mediterranean basin in order to genetically describe the biodiversity of these endangered agro ecosystems.
To study the palm tree rhizosphere and phyllosphere in order to develop and optimize pest and disease bio-control methods that contribute to agricultural sustainability.
To obtain high value-added compounds useful as biocontrol agents and food ingredients to improve the socio-economic level of local population.
Transfer of knowledge generated in the project, by implementation of good farming practices that are easily applicable and economically viable in date palm production areas

PRIMA Thematic area: Agro-food Value Chain Topic - Topic - Enhancing horizontal and vertical integration in Mediterranean agro-food value-chains
MEDISMART Mediterranean Citrus: innovative soft processing solutions for SMART (Sustainable, Mediterranean, Agronomically evolved, nutRitionally enriched, Traditional) products (Reference Number: 2019-SECTION2-20)
Website: https://www.era-learn.eu/network-information/networks/prima
Use of eco-friendly substances as an alternative to any chemicals in agricultural practices;
Extraction and purification of some valuable compounds which can be used in agriculture, pharmaceutical, nutraceuticals, food and cosmetic industries;
Identification of innovative packaging materials;
Application of a hydrogel as soil improvers to increase the water-holding capacity and/or nutrient retention of sandy soils;
Identification of innovative process technologies strongly preserving the naturalness and properties of the products raising final quality in terms of nutrition and sensory aspects: HPP, US.

5. Concluding remarks

-Projects were collected by all available databases (LIFE, PRIMA, Cordis, Sciencedirect, Scopus, Google etc.). It is noticeable that a limited number of projects have been implemented with regards to the composting and biochar processing of date palm residues.
-Valorization of the use of date palm residues in arid and semi-arid regions, is dependent on the date palm waste localization where the waste is available. The research limitations in co-composting could be related to the manure typology and abundance

- The future research could focus on the time optimization of composting processes and the use of others agricultural wastes in combination with date palm waste. Studies with composting date palm wastes and residues should be focused on the use of the produced compost in arid areas against soil erosion and degradation.
- Biochar characteristics vary according to the raw biomass materials, heating temperature, heating time and conditions of biochars' production. Biochars are highly suitable as soil amendments of contaminated soils with organic and inorganic compounds. They influence microbial biomass and composition due to their unique porous structure. They provide essential nutrients to soils improving crop yields and food quality. They improve soil physicochemical properties.
- Future studies need to focus on the investigation of biochars with varying characteristics on enhancing metal phytostabilization of contaminated soils and plant growth. In addition, the effect of date palm waste biochar on different pollutants (dye, heavy metals, phenols, etc.) in both wastewater and soil media should be considered. Studies about the use of different parts of the date palm for biochar production could be contacted.
-With increasing the beneficial uses of palm waste will increase people's interest in planting this crop and can lead to sustainable industrial and economic growth in different areas, Thus, there is a need to investigate the potential of using date palm in different applications for encouraging the industries to make value-added products from date palm which can be used in future.

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