


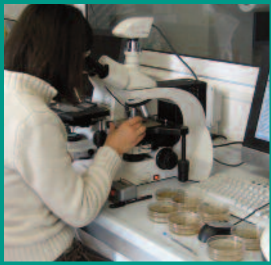

Best Practices for Agricultural **Wastes** Treatment and **Reuse** in the Mediterranean countries

WASTEREUSE

Official Edition

with the WasteReuse project's results

Project co-funded under the LIFE+ Program

www.wastereuse.eu

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WASTEREUSE

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1. THE WASTEREUSE PROJECT

1.1 Agricultural Waste (AW)

In a strict sense the concept of agricultural waste (AW) refers to crops and pruning remains. These materials are characterized by high variability in water content (depending on crop development and harvest season), high organic matter content, changeable mineral fraction and high C/N ratio, depending on the residue nature and composition. The biodegradability of such residues depends on their relative content of easily biodegradable compounds (sugars, cellulose and hemicellulose) and more recalcitrant compounds such as lignin and polyphenols. Agricultural wastes may exhibit bad phytosanitary state as a result of the incidence of illness and plagues in the original crop, which should be taken into account when considering their treatment and management. Agricultural wastes are characterized by the seasonality of their production and the need of rapid withdrawal from the field, avoiding interferences with other agricultural management options and preventing plagues or fire propagation.

In a more broad sense, the by-products of vegetal origin generated in food industries such as olive oil production, dry fruits elaboration, wine industry, etc. as well as, particular residues such as composts from mushroom cultivation, or substrates already utilized in greenhouse cultivations can be also considered as agricultural wastes. Agrarian wastes include also slurry and farmyard manure. Waste waters are generated during washing, peeling or whitening processes and contain dissolved organic matter and suspended solids. Remaining pesticides, insects and juices can also be found.

The agricultural industry generates mainly liquid and solid residues with a high load of organic matter. The seasonal character of this type of

industry means that high amounts of residues are generated in a short period of time. The amount of waste generated, as well as their characteristics, depends on the type of crop processed.

The environmental impact of this kind of residues is considered significant and a sustainable management plan is required to avoid environmental degradation. Their inappropriate disposal causes soil and aquifer contamination as well as, emission of gases such as methane, ammonium and carbon dioxide to the atmosphere. The presence organic matter contained in these residues in superficial or groundwater can cause reduction of dissolved oxygen and fish death, production and emission of biogas, formation of a film of floating material and also eutrophication. When solid concentration in wastewaters is high, sediments can be formed in the bottom of the receiving waters where anaerobic degradation can take place with consequent production of bad odours. Water can also be contaminated by residual pesticides and other agrochemicals contained in wastewaters. In soils, wastes cause increase in N content which, further undergoes slow mineralization; only part of this N is used by crops and the rest is lixiviated contaminating groundwater with NO3- ions, which degrade aquatic environment and become harmful for human health.

Large quantities of AW are produced annually in the Mediterranean region. For example, it is estimated that cereal cultivation produces about 5.5 - 11.0 tons dry matter of residues per ha, residues from woody tree pruning constitute about 1.3 - 3.0 tons dry matter per ha, while the average total production of Olive Oil Mills Wastes ranges between 10 x106 and 12×106 m^3 and occurs over a brief period of the year (November-March). These examples give an idea of the huge amount of residues generated and the necessity for developing sustainable management plans which will include recycling and reuse.

1.2 Reuse of AW: Economic and Environmental Benefits

Water resources shortage and environmental concerns have already led to wastewater reuse for irrigation. Most Mediterranean countries are arid or semi-arid with mostly seasonal and unevenly distributed precipitation. Due to the rapid development of irrigation and increased demand for domestic water supplies, conventional water resources have been seriously depleted. As a result, wastewater reclamation and reuse is increasingly being integrated in the planning and development of water resources in the Mediterranean region, particularly for irrigation.

Water, soil and air quality protection requires proper management of organic waste derived from agricultural operations. Recycling of AW through land application for plant uptake and crop production is a traditional and proven waste utilization technique. If properly done, it is an environmentally sound method of waste management resulting also in economic benefits due to the reduction of commercial fertilizers use.

Since agricultural wastes are rich in inorganic nutrients (micro- and macro- elements) and organic matter, recycling of this type of wastes in agriculture would contribute to:

- **significant reduction of harmful wastes disposed in the environment**
- **recycling of elements and water in agriculture which in turn, will reduce production cost and contribute to the increase in European products competiveness and profits**
- **protection of renewable and non-renewable resources (soil, aquatic bodies, phosphoric minerals) through elements recycling**

The reuse of AW for crop cultivation may, without doubt, offer a series of environmental and economic benefits. Among the environmental benefits, the most important are:

- **Increase of water** infiltration and retention;
- **Inhibition of pests and diseases** - the organic action of compost and organic treated wastes can help to inhibit pests and diseases within the soil;
- **Pollution reduction:** use of composts and recycled AW keeps organic matter out of landfills, reducing the amount of methane production happening in garbage disposal areas;
- **Erosion prevention:** Organic wastes in soil strategically placed can eliminate or reduce erosion;
- **Healthy growth promotion:** Soils, trees and plants in areas with compost and organic wastes are healthier. Incidences of plant diseases and pests that kill or damage plants and trees are lower when the soil has composted matter in it;
- **Toxins reduction:** Soils that have been exposed to toxic matter, such as fuels or pesticides, regenerate into healthy soil faster if composted soil is added to the mix. Composting prevents the spread of these contaminants into water sources and nearby plants, meaning that not only the soil, but also the water and plants in the area will be healthier;
- **Reuse of AW in soil** assist also in climate change mitigation by increasing soil organic matter (carbon sequestration) and reducing greenhouse gases emission.

Regarding economic benefits of AW reuse, it should be highlighted that these are dependent on many factors, such as composts/wastes prices, transport costs, operational farm costs and others. In general, it can be said, that the reuse of AW for agricultural purposes may have economic benefits, which could be achieved in the short-term or the long-term. Among the economic benefits, the most important are:

- Higher yields;
- **Inorganic fertilizer substitution:** The use of composts or organic materials (with subsequent decrease in inorganic fertilizers amounts) enriches soil with slow release, crop-available nutrients, including phosphorus, potassium, magnesium and sulphur, which in the long-term may further reduce the use of mineral fertilizers. Fertilizer and pesticide costs are generally also reduced on a sustainably managed farm because crop rotations tend to be less expensive than their synthetic alternatives;
- Improvement of soil structure for better workability and better crop establishment, saving fuel and time.

1.3 The WASTEREUSE Objectives

WasteReuse focused on **two significant environmental problems:**

- the uncontrolled disposal of agricultural wastes (olive oil mill wastes, wastes from the wine industry, etc) as well as, their uncontrolled use for crops/land fertilization;
- the excess use of nutrients and natural resources (water, phosphoric minerals used for the production of fertilizers) and the potential to increase recycling of nutrients and water with sustainable use of treated - or potentially untreated - agricultural wastes.

The main objectives of the project were:

- The evaluation of innovative as well as, traditional technologies for agricultural wastes treatment regarding their suitability for crop cultivation;
- The development of Alternative Cultivation Practices for the most widely cultivated and water consuming crops in Mediterranean by recycling nutrients and water from AW via identification and development of Best Management;
- The development of practices for waste application to main market crops aiming at maximizing yields and minimizing offsite environmental impacts;
- The protection of soil quality from the disposal of processed and unprocessed AW by developing and using cultivation practices which are suitable for representative, including degraded and vulnerable, Mediterranean soil types;
- The reduction of carbon footprint by recycling AW and minimizing the use of fertilizers. Conservation of natural resources from excessive use and uncontrolled wastes disposal;
- The increasing of competiveness of Mediterranean agricultural products and profits via the reduction of external inputs.

In the framework, the WasteReuse project was implemented through twenty-four concrete activities:

- Development of an inventory of the technologies related with AW treatment and applicability for crop production, developed so far through EC funding and other sources at European, national and regional level as well as, worldwide, based on development level (lab, pilot scale, full scale);
- Evaluation of the treated wastes derived from the technologies regarding their suitability for irrigation and fertilization of the widely cultivated and water demanded crops in Med countries;
- Collection of treated and untreated AW produced in Spain and Italy and identification of their physicochemical characteristics. Preliminary evaluation of their suitability to support plant growth;

- Evaluation of application practices of the treated wastes (wastewater and composts) on crops after considering the crop input needs;
- Potential modification of wastes physicochemical properties in order to conform by input demands of field and protected crops through laboratory studies;
- Assessment of the impact of waste use and application on soil quality through experimentations using different soil types;
- Development of new/alternative cultivation practices for the main water consuming and market crops with the use of processed (and potentially unprocessed) wastes as source of water and nutrients;
- Two demonstration actions, which include four pilot areas will be conducted in Spain and Italy, in order to implement the developed agricultural practices in greenhouses and in open field;

- Cultivation of the most widely cultivated and water demanded crops (vegetables, cereals, ornamentals) using treated wastewater and composts produced from different AW treatment options;
- Periodical sampling and chemical analysis of plant tissues and soil samples to assess potential long term phytotoxicity;
- Periodical monitoring of plant development indicators, soil quality parameters and input consumption to assess improvements in growth, yield, nutrients and water consumption as well as, soil degradation process;
- Identification of soil-nutrient loading capabilities, following application of wastes, for different soil types;
- Life Cycle Analysis (LCA) for all processes implemented in Spain and Italy, in terms of raw materials consumption, energy use and emissions;
- Risk Analysis to assess the impacts of the proposed practices and processes in soil and waters;
- Techno-economical and environmental assessment for the practices and processes developed during the project;
- Development of a Code of Waste Management Practices for Agricultural Application;
- Extensive analysis of European and national legislative frameworks as well as comparison between national laws and EU directives;
- Establishment of a set of actions, measures and means that should be taken by Mediterranean national policy makers to conform to European legislation requirements;
- Legislative recommendations for AW reuse policy;
- Wide dissemination of project's results and achievements through a well-designed and attractive web-site, publications, organization of workshops and visits at demonstration areas, etc;
- Meetings with national and European policy makers to present project's achievements
- Establishment of a network between scientific/research; industry/market and policy makers communities;
- Periodical communication between network members;
- Establishment of a well-structured "After-LIFE communication plan" for the widest possible dissemination of the projects' results after its completion.

1.4 WasteReuse Beneficiaries

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1.5 The WasteReuse Project Demonstration areas

The **WasteReuse** project demonstration actions have been initiated on April 2013 in Spain and Italy and have been completed by June 2015.

Their objective was to demonstrate the feasibility of the application of treated wastes in open field and greenhouse cultivations using cereals and vegetables.

DEMONSTRATION AREAS IN SPAIN

Two study areas have been used in Spain:

i ***Las Tiesas area in Barrax*** which is a municipality in the province of Albacete, Autonomous Community of Castile-La Mancha, where open-field cereal (barley and soft wheat) cultivations have been implemented.

Figure 1: *Location of Spanish demonstration areas, Barrax (left) and Santomera (right)*

The study area is intensively cultivated (10.000 ha) with its major land uses covered by orchards, vineyards and cropping fields. Approximately 65% of dry land (of which 67% are winter cereals and 33% fallow land) and 35% irrigated land (corn 75%; barley/sunflower 15%; alfalfa 5%; onions 2.9%; vegetables 2.1%) are cultivated in Barrax. Agricultural activities affect water-resources availability and have caused a significant decrease in the piezometric levels of the aquifer system over the last two decades.

ii ***Tres Caminos area in La Matanza,*** a district in the municipality of Santomera in the region of Murcia, where cultivations of tomato and lettuce have been implemented in greenhouse.

Production of fruits, wine, olive oil, vegetables, cereals and flowers are the main activities in the area due to the typical Mediterranean climate with 18°C mean annual temperature. However, the precipitation level is low (mean annual precipitation of 350 mm), thus resulting in increasing water demand for crops. Water in the area under study is mainly supplied by Segura River.

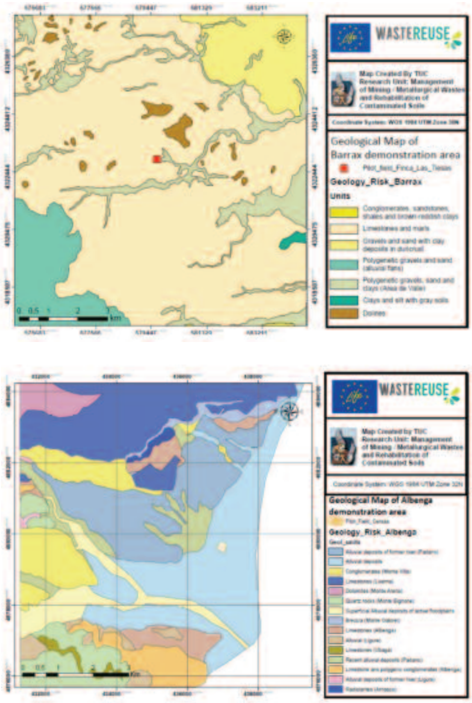


Figure 2: Geological maps of Spanish and Italian demonstration areas (left to right) created by TUC using ArcGIS 10.1

DEMONSTRATION AREA IN ITALY

The Italian demonstration area was located in Albenga, a city in the gulf of Genoa, Province of Savona, Liguria region, in northern Italy. Greenhouse cultivations of basil, rocket and lamb's lettuce as well as open-field cultivations of rosemary, lettuce and cabbage were carried out at CERSAA premises. Open-field cultivation of cabbage was also carried out at a private farm at Loano, Savona, Italy.

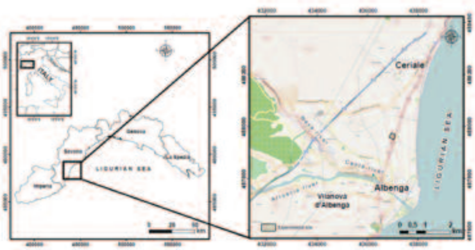


***Figure 1:** Location of Italian demonstration area*

Western Liguria is characterized by Mediterranean humid mesothermophilous vegetation; increasing elevation subalpine and mountain type vegetation is also seen. The Albenga surrounding area is characterized by a typical Ligurian landscape, with its major part (namely 55 %) covered by intensive cultivations (vineyards, fruit orchards, olive groves and horticultural crops). Olive cultivation has been developed since 2002 due to the relevant policy of the Region regarding development of olive tree orchards and mills. In the province of Savona some 50 mills are active while olive mill waste management practices involve **a)** disposal on soil, **b)** disposal in sewage collection systems and **c)** composting and use for heat generation.




2. THE WASTEREUSE PROJECT RESULTS

2.1 Initial assessment of existing AW treatment technologies

In the line of Initial assessment of existing AW treatment technologies, all available data regarding funded projects focused on the development/application of technologies for the treatment of agricultural wastes (AW) produced in the Mediterranean region, have been collected. Data collection has focused on AW treatment technologies developed and used in Spain, Italy, Greece and other Mediterranean countries.

The outcomes of Initial assessment of existing AW treatment technologies, were key to the further implementation of the project. Laboratory experiments were carried out in order to evaluate the treated wastes derived from the different technologies developed so far, regarding their suitability to improve crop production and quality as well as to assess the potential effects on soil properties. The most suitable, environment friendly, low cost technologies have been used for the development of alternative cultivation practices for the main water and nutrient consuming crops in Spain and Italy; the feasibility of the application of treated wastes in open field and greenhouses cultivations has been also demonstrated.

European Commission has funded so far many projects (especially LIFE) pertinent to the development / application of AW treatment technologies aiming to recover useful by-products, minimize environmental impacts as well as produce “cleaner” waste for safe disposal. Also, some technologies to treat AW have been developed by private funding.

AGRICULTURAL WASTES

The most important AW produced in the Mediterranean region includes olive oil mill wastes (OMW), wine, swine and other animal waste, rice straw and various other AW (such as waste from handling of fruits and vegetables, horse or chicken manure, wheat straw etc). AW can be in the form of solid, liquid or slurries depending on the nature of agricultural activities, are mainly characterized by seasonal production and should be rapidly removed from the field to avoid interferences with other agricultural activities (Sarmah, 2009).

Although the volume of wastes produced by the agricultural sector is significantly lower compared to wastes produced by other sectors, their pollution potential is usually very high. For example, AW may be characterized as potentially hazardous and toxic when disposed untreated on soil or in water bodies due to their high content of recalcitrant compounds. Application of AW such as manure on crop land and pasture can result in decrease in soil permeability and also adversely affect crop growth due to inhibitory amounts of nitrite nitrogen (NO_2-N) or salts added in soil. Excess loading of nitrogen and phosphorus from AW applied on land may cause eutrophication of water bodies or contamination of drinking water (Sharpley et al., 1984; Anderson et al., 2002).

ASSESSMENT OF POTENTIAL ADVERSE EFFECTS

In the line of Initial assessment of existing AW treatment technologies, the potential adverse effects of the disposal of the most important AW produced in the Med region, on soils and water bodies were discussed. For instance, toxicity is a very significant parameter for the characterization of AW and it should be taken into account before and after treatment to a) select the most appropriate treatment technologies which should reduce the toxicity of treated AW to acceptable levels, b) define the use of the final products and c) define the optimum management strategy of the secondary wastes produced in order to eliminate adverse impacts on humans and environment.

Organic and inorganic contaminants contained in AW can adversely affect living organisms (humans, microbes, bacteria, vertebrates, aquatic organisms etc.) as well as the physical and chemical properties of the soil, water and plants. Toxicity tests are mainly used to assess the hazard of contaminants, singularly or in mixtures, to particular test organisms and are based on the measurable and progressive relationship between dose and effect under a set of given test conditions (Cal/EPA, 2009; Karaouzas et al., 2011; Di Bene et al., 2012).

Leaching tests are used to estimate potential concentration of compounds that can leach from a solid waste. Typical leaching tests use a specified leaching fluid mixed with the solid waste for a specified time. Solids are then separated from the leaching solution, which is tested for various contaminants. The type of leaching test performed can vary depending on the chemical, biological and physical characteristics of the waste or the environment in which the waste will be disposed. The most commonly used leaching tests for the determination of toxicity of solid wastes are: Extraction Procedure (EP) toxicity test, Toxicity Characteristic Leaching Procedure (TCLP) test, Synthetic Precipitation Leaching Procedure (SPLP) test, Multiple Extraction Procedure (MEP) test, California Waste Extraction Test (WET) and Shake Extraction of Solid Waste with Water or Neutral Leaching Procedure).

Composting of AW is the most commonly used management option and the final product can be used as soil improver to enhance crop production and minimize risk for soil, water and ecosystems.

The application of treated organic wastes (compost) on soil improves soil fertility, increases soil organic matter and nutrients content, improves physical properties of soil such as aggregate stability, enhances crop production and contributes to minimization of risk for soil, water and ecosystems. Compost can replace fertilizer in many applications such as in commercial greenhouse production, farms and land remediation contributing also to fertilizer cost reduction.

A risk assessment should be designed to estimate the increase in lifetime risk to human (mainly farmers and their children) who are exposed to various recalcitrant compounds such as metals contained in treated or untreated AW. Both direct and indirect exposure to contaminants through ingestion of vegetables produced on fertilized soil or animals fed in these areas, should be taken into consideration. Therefore the concentrations for each metal in soils, surface water, plant tissue (fruits, vegetables, grains and forage) and animal tissue (fish and beef and dairy products) should be measured (U.S. EPA and CEA, 1999).

It is mentioned that regarding management of AW, no integrated specific EU legislation exists and thus each country issues different guidelines. However, pre-treatment of AW, careful application on soils, use of standardized procedures to evaluate toxicity and determination of the fate of contaminants in soil and water will maximize sustainability in agriculture and minimize impacts on ecosystems.

INVENTORY OF ALL AVAILABLE TECHNOLOGIES FOR AW TREATMENT

Data collection has focused on technologies developed/applied for the treatment of the most important AW produced in Spain, Italy and Greece, namely olive oil mill wastes (OMW), wine, swine and other animal waste, rice straw and various other AW (eg. waste from handling of fruits and vegetables, chicken manure, wheat straw etc). TUC has searched all relevant and available databases (LIFE, Sciencedirect, Scopus, Cordis, Google etc.) to collect data. A total of 49 projects funded within European Funding schemes and especially LIFE have been identified (***Table 1***).

All of the projects have focused on the development of innovative technologies for AW treatment as well as on the recovery of useful by-products and energy, minimization of the environmental impacts and production of "cleaner" wastes for safe disposal. Apart from European research / scientific communities, some technologies to treat AW have been developed by private funding, aiming at improving quality of the final products, minimizing waste volume and thus environmental degradation caused by their disposal. All available technologies for AW treatment have been included in a comprehensive inventory grouped by type of waste, level of development and coordinating country; the inventory has been also uploaded on the project website. Details for each project (duration, funding scheme, budget, beneficiaries) as well as a short description of the developed technology were also included. More details can be found on the website of each project, where available.

Treated wastewaters or composted sludges produced by these technologies could potentially be used for irrigation and/or fertilization of crops after evaluation and definition of specific terms and conditions regarding their suitability to support plant growth, without causing phytotoxicity and other environmental problems.

TABLE 1. NUMBER OF FUNDED PROJECTS PER TYPEOF AW (BY MARCH 2012)

Waste	Number of funded projects (funding scheme)
Olive oil mill wastewaters (OMW)	20 (11 LIFE, 3 FP5, 3 FP7, 1 ERDF Innovative Actions 2000-2006, 1 SME, 1 FAIR)
Wine waste	4 (LIFE)
Swine waste	7 (LIFE)
Other animal waste	7 (6 LIFE, 1 FP7)
Rice straw	2 (LIFE)
Various other AW	9 (LIFE)

PRELIMINARY TECHNO-ECONOMICAL AND ENVIRONMENTAL EVALUATION OF AW TREATMENT TECHNOLOGIES

The preliminary techno-economical and environmental evaluation of the technologies for the AW treatment was based on the data collected, where available, regarding the efficiency of each technology (e.g. ease of application and final products), total cost as well as environmental benefits such as contribution to the minimization of surface- and groundwater contamination etc. The technologies were initially evaluated according to various technical, environmental, economical and socio-cultural indicators, using a scale of 1 to 3.

Some of the indicators used to assess the efficiency of AW treatment technologies and their potential use in agriculture include:

- **Technical indicators:** agricultural inputs production, co-utilization of a specific AW with other agricultural or industrial waste, ease of application of the technology that treats AW;
- **Environmental indicators:** prevention of soil, water and air contamination, phytotoxicity minimization, ecotoxicity minimization, global warming mitigation, ozone depletion potential minimization;
- **Economical indicators:** total cost, operating (production) cost, payback period, direct revenues;
- **Socio-cultural indicators:** compliance with relevant environmental legislation, public acceptance of treatment technology, employment growth and development, socio-economic risk.

Best available AW treatment technologies were selected according to highest evaluation scores and have been considered by the responsible Beneficiaries of Actions 3 and 4 (CEBAS-CSIC, LABCAM and CERSAA) for the evaluation of treated solid wastes (compost) and wastewaters to be used in lab experiments, regarding their suitability to improve crop production and quality as well as to assess the potential effects on soil properties.

This preliminary evaluation is very useful for the LIFE Unit since it was the first time that so many funded LIFE projects related to AW treatment were screened and evaluated, using technical, environmental, economical and socio-cultural indicators.

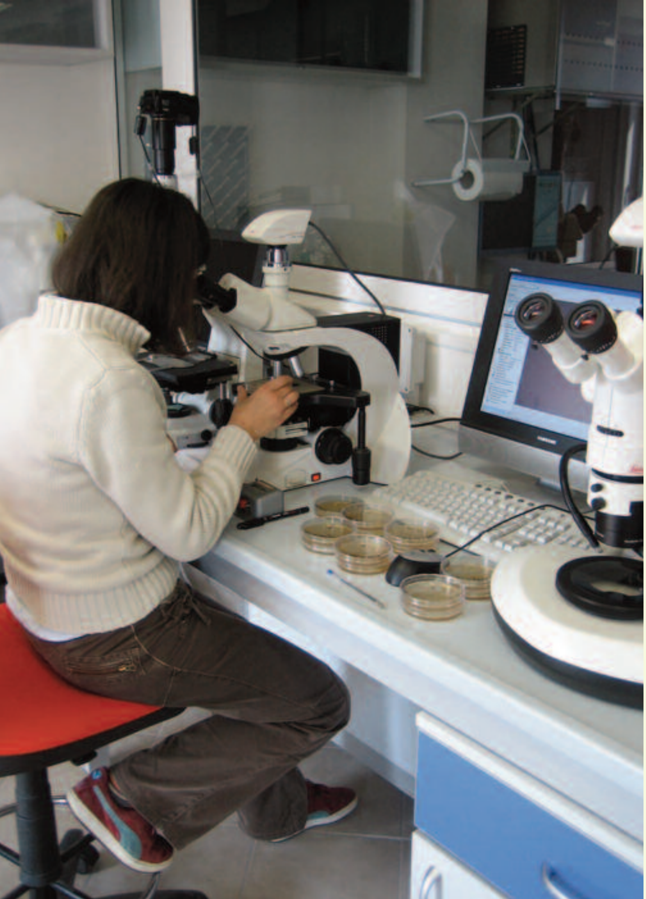
QUANTITATIVE EVALUATION OF AW TREATMENT TECHNOLOGIES

The quantitative weight-based evaluation of the technologies developed for AW treatment was based on the selected indicators, considering also four different scenarios. All available data, regarding the efficiency of each treatment technology, total cost, environmental benefits such as minimization of surface- and groundwater contamination as well as socio-cultural aspects and compliance with relevant environmental legislation, were taken into consideration.

According to the evaluation score obtained after considering the different scenarios, the best AW treatment technologies were selected for OMW, wine, swine and other animal waste, rice straw and various other AW eg. waste from handling of fruits and vegetables, chicken manure, wheat straw etc. (10 out of 20, 2 out of 4, 3 out of 7, 3 out of 7, 2 out of 2 and 3 out of 9, respectively).

ENVIFriendly, OLEICO and Eco Olive Cleaner have focused on the development of environment friendly and innovative technologies for OMW management and also minimization of water and soil contamination. The goal of DIONYSOS and GRAPE TANNINS was the development of economically feasible processes for the

integrated management of wine waste as well as for the valorization of by-products such as polyphenols. Ecodiptera, ZNP and PIGS have demonstrated methods for the treatment of solid and liquid swine waste and the production of stabilized end products. DUCK SLURRY, ECOREGA and ENERWASTE have demonstrated good practices for the treatment of various other animal waste including duck slurry, cattle and slaughterhouse waste mainly for the production of fertilizers or energy. For the treatment of rice straw only two LIFE projects have been funded (ECORICE and BIOCOMPOST) aiming to eliminate air pollution caused by rice straw incineration. ECOFILTER, INTER-WASTE and INTEGRASTE have focused on the treatment of various AW such as waste from handling of fruits and vegetables, wheat straw etc. usually for the production of compost.



2.2 Development of alternative agricultural practices

A. LAB EXPERIMENTS IN ITALY - ALBENGA

Thirty (30) kinds of solid and liquid wastes were collected and analyzed with regards to thirty (30) chemical parameters in order to get a clear indication about the absence of critical parameters that could have impaired the overall quality of soils when mixed with the selected wastes and, consequently, to negatively affect the growth of the plant species used for the experimentation. Around nine hundred (900) analyses were carried out in the time span between January and March 2013. Based on the results of analyses and of in vitro tests, two solid wastes (composts) were chosen based on the absence of hazardous compounds and of phytotoxic effects on the plant used as indicators for the trial (cress). Such composts were applied in mixture with natural soils, zeolite and fertilizer in pot cultivation trials to develop specific agricultural practices for the most common cultivated crops in Italy with specific regards to potted plants which represents a key element of the agricultural production in the Albenga area (North-Western part of Italy) where the Italian partners are based.

The composts used as amendments of the growing media for the pot trials showed some interesting properties that make them suitable to be used as substrate for potted species, but only when mixed with naturals soil or peat at certain rates as it was also demonstrated by different authors e.g. Minuto et al. (2006). Rates of compost (ACV or ACM) variable from 20 to 40% (v/v) mixed with natural soil characterized by a medium/high content in macroelements, Ca and Mg appeared to be the most suitable for potted cultivations at comparable level with traditional peat based substrates. ACM composts are normally richer than ACV with regards to different chemical elements as it was demonstrated even by the analysis carried out on the composts used for the present experimentation as well as by literature (Centemero, 2009), therefore different mix rates should be taken in account when preparing substrates for potted plants cultivation: maximum of 20% (v/v) for ACM composts, maximum 40% (v/v) for ACV composts.

Compost may have a quite significant buffer potential when used to amend natural soils or even peat that is normally adopted for the preparation of growing media. Such property can be exploited in case the correction of the growing media is needed without using particular chemical compounds as correctives and when plants need a certain interval of pH values for their proper growth.

Even though no levels of concern were reached regarding EC, the addition of compost can easily increase EC of the substrates especially for potted cultivations. In fact, when adopting compost-based growing media it should be kept in mind that they can reduce root development in the first cultivation phases especially for potted plants due to the significant content in highly soluble mineral salts, but they can afterwards promote plant growing – even more than when just peat is used - when nutrient request increases and normal watering is applied favouring the dilution of nutrients and avoiding potential phytotoxic effects (Gonzalez and Cooperband, 2002).

From a more general point of view, composts were able to significantly increase the content of macro- and micro-elements of the growing media (with the exception of P), organic matter and CEC. With regards to CEC, values recorded stressed the fact that compost is able to store nutrients in a more efficient way than peat and slowly release them during time.

The addition of zeolite had no clear effect on the composition of substrate when considering each parameter separately. It was anyway proved by the trials carried out in the frame of Action 4 that a growing media amended with zeolite can improve the production of plant biomass till levels that are even higher than the ones recorded for peat based substrates especially when combined with fertilizer at the dose of 2 g/L.

An extensive survey carried out on around 30 wastes based on chemical analysis and laboratory assays allowed the selection of two kinds of composts with promising agronomic properties that were further investigated through pot trials using cress as indicator plant. The suitability of such composts as growing media when mixed with natural soils and other inorganic materials (zeolite) was put in comparison with a peat based substrate traditionally used for pot cultivation. Rates of compost (ACV or ACM) variable from 20 to 40% (v/v) mixed with natural soil characterized by a medium/high content in macroelements, Ca and Mg can lead to a production of biomass – at least regarding the plant species used as indicator in the present trials - comparable to the one obtained with a peat based compost. The addition of fertilizer and zeolite to soil can further improve the production of biomass and mitigate the negative effect on biomass production deriving from the application of higher rates of compost.

When compost is adopted in nurseries or for the cultivation of ornamentals, the assessment of its chemical and physical parameters (according to the indications given by the law) as well as its main agronomic properties is crucial. Among the latter, recording of indexes regarding growing, rooting and development of plants can help in defining compost properties. It is finally important to stress that the good properties of compost and, at the end, the related agronomic performances depend mainly on the starting materials used, on the rate of maturation reached, on the composting process adopted and on the care posed in storing of the final product. Moreover the assessment of potential suppressive properties of compost can represent an opportunity for a sustainable control of certain soil borne pathogens.

Based on the results obtained from the experiments, there were indications about the possibility to use composts for the cultivation of some key crops defining amounts that can be applied in order to assure a correct establishment of the crop (on average: 25-30 t/ha for open field crops, mixture of 20 to 40% (v/v) compost with natural soil or peat for potted plants). From an ecological point of view the use of compost can have an important added valued due to the possibility of being assigned the ECOLABEL brand that is recognized at EU level.

Organic materials like composts can be profitably used as substrates and for the fertilization of soils but they can supply only a fraction of the nutrients that are totally needed by the crop. Therefore mineral fertilization is anyway essential in order to restore the overall needs of the crop.

The use of compost as organic amendment, together with a direct supply of mineral nutrients (N, P, K, Mn, Mg, Fe) that are released during the mineralization of the organic matter, can also:

- cause a mobilisation of the organic sources in the soil;
- increase the availability of the mineral nutrients already present in the soil;
- increase the effectiveness of the mineral fertilizations.

The average dose to be used in open field for crops normally characterized by deep tillage such as corn, sorghum, beet is: 25-30 t/ha of compost to be distribute before sowing at main tilling. When considering potted plants rates of compost (ACV or ACM) variable from 20 to 40% (vol/vol) mixed with natural soil characterized by a medium/high content in meso and microelements or peat are normally the most suitable ones. The key issue about the possibility to safely and productively adopt composts for cultivation of different crops according to the guidelines given above is its compliance to defined quality standards that apply to all the compost productive chain (plants and equipment, processes and products). Such standards are defined in order to guarantee the production of compost irrespective of the presence of laws or regulations which can be more or less restrictive. With respect to this, ECOLABEL brand was established through Reg. n° 880/92 that was revised by Reg. n. 1980/00.

B. LAB EXPERIMENTS IN SPAIN - MURCIA

In order to evaluate, from an agricultural point of view, a wide range of technologies used for organic waste treatment, thirty-one (31) different organic wastes were collected for exhaustive characterization and evaluation. The wastes collected were end products from nine (9) different waste treatment methodologies such as aerobic or anaerobic digestion, composting, vermicomposting, centrifugation, fly larvae addition, aerobic fermentation with bacteria inoculum, thermic dried treatment and combustion under low oxygen conditions.

The chemical characterization of the studied wastes showed that they are suitable products for recycling in soil with agricultural purposes. Organic carbon content in the studied OW ranged from 40% to 80% depending on the nature of the OW, and although a fraction of the organic matter added to the soil is mineralized, a considerable proportion remains in the soil contributing to increase the pool of soil organic carbon and to improve soil quality and fertility. The load of organic compounds that the organic wastes provide to the soil depends on the stability of their organic matter. The more stable the OW the greater the load of organic carbon remaining in the soil with time. In this sense composted residues will contribute in a greater extent to the maintenance of soil organic matter levels than fresh residues.

Although the main function of organic wastes in soil is to act as soil improvers, they can also act as fertilizers due to the considerable amount of macro and micronutrients they content. It can also be asserted that nutrient content in wastes is more closely related to the nature of the waste than to the treatment method used for its stabilization, whereas the rate of waste organic matter mineralization and the risk of phytotoxicity derived from the use of the end-product are greatly influenced by treatment technology. In this sense composting seems to be one of the most promising and used techniques for waste treatment. Treatments such as aerobic or anaerobic digestion also help to stabilize waste organic matter, but the level of organic matter stabilization and product sanitization is lower than that reached with composting. A more stabilized end-product is obtained by anaerobic digestion or thermic dried than with anaerobic digestion treatment. The use of fly larvae is an innovative waste treatment but the ammonium content in the end-product is too high (2.5-3%) and in addition, it is not a widely used methodology. It can also be asserted that the co-utilization of various wastes is a matter of paramount importance in waste treatment since allow the elimination of several wastes at the same time and to combine wastes with complementary characteristics in order to give a higher added value to the end product.

The study of the stability of the organic matter of these OW indicated that the organic matter mineralization rate was different depending on the nature of the organic waste and the treatment underwent by the waste. In general terms composts as well as vermicomposts showed a more stabilized organic matter with low losses of organic carbon during a two month incubation period. Aerobically digested sewage sludge showed higher rate of organic matter mineralization than anaerobically digested or composted sewage sludge, indicating that the latter treatment techniques are more suitable than aerobic digestion for obtaining a stable end-product that can be used as soil improver increasing soil C pool. Sewage sludge thermically dried also showed a more stabilized organic matter than aerobically digested sludge.

The added organic wastes stimulated soil microbial growth and activity, improving soil functioning, and also can supply macronutrients (N, P and K) and micronutrient to be used by plants, being a suitable alternative to traditional inorganic fertilization. Nutrients contained in organic wastes are released more slowly and are stored for a longer time in the soil than mineral fertilizers, thereby ensuring a long residual effect in the soil. Contrarily, the rate of nutrient release in the soil from the organic waste is higher when less stabilized wastes are applied. The type of nutrient supply depends on the nature of the organic waste. Thus, as it has been observed in this study, sewage sludge and animal slurries are rich in N and P whereas animal manures can provide a high load of K.

It has been observed in this study that N mineralization differed greatly among the different organic wastes, which is due to the fact that the inorganic/organic fraction and quality of organic N varies among the type of waste. Mineralization of organic N is expected to be low for composted manure and high for less stabilized wastes. The analyzed organic wastes have proved also to supply available P and K to the soil, which make these wastes suitable for deficient soils.

Assays of barley and ryegrass cultivation on soil amended with different OW at growth chamber scale showed that the use of organic wastes in crop cultivation as alternative method to the traditional use of inorganic fertilizers can be a desirable strategy to replenish the losses of soil organic matter caused by successive and intensive cultivation, thus contributing to a sustainable agricultural soil management.

It has been shown that the addition of organic wastes to the soil can constitute an important supply of N to the soil, but the availability of this N to plant may vary depending, among other factors, of the characteristics of the organic amendment. Thus, this N may be in form immediately available to plants or need the mineralization of the OW organic fraction to become available. Immediately after the incorporation of the OW to the soil, processes of mineralization and immobilization take place, which determine the rate of organic N mineralization and consequently its level of availability to plants. It was also observed that the addition of organic materials increases with respect to the addition of inorganic fertilizers, soil microbial biomass growth and activity. As a result of this increase, part of the N provided by the organic amendment can be immobilized, the extent and duration of this process depends on the type of OW, soil moisture, temperature and texture.

The use of OW in ryegrass and barley crops has resulted in similar and even greater yields, in some cases, than with the use of mineral N. However, since a great part of the organic nutrients contained in the OW needs to be mineralized in order to become available to the plant, it cannot be assured that plants will have the necessary nutrients the moment they actually need them. In any case, the addition of OW as alternative to mineral fertilizers can contribute to save an important amount of inorganic fertilization.

The use of organic wastes for crop production is a good alternative to the use of inorganic fertilizers, although due to the slow release of nutrients from the organic wastes, organic fertilization needs some times to be supplemented with inorganic fertilization. Organic fertilization has the advantage as regards inorganic fertilization, of improving soil characteristics and replenishing the losses of organic matter due to successive crops while at the same time supplies nutrients to be used by the plants.

Land application of organic wastes as fertilizers not only provides essential nutrients to plants but also improves soil quality and degree of valorization of OW. Improvement of environmental conditions and public health as well as the need to reduce costs of fertilizing crops are also important reasons for advocating increased use of organic materials.

C. DEMONSTRATION IN GREENHOUSE AND FIELD EXPERIMENTS IN ITALY - ALBENGA

The outcomes of the trials carried out in open fields are summarized below. They can be used as terms of reference for the set up of good practices that can be implemented in vegetable cultivation:

1. The suitability of certain agricultural processed wastes to be used as soil amendments after a careful evaluation of their characteristics and the exclusion of hazardous phytotoxic effects was proved;
2. All trials demonstrated the possibility to lower and even halve the rate of chemical fertilizer without any impairment of biomass production thanks to the addition of compost and zeolite at defined percentages;
3. The addition of compost and zeolite into the soil can have positive effect on biomass production of certain salad species;
4. The need to correctly adapt the dose of compost to the different crops considered. On the whole highest biomass production where obtained when a dose of 5-10% v/v compost was added;
5. Addition of zeolite in the substrate at a rate of 3% w/w may have different positive effects:
    - The possibility to increase the availability of soluble nutrients (exchangeable cations, i.e. Ca, Mg and K) in the soil;
    - Reduce the leaching of nitrates in the soil, preserve superficial and deep water bodies and protect the environment.
6. The use of selected agricultural wastes (i.e. compost) is sustainable also from an economical point of view and it is possible to save money when resorting to the combination of traditional chemical fertilizer and agricultural wastes.

On the contrary the present experimentation did not allow to stress any significant effect caused by the addition of zeolite and compost to the cultivation substrate on the variation of some selected parameters analyzed in plant tissues of the different crop species taken in consideration.

Addition of organic matter through the application of compost is beneficial from a general point of view in terms of improvement of soil properties that can lead to better crop establishment and increased yields. The chemical and nutritional benefits of organic matter in terms of enhancement of plant nutrient cycling determined the possibility to lower and even halve the rate of chemical fertilizer without any impairment of biomass production when compost and zeolite were added to soil substrates at defined percentages and it is shown in more detail in the deliverable: "Report with cultivation practices applied during the action, followed by technical and economical assessment as well as,

qualitative and quantitative comparison between new and traditional cultivation practices (Italy)". More specifically it is also proved that it can decrease the incidence of plant diseases caused by soilborne pathogens and therefore it can represent a valuable tool to be adopted in Integrated Pest Management strategies reducing the recourse to soil disinfectant at least after the evaluation of compost suppressive effectiveness related to specific pathosystems (pathogen/host) and cultivation site. Finally, the enrichment of cultivation substrates with zeolites may represent a good agricultural practice to be adopted by farmers and reasonable costs in order to lower the concentration of nitric nitrogen in soils and water bodies especially in those areas that are recognized as vulnerable to nitrates as the Albenga plane where the trials of WasteReuse project were carried out.

On the basis of the outcomes obtained in the frame of the project through the demonstrative activities carried out it is possible to outline some main benefits deriving from the use of compost.

- **Compost enriches soils:** Compost has the ability to help regenerate poor soils. The composting process encourages the production of beneficial micro-organisms (mainly bacteria and fungi), which in turn break down organic matter to create humus. Humus - a rich nutrient-filled material - increases the nutrient content in soils and helps soils retain moisture. Compost has also been shown to reduce the need for chemical fertilizers, and promote higher yields of agricultural crops. The trials carried out on potted aromatic plants (rosemary) in the frame of the project showed that 10% (v/v) of compost is the percentage that can basically allow to halve the rate of chemical fertilizer without any impairment of biomass production;
- **Compost helps prevent pollution,** specifically deriving from nitrates in soil: It was proved that the adoption of clinoptilolite mixed in the growing substrate at a rate of 3% (w/w) enables a reduction in the amount of nitrates found through soil analysis both in pots and plain soil and, consequently, on the rate that is leached into superficial and deep water bodies. In open field the comparison between analogous treatments that included zeolite (3% w/w) and treatments without it shows that the addition of clinoptilolite is able to reduce significantly the concentration of nitrates in soil samples (e.g. up to 8 times in cabbage cultivation and up to 2 times for lettuce);
- **Compost control soilborne diseases:** Exploitation of suppressiveness of organic amendments with specific regards to compost can be considered as a tool among others in an integrated approach for the control of soilborne plant pathogens therefore reducing the amount of pesticides normally applied. Although reported levels of disease suppression are normally variable according to crop species, type of cultivation (greenhouse or open field) (lettuce cultivated in greenhouse but not for other species., inclusion rates of at least 20% (v/v) of compost are normally required to consistently obtain a disease suppressive effect, particularly in peat-based media;
- **Compost improves the characteristics of growing media and allows peat saving:** Agricultural wastes (especially plant based wastes) can be used to produce compost mixtures which have characteristics not originally present in the mix which can be used in high value agriculture. Tests carried out confirm that some composts can be used in floriculture when mixed with from 20 to 40% of peat based growing medium. Mixing compost to peat based growing media allows the saving of significant amounts of peat that turns into safeguarding and preservation of natural environments where peat bogs are normally created and exploited.

D. DEMONSTRATION IN PROTECTED AND OPEN FIELD EXPERIMENTS IN SPAIN

In order to demonstrate the potential agronomic value of different treated and untreated organic wastes, regarding their suitability to promote crop production and quality and the potential effect on soil quality, different agricultural practices were implemented for crops widely cultivated in Spain such as vegetables and cereals. The effect of different fertilization treatments (compost addition, traditional mineral fertilization and combined organic and inorganic fertilization) on crop quality and yield and on soil quality was evaluated. This action includes two demonstration sub-categories:

i) Protected cultivations of tomato and lettuce: two successive cultivations of each crop using two different composts as organic fertilizer as well as two successive cultivations of each crop using the liquid fraction of pig slurry in irrigation.

ii) Open field cultivation of winter cereal: two successive cultivations of each, barley and soft wheat.

The agricultural practices carried out have demonstrated that quality organic wastes can be used, at suitable rates, alone or in combination with inorganic fertilizers, as a good alternative to inorganic fertilization for vegetable and cereal cultivation, improving soil characteristics whilst giving similar yield and crop quality than conventional inorganic fertilization.

It has been observed that composts, at the rate used in this experiment, have no significant effect on tomato yield due to the slow mineralization of their organic matter and the possible immobilization of nutrients, mainly N. As a result, there are not enough nutrients to meet plant requirements. However, the combined application of compost and inorganic fertilizer (60% of the usual inorganic fertilization), improved the efficiency of inorganic fertilizers and led to tomato yields similar to those resulting from the conventional inorganic fertilization, the fruits obtained being of similar size and quality. This approach will make it possible to reduce mineral N fertilizer consumption, thus decreasing the contamination risks derived from N lixiviation, with the extra benefit of improving soil microbiological properties and reusing organic wastes.

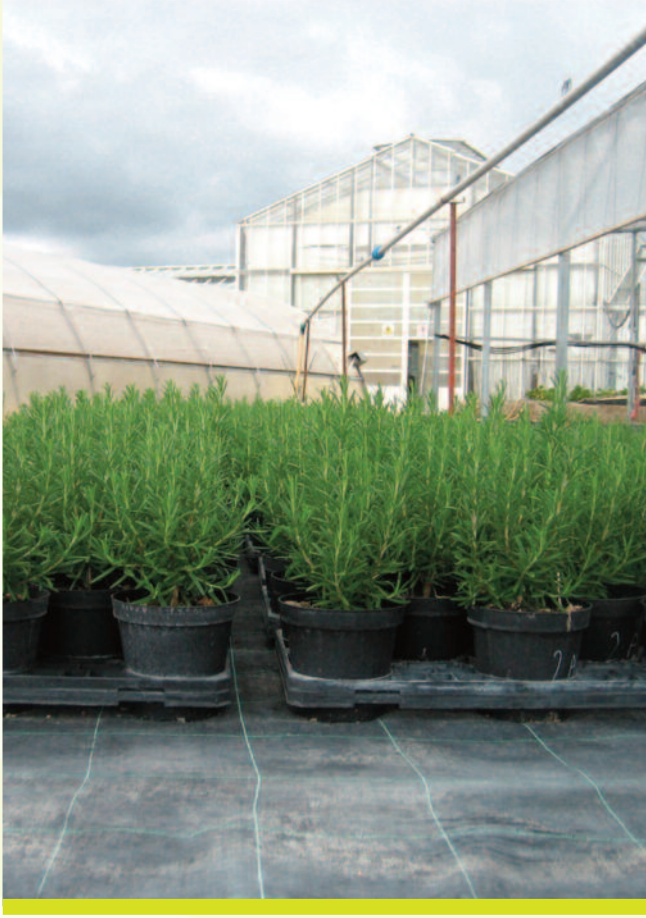
The organic waste application method will depend on both, the characteristic of the organic waste and the plant nutrient requirements. Organic wastes contain nutrients but most of them are in organic form and must be mineralized to be available to plants. Thus, in crops such as tomato with high nutrient requirements, mainly nitrogen, fertilization only with composts is not sufficient (at least it is applied at a high dose) to provide the amount of nutrients needed for plant growth. However, in crops such as lettuce with lower nutrient requirements, fertilization only with organic waste can lead to yields similar or even higher than those obtained with conventional fertilization.

Likewise, it has been demonstrated that the addition of stabilized organic wastes (compost) as fertilizers and soil improvers in cereal crops, at a rate high enough to cover N plant requirements, leads to similar grain yield and quality than conventional inorganic fertilization. The same can be observed when a lower amount of organic waste is used but in combination with inorganic fertilization.

In both, vegetable and cereal crops the use of combined organic and inorganic fertilization has demonstrate to be a good cultivation practice driving to yields similar to those of the conventional cultivation. Irrigation with liquid organic wastes (pig slurry liquid fraction), rich in N, also allows saving N fertilizer whilst yielding similar production and quality than conventional cultivation for tomato and lettuce. However care must be taken to avoid risks of soil salinization due to the high content of salt in this kind of waste. In addition, due to the fact that this type of waste contains a great amount of water (from 1 to 5 % dry matter) their use as fertilizer will only be income-yielding when the cultivation area is near the site where the liquid waste is produced. Otherwise the saving in fertilizer costs is not compensated by transport costs.

Inorganic fertilizers provide to the plant the nutrients it needs, increasing productivity. However, they do not produce in the soil the beneficial effect than organic materials do. Thus, the addition of compost has led in comparison with the inorganic fertilization to a higher increase in soil porosity, soil stable aggregates and soil water holding capacity improving soil structure and water retention, which in turn, will positively influence soil aeration and microbial growth. Compost addition also increases soil water holding capacity and the contents of macro and micronutrients in the soil, which will be available for future crops. In addition, it can be said that the sustainable use of organic wastes in agriculture leads to a greater positive effect on the growth and activity of soil microbial communities in comparison with the conventional inorganic fertilization as reflected by the higher values of microbial respiration and dehydrogenase activity observed in the amended soils.

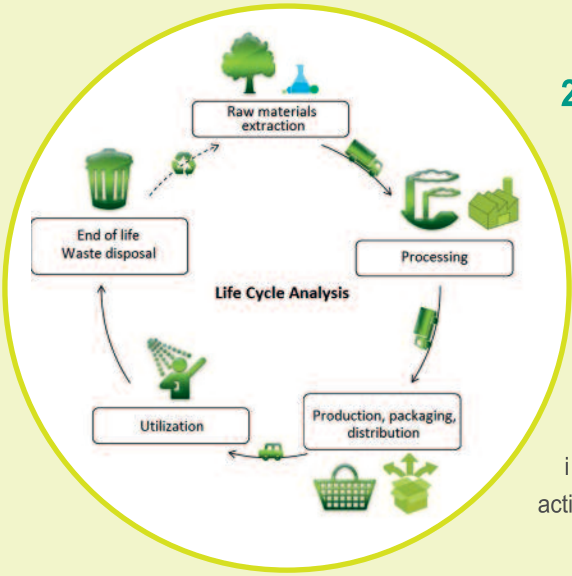
It can also be asserted that the use of organic wastes (composts) in agriculture increases the levels of organic carbon in the soil and the contents of humic substances and humic acids. Humic substances and humic acids are the most important fractions of soil organic matter since they are closely related with soil fertility and soil aggregate formation. Soil humification processes greatly contribute to the increase of soil organic C pool. Since the first crop, the level of soil organic matter was increased with the use of compost as reflected by the higher contents of organic carbon detected in the soils treated with compost with respect to the conventionally fertilized soil. Little differences between treatments were observed as regards the total content of the rest of macro and micronutrients in the first year but after two successive composts additions soil nutrient content increased.



The saving of inorganic fertilizers with the use of stabilized organic wastes (compost) can be estimated as 64 kg N/ha; 37.5 kg P_2O_5 and 178 kg K_2O/ha in tomato cultivation; 66 kg N/ha; 25 kg P_2O_5 and 98 kg K_2O/ha in lettuce cultivation and 118-148 kg N/ha, 84 kg P_2O_5 and 28 kg K_2O in winter cereal cultivation. Cultivation costs using the new cultivation practices can be lower, similar or higher than those of conventional cultivation practices for vegetable and cereal cultivation, depending on the price of the compost used as organic fertilizer. However, it must be highlighted that the benefices derived from the use of treated organic wastes as alternative to conventional fertilizers should not be only measured in economic terms but in terms of environment protection and agriculture sustainability. These new cultivation techniques will make it possible to reduce mineral N fertilizer consumption, with the extra benefit of improving soil physical and microbiological properties and reusing organic wastes. The saving of inorganic fertilization represents a clear benefit from an environmental (reduction of the risk of groundwater contamination; avoiding the exhausting of natural resources) and energetic (less energetic consume for inorganic fertilizers fabrication) point of view.

Pig slurry costs are only those derived from transport. Therefore to evaluate the possible save in fertilizer costs, the distance between the pig farmer and the cultivation area must be taken into consideration. Since transport cost are high, the use of this type of organic waste would be only incoming-yielding for cultivation field in the neighborhood, when the cost of the transport of the fertilizer to the cultivation area is compensated by the saving in mineral fertilizer (N fertilizer).

The greenhouse and open field experiments carried out have demonstrated that the suitable use of organic materials in crops cultivation contributes to a sustainable agriculture, protecting soil from degradation processes through the improvement in soil physical chemical and microbiological properties they produce.



2.3 Life Cycle Analysis & Risk Analysis

In the line of Action 7, a complete Life Cycle Analysis (LCA) in terms of raw materials consumption, energy use and emissions, as well as a Risk Analysis (mapping and modelling) by considering the use of a well-established risk assessment methodology (DRASTIC approach) were carried out, regarding the options considered in laboratory experiments and demonstration activities (Actions 3-6).

3.2 METHODOLOGY FOR IDENTIFICATION OF CARBON FOOTPRINT

In the frame of WasteReuse, a methodology for the assessment of CF generated from various anthropogenic activities with emphasis on waste production and management was discussed. CF is a widely used measure of environmental impacts of GHGs such as CO_2, CH_4, N_2O and others in the atmosphere and is quantified using the Global Warming Potential (GWP) and considering a fixed time period, such as 100 years.

A carbon footprint (CF) analysis is a form of LCA limited to assessing the impact of emissions that affect climate change. CF is a more publicly understood and widely used measure of environmental impact. The definitions and measurement units for the CF both vary as can be seen in Table 1 (EC, 2007; Wiedmann and Minx, 2008; De Benedetto and Klemeš, 2009; Čuček et al., 2012).

TABLE 1.
DEFINITIONS AND UNITS FOR CF

Definition for CF	Unit
Amount of CO2 and other GHGs emitted over the full life cycle of a process or product	mu CO_2eq/FU
Result of life cycle thinking applied to global warming	mu CO_2eq/FU
Land area required for the sequestration of fossil-fuel CO_2 emissions from the atmosphere through afforestation	au CO_2eq/FU
Measurement of the exclusive direct and indirect CO_2 emissions over a life cycle	mu CO_2/FU
Measurement of the imbalance within the carbon cycle	mu C/FU

***FU:** functional unit, mu: mass unit, au: area unit*

In order to assess the CF, the methodology and assumptions followed are similar to LCA, but inputs used are related only to the GHG emissions. A CF analysis is typically completed in the following five phases **I)** Identify sources, **II)** Select calculation approach, **III)** Collect data, **IV)** Apply calculation tools and **V)** Analyze results. Fair comparisons of the results can be drawn when the system boundaries are precisely defined through cradle-to-gate or cradle-to-grave assessment and CF calculators based on globally accepted standards are used.

3.3 LCA STUDY

A complete LCA in terms of raw materials consumption, energy use, transport and greenhouse gas (GHG) emissions was carried out for all processes considered in Italy and Spain in order to define:

- agricultural and environmental feasibility of using agricultural waste (AW) for crop cultivation in open-field and in protected cultivations (greenhouse) in Mediterranean countries and
- the potential reduction of carbon footprint.

In Spain, two study areas have been defined: i) Las Tiesas area in Barrax which is a municipality in the province of Albacete and belongs to the Autonomous Community of Castile-La Mancha, where the open-field experiments of cereals (barley and soft wheat) cultivation were implemented; ii) Tres Caminos area in La Matanza which is a district in the municipality of Santomera, in the region of the Huerta de Murcia in Murcia, where the cultivation of tomato and lettuce in greenhouse were implemented.

The Italian demonstration area (CERSAA premises) was located in Albenga, Savona province, Liguria region, in northern Italy. Basil, rocket and lamb's lettuce were cultivated in greenhouse, while open-field cultivations of rosemary, lettuce and cabbage were carried out. Open-field cultivation of cabbage was also carried out at a private farm at Loano, Savona, Italy (almost 10 km away from Albenga).

LCA may be efficiently used to evaluate the environmental impacts of the agricultural practices implemented in demonstration Actions and may be also applied to horticultural/cereal cultivations in open-field and greenhouse in other Mediterranean countries.

LCA was carried out by compiling an inventory of relevant inputs and outputs of a system (the inventory analysis), evaluating the potential impacts of those inputs and outputs (the impact assessment) and interpreting the results (the interpretation) in relation to the objectives of the

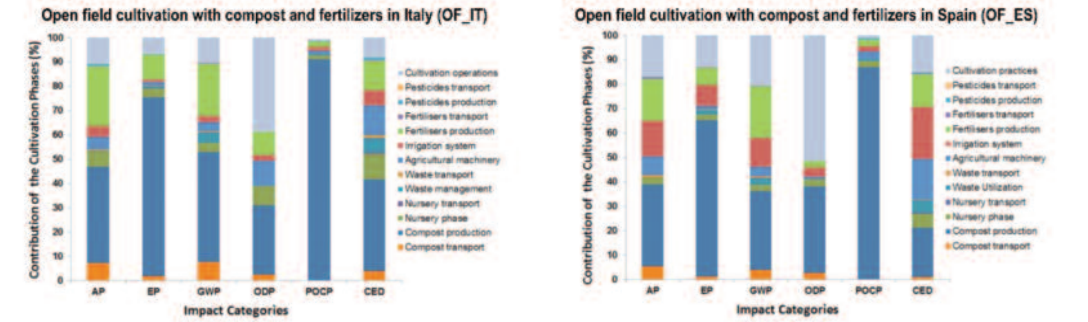
study. The GaBi 6 software, an LCA tool developed by PE International, was used to model the system and to evaluate its environmental impact.

Based on the system boundaries and the "cradle to gate" approach, different phases/sub-phases were user defined/created using available LCA software within each studied case. The main phases included: compost production and transport, nursery phase and transport, waste transport, waste utilization and full production of each crop. This latter included the sub-phases of cultivation operations in open fields, fertilizers production and transport, pesticides production and transport, the agricultural machinery and the irrigation system. For greenhouse cultivation of the studied crops, the greenhouse phase was also considered.

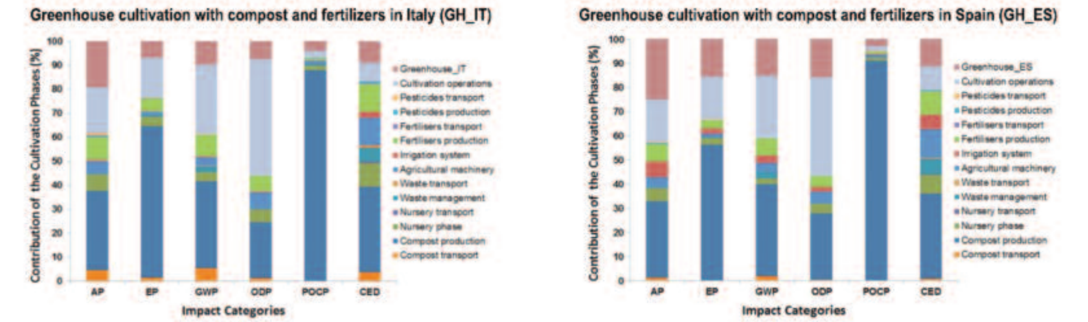
Five environmental impact potentials were assessed: global warming potential (GWP), acidification potential (AP), eutrophication potential (EP), ozone layer depletion (ODP), photochemical ozone creation potential (POCP) and cumulative energy demand (CED) as an energy flow indicator.

In order to cover the data requirements for the inventory, different data sources were used to obtain representative production data. Furthermore, in evaluating the environmental impact, consideration is given to the net environmental balance between the environmental benefits and assigning burdens, including waste management and utilization aspects, associated with the adaptations throughout the various cultivation phases of the crop products being considered.

Figures 1 and 2 show the results of the impact assessment phase for the open-field cultivation of lettuce in Italy (Albenga) and barley in Spain (Albacete) and for the greenhouse cultivation of lettuce in both countries, respectively.



Contribution to cumulative environmental impacts of the open-field cultivation of lettuce in Italy (Albenga) and barley in Spain (Albacete)a



Contribution to cumulative environmental impacts of the greenhouse cultivation of lettuce in Italy (Albenga) and Spain (Albacete)

The results obtained have shown that, in a general overview, impacts were different for the open-field cultivations in the two countries, while the greenhouse cultivations of lettuce showed quite similar results in both demonstration areas. Results pointed out a range from 0.171 to 0,243 kg CO_2-eq for 1 kg of crop product (lettuce or barley), showing a higher impact for open-field cultivations than greenhouse ones. Compost production phase, irrigation system sub-phase and greenhouse sub-phase were three of the phases/sub-phases with the highest impact contributions in the four cultivation cases.

The LCA identified the phases of the process and the related inputs and output in terms of energy, emissions, raw materials, natural resources, transport and waste. LCA results revealed the existence of three crucial phases/sub-phases that are the most impacting ones; the industrial compost production, the irrigation system and the greenhouse structure. The main reasons to the higher impact associated to these phases were the high energy and water consumption as well as the great volume of non-recycled materials needed.

The importance of including compost production in the assessment was demonstrated as it was the major GHG and energy contributor. The use of compost produced from AW for the organic fertilization of horticulture/cereal crops can be an interesting alternative for this by-product, although it would be necessary to propose some improvements for the reduction of the environmental impacts during the composting process at industrial scale.

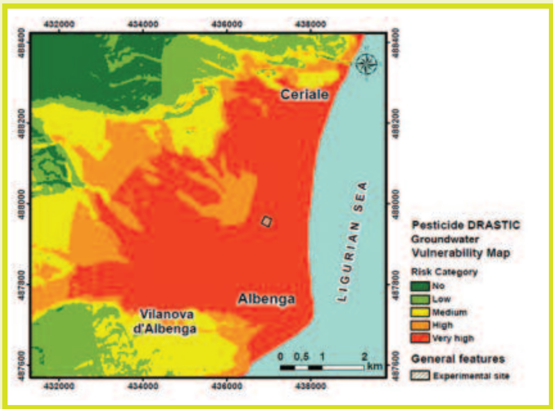
Overall, the present study showed the viability of the application of LCA to evaluate the environmental impact caused by an agricultural practice and can be extended to horticultural/cereal cultivations in the open-field and in greenhouse in other Mediterranean countries.

3.4 RISK ANALYSIS

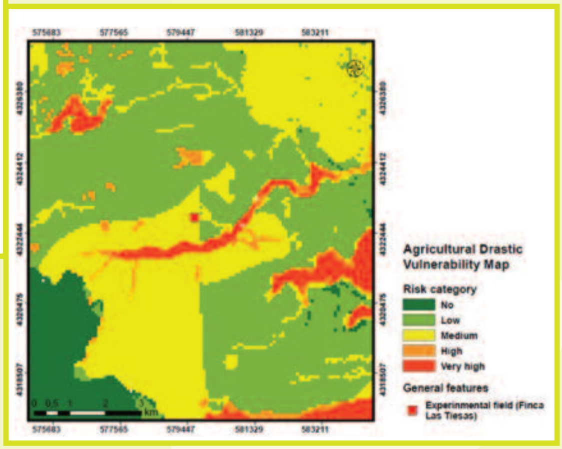
Risk for Spanish and Italian study areas selected for the implementation of demonstration activities, was assessed by using the DRASTIC approach. Risk for groundwater was assessed since groundwater is the main source for water irrigation in both demonstration areas. The DRASTIC approach was used as it is the most commonly used groundwater vulnerability/risk mapping approach, using a relatively large number of parameters for the calculation of risk index which ensures the best representation of the hydrogeological setting (parameters such as soil permeability, land use, precipitation-evaporation, depth of water table and potential pollutants have been considered). Once the DRASTIC index is evaluated, it is possible to identify areas that are more susceptible to groundwater contamination.

The maximum estimation probability of the values of the most representative parameters namely depth to water, net recharge, aquifer media, soil media, slope, impact of vadose zone and hydraulic conductivity, was selected and the DRASTIC vulnerability indexes were calculated. The contamination potential in the study areas was classified into five categories of risk ranging from “low” to “very high”. Figures 3 and 4 show the groundwater risk maps obtained for the Albenga and Barrax demonstration area through the application of the Agricultural DRASTIC models.

The groundwater risk analysis (DRASTIC approach) was validated using available groundwater quality data provided by Spanish and Italian partners and found (after a TUC search) in Spanish and Italian public/government agencies. The results show strong relationship (high correlation) between the DRASTIC risk mapping and the actual nitrate concentrations in both demonstration areas. The groundwater contamination potential from agricultural activities is greater than the contamination potential from municipal and/or industrial activities in both demonstration areas.



Agricultural DRASTIC vulnerability map of the Albenga demonstration area



Agricultural DRASTIC vulnerability map of the Barrax demonstration area

From risk analysis it is concluded that:

a) in Barrax, areas mainly covered by limestone formations with “low” to “medium” risk are identified

b) in Albenga, areas with “high to “very high” risk along the coastline and the middle of the study area especially where alluvial deposits are present, are identified

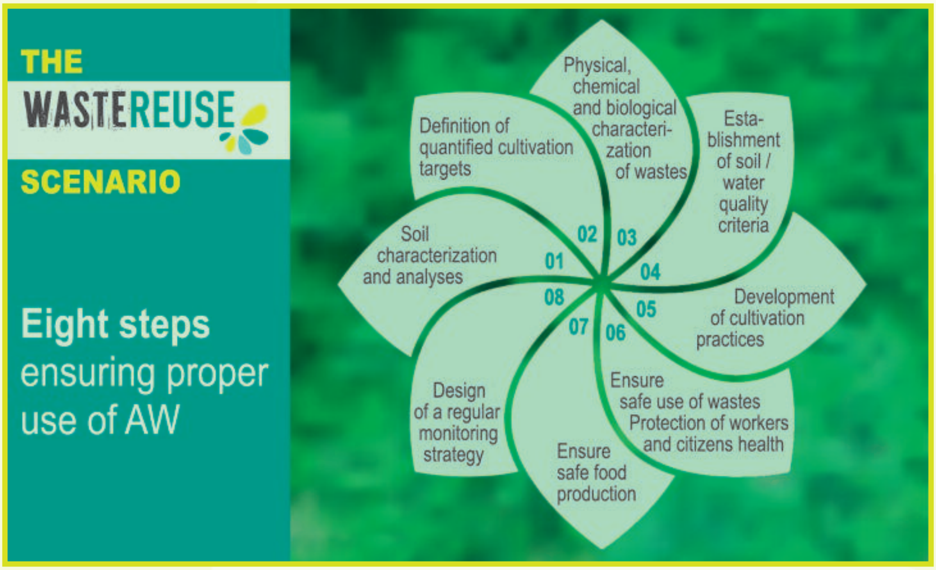
High and very high nitrate levels in groundwater in Barrax and Albenga, respectively, can be attributed to the extensive agricultural activities and the intensive use of nitrogenous fertilizers, by taking also into consideration the high hydraulic conductivity of the surface soil.

In the frame of Wastereuse, TUC produced several maps (e.g geological, aquifer media), using data obtained after an extensive search of several sources. These maps were given to the Spanish and Italian partners to be forwarded to local/regional authorities and any other interested stakeholders free of charge.

2.4 The Code of Waste Management Practices for Agricultural Application

Through the study of the application and characteristics of different types of agricultural waste the project developed an integrated scenario for the use of AW including strategies to monitor soil and water bodies and to control the use of liquid/solid wastes in crop production. This scenario was also translated to specific policy recommendations for regulatory interventions and other policy measures that could facilitate the promotion and safe application of the practices for the reuse of AW.

As it is illustrated in the figure below, the suggested scenario includes eight steps.



1. SOIL CHARACTERIZATION AND ANALYSES

Without doubt, the choice among cultivation practices, available waste types and fertilization schemes depend upon the type of cultivated crops and soil properties. For this, prior to the selection and application of any cultivation practice, the soil to be cultivated should be analysed for a series of parameters that determine its quality and fertility. Soil analysis should be repeated annually, not only to assist farmers to identify the most appropriate cultivation practice but also in order to define any potential adverse effects caused to soil health due to previous practices or waste use. Soil analysis is therefore recommended to determine its level of available nutrients in order to establish the baseline level of micronutrients.

If waste-land spreading is planned, then apart from the soil fertility parameters, the soils heavy metals' content should be defined as well. According to the Sludge Directive (86/278/EC), the total form of heavy metals (i.e. Zn, Cu, Ni, Cr, Cd, Pb and Hg) should be defined and the results compared to the thresholds of Table 21, either according to the EU legislative framework or to national thresholds if they exist. If soil heavy metals are above the established thresholds, then waste land spreading must be avoided. Moreover, other soil properties as well as hydro- and geo-morphological characteristics of the area should be considered, e.g. infiltration rate, depth to water table, soil texture, slope, etcetera (LIFE PROSODOL, 2012).

Collection and analyses of soil samples from the neighbouring area (i.e. not cultivated) is also recommended in order to define soil properties of undisturbed areas to be used during the monitoring stage of soil quality after wastes land spreading.

TABLE 1. ANNEXES IA, IB AND IC OF DIRECTIVE 86/278/EEC			
	Limit values for concentrations of heavy metals in soil (mg/kg dm)[1]	**Limit values for heavy metal concentrations in sludge for use in agriculture (mg/kg dm)**	**Limit valuesof heavy metals which may be added annually to agricultural land, based on a 10 year average (kg/ha/y)**
Cd	1 - 3	20 - 40	0.15[2]
Cu	50 - 140	1000 - 1750	12
Hg	1 - 1.5	16 - 25	0.1
Ni	30 - 75	300 - 400	3
Cr	-	-	-
Pb	50 - 300	750 - 1200	15
Zn	150 - 300	2500 - 4000	30

[1] *For 6<pH<7*

[2] *The proposed limits for the new Greek Decision on Sewage Sludge are in parenthesis (MEECC, 2012)*

2. DEFINITION OF QUANTIFIED CULTIVATION TARGETS

Having identified the properties of the land to be cultivated, farmers should proceed to the next step, which is the setting and the quantification of their targets. The most acceptable strategy for maximizing the agronomic and economic benefits is to specifically quantify the anticipated benefits, economic and environmental. Generally speaking, the main goals of farmers are:

- High yield and subsequent profit;
- Good quality crops that satisfy market demands;
- Low cultivation and operational costs.

In order for farmers to benefit the most by the reuse of AW, they should exactly determine what they are trying to achieve, e.g. restoration of the productivity of an eroded soil, provide supplemental nutrients to a high value crop, and to determine what practical and workable combinations of organic materials and mineral fertilizers are most appropriate to accomplish the proposed task.

3. PHYSICAL, CHEMICAL AND BIOLOGICAL CHARACTERIZATION OF WASTES

Prior to reuse of processed or unprocessed AW in the agricultural sector, the suitability of wastes should be proved. Suitable wastes need to be identified through chemical / physical characterization and, if appropriate, grouped into the three categories to make for a workable classification for use across the EU. The three categories are:

- **Class 1:** Farm residues recycled on the farm of production e.g. manure from animals grazing in situ. Information needed: (a) source of waste, (b) extent of treatment (e.g. storage for 3 months at ambient temperature).
- **Class 2:** Benign wastes containing negligible levels of contaminants e.g. green waste, biological sludge from food waste treatment. Information needed: (a), (b) plus (c) basis for benefit to agriculture (e.g. content of nitrogen), (d) content of plant nutrients and lime

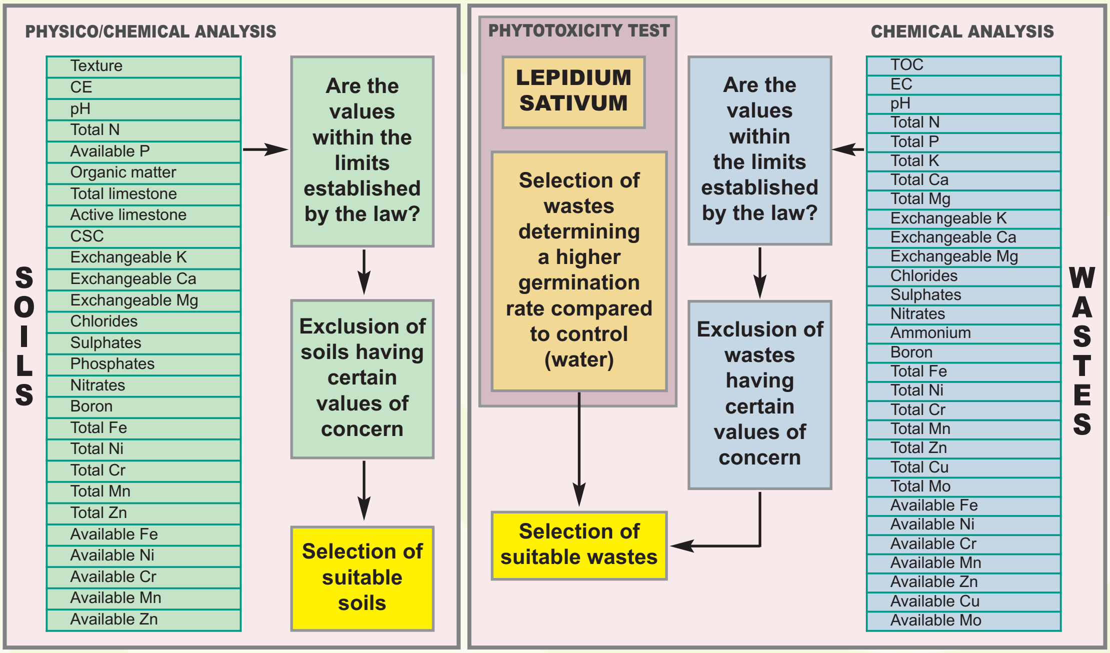
(nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, trace elements), organic matter, dry solids, pH value, and (e) evidence that the waste contains only negligible concentrations of contaminants.

- **Class 3:** Wastes which may contain contaminants (pathogens, heavy metals and other potentially toxic elements, organic contaminants) e.g. dredgings from waterways, tannery waste, paper waste. Information needed: (a)-(d) plus (f) content of contaminants (pathogens – most probable numbers; concentrations of heavy metals, other potentially toxic elements and organic contaminants) and (g) evidence that the waste is free of contaminants other than those specified.

Total heavy metals concentration should be measured and compared to the thresholds of Table 21 or to national thresholds.

Toxicity to humans, soil and water bodies, although not required by the Sludge Directive (86/278/EC) should be also defined in order to ensure public and workers health. Toxicity could be also assessed by using the standard methods for the determination **(a)** of nitrogen mineralization and nitrification in soils and the influence of chemicals on these processes (ISO 14238); **(b)** of the effects on earthworms (ISO 11268-1); **(c)** of the chronic toxicity in higher plants (ISO 22030); and **(d)** of soil biomass or soil respiration (ISO 14240).

The selection among the available methods should be based on several factors, such as current soil quality, present and future use of the area, amounts of produced waste and treatment level, and others. Figure 2 provides an outlook of the appropriate sequence regarding soil and wastes characterization.



Relation of soil quality and composition of various types of wastes

Wastes' nutritional status is also an important factor that should be identified in order for the appropriate fertilization plan to be determined. Nutritional status can be defined by evaluating the results of the chemical analyses and comparing them with generally accepted values for composts and AW, as can be found in the leading literature in this field.

4. ESTABLISHMENT OF SOIL / WATER QUALITY CRITERIA

In order to maintain the environmental quality at waste reuse areas, it is important to ensure that the reuse will not cause any adverse effect on soil and water quality and will not negatively affect established standards for the surrounding area (e.g. aesthetic, touristic, etcetera). These standards and preconditions should be carefully studied and considered before waste land spreading as well as general and specific area properties and regional and local development plans are or will be defined by the local/regional priorities. Responsible authorities should be informed and provided with detailed plans regarding data collected during the previous 3 steps. The period and duration of land spreading should be taken into account and a time plan should be submitted to the responsible local/regional authorities so as to be able to design the appropriate monitoring plan. A Risk Assessment study should be also carried out and submitted. Instruction on how to conduct a risk assessment study for waste reuse or disposal areas is provided by other LIFE projects (PROSODOL, 2012; Doula and Sarris, 2015; Papadopoulos et al., 2015).

If land distribution is planned, the organic load and the toxic substances (e.g. polyphenols) of treated or untreated wastes should not be the only issues of concern. Specific care should be taken also for inorganic constituents and especially for K, Cl^-, NO_3^-, SO_4^{2-}, P, Mg, Fe, Zn and others, since the very high amounts disposed on soil, change its quality properties drastically, while the concentrations of the inorganic soil constituents and the electrical conductivity steadily increase over the years (Kavvadias et al., 2010). In order for the farmers and the responsible authorities to be able to identify changes in soil quality, an initial soil survey at field, regional or larger level should be performed and be available for future monitoring of the area. After having completed steps 1 to 4, farmers could proceed to the next step to define the most appropriate cultivation practices for their specific case and conditions.

5. DEVELOPMENT OF CULTIVATION PRACTICES

It should be highlighted that soil must always maintain all its functions and its absorption capacity to ensure a sustainable system and for this, the ultimate goal when applying AW to land should be to apply them in such a way that the soil either filters the potential toxic elements effectively, or electrochemically absorbs them or decomposes them in order for a clean solution to infiltrate through the soil body.

When considering the use of organic wastes in crop production or field application, application rates should be carefully estimated and should be based upon soil fertility, crop requirements, and chemical characteristics of waste. The concentration of available soil nutrients depends on soil properties, cropping and fertilizer history, land management and climatic conditions. Plant nutrient requirements depend on soil fertility; crop type and the target yield (Doula and Sarris, 2015; Papadopoulos et al., 2015).

After the definition of all the appropriate soil and waste parameters, the rate of nutrients to be applied, meaning the doses of AW and supplementary inorganic fertilizers, can be estimated, considering that the applied nutrients should be equal to or greater than the nutrients removed by the crop over time so that soil fertility can be maintained.

Irrigation water quality and composition should also be taken into account. Irrigation water contains soluble salts, some of them are considered nutrients (e.g. potassium, sulphur) or pollutants (e.g. heavy metals, nitrates). Therefore, the chemical analysis of the water to be used for irrigation can provide valuable data and sometimes may be a restrictive factor to the chosen practice (e.g. in case of high heavy metals and nitrates content, or high salinity). If the nutrient content of the irrigation water is considerable, then the respective nutrient amounts should be extracted from the total estimated nutrient supplement. An example of doses estimation considering soil, wastes and irrigation water parameters is given by the "Cultivation Management Software" developed by the LIFE AgroStrat Project (LIFE AgroStrat, 2014; Doula and Sarris, 2015; Papadopoulos et al., 2015).

Three more parameters should be determined:

I. Maximum permitted AW amount. This is the maximum amount of AW that a soil can afford based on its physicochemical properties. The estimation of the maximum amount could be performed by considering the concentrations of all wastes elements/substances and after definition of the one that is the restrictive factor for the application taking also into account local soil properties. For instance, this factor could be the element or the substance with the highest concentration or with the lowest threshold.

II. Annual permitted application of AW. The annual rate of application could be determined by taking into account the maximum permitted amount and the general rules of soil fertilization.

III. Time of AW application for different crops. The time of application has to be defined considering the annual rainfall rate, intensity and distribution throughout the year and the temperature, in relation to water balance, soil properties and processes, microbial activity and AW decomposition.

6. ENSURE SAFE USE OF WASTES AND PROTECTION OF WORKERS AND CITIZENS HEALTH

A vital priority when considering reuse of AW on soil is the protection of workers and citizens health during and also after land spreading. For this, the users should follow certain instructions (see below). It is also important that the responsible local, regional or governmental services undertake or supervise the monitoring of all appropriate actions that ensure safe reuse.

General rules for secure storage, transfer and use

Waste poses a threat to the environment and to human health if it is not managed properly and recovered or disposed of safely. There are safe ways of dealing with any waste, while any waste can be hazardous to human health or the environment if it is wrongly managed. Deciding

whether any waste poses a problem requires consideration not only of its composition but also of what will happen to it. Even everyday items may cause problems in handling or treatment. Anything unusual in waste can pose a problem and what should be identified as potential problems in a consignment of waste, are significant quantities of an unexpected substance, or unusual amounts of an expected substance.

Therefore, prior to any action, the following issues should be defined/clarified (PEI, 1996):

- does the waste need a special container to prevent its escape or to protect it from the elements;
- what type of container suits it and what material can the container be made of;
- can it safely be mixed with any other waste or are there wastes with which it should not be mixed;
- can it safely be crushed and transferred from one vehicle to another;
- can it safely be incinerated or are there special requirements for its incineration, such as minimum temperature and combustion time;
- can it be disposed of safely in a landfill site with other waste; and
- is it likely to change its physical state during storage or transport?

Waste must be kept safely in order to prevent:

- corrosion or wear of waste containers;
- accidental spilling or leaking or inadvertent leaching from waste unprotected from rainfall;
- an accident or the weather breaking open contained waste and allowing it to escape;
- waste blowing away or falling while stored or transported;
- scavenging of waste by vandals, thieves, children, trespassers or animals.

Therefore, holders should protect waste against these risks while it is in their possession. They should also protect it for its future handling requirements. Waste should reach not only its next holder but also a licensed facility or other appropriate destination without escape. Where waste is to be mixed immediately, for example in a transfer station, a civic amenity site or a municipal collection vehicle, it only needs to be packed well enough to reach that immediate destination. Security precautions at sites where waste is stored should prevent theft, vandalism or scavenging of waste and holders should undertake regular reviews of the waste in their possession to ensure that it has not been disturbed or tampered with.

Segregation of different categories of waste where they are produced may be necessary to prevent the mixing of incompatible wastes (for example, avoiding reactions in mixtures). Segregation may assist the disposal of waste to specialist outlets. Where segregation is practiced on sites, the waste holder should ensure that his employees and anyone else handling waste there are aware of the locations and uses of each segregated waste container. Labeling drums or similar closed containers with a note of the contents when stored or handed over are a good practice. This could be a copy of the waste description. To avoid confusion, old labels should be removed from drums, which are reused. Waste left for collection outside premises should be in containers that are strong and secure enough to resist not only wind and rain but also animal disturbance. All containers left outside for collection will therefore need to be secured or sealed. To minimize the risks, waste should not be left outside for collection longer than is necessary. Waste should only be put out for collection on or near the arranged collection times (in case such an organization for waste collection exists). Waste may be handed on only to authorized persons or to persons for authorized transport purposes. When someone receives wastes, he/she must check the source of the waste. No one should accept waste from a source that seems to be in breach of the duty of care.

7. ENSURE SAFE FOOD PRODUCTION

Apart from the ordinary tests for the harvested crops (e.g. nutritional status, pesticides residues, etcetera) other constituents, typical of the wastes used during the cultivation, should also be measured by following a well-designed sampling and laboratory analysis plan. The elements or constituents to be determined are those defined during step 3 while the analyses results should be compared to standards for safe food production.

8. DESIGN OF A REGULAR MONITORING STRATEGY TO ASSESS POTENTIAL RISKS AND SAFE REUSE

Monitoring areas of AW reuse should be performed by local, regional or governmental authorities, but farmers could also play a significant role in monitoring and maintaining soil and water quality. An effective monitoring system has to consider the geomorphology, the hydrology, the soil types of the application area, the peculiarities and the characteristics of the produced AW as well as, the local meteorological conditions.

It is, therefore, recommended that a monitoring tool fully suited to AW reuse in the agricultural sector should include:

- An optimized set of soil quality indicators;
- Threshold values for the quality indicators;
- Periodical soil and water quality monitoring.

These three axes of the proposed strategy to assess the potential risks from the reuse of agricultural waste.

a) An optimized set of soil quality indicators

In order for the cultivated or disposal area to be monitored, the establishment of a set of soil and water indicators is required. This requires scientific work to be done and a strategy should be designed and implemented by experts. It includes soil and water sampling in order to identify background levels of key soil and water parameters, as well as the definition of the parameters that are most likely to be influenced by the reuse of waste on land. The latter are also depending on the properties and characteristics of the waste type to be used.

If a methodological study could not be performed, it is recommended to identify the most appropriate soil and water parameters by assessing quality parameters of the surrounding area and start monitor them over time. Some common and sensitive soil parameters can also be used, as for example, soil pH, electrical conductivity, polyphenols, total organic carbon, nitrogen, and phosphorus. For water, BOD, electrical conductivity, nitrates, phosphates, pH and maybe some bio-indicators for water life could be used.

Additionally, it is important to ensure that EU and national legislative restrictions regarding mainly heavy metals in soil and water are met.

In general, the monitoring of quality indicators within a defined ecological zone requires (Arshad and Martin, 2002):

- Direction of change-positive or negative increase or decrease, etcetera;
- Magnitude of percent change over the baseline values;

- Rate of change-duration: months, years;
- Extent of change-percentage of the area being monitored, i.e. what percentage of the area has changed with respect to the selected indicator during a specified period.

The monitoring of soil and water indicators needs to set up sampling strategies allowing for assessment of changes in the systems' quality.

b) Threshold values for the quality indicators

In general, changes in soil and water quality can be assessed by measuring appropriate indicators and comparing them with critical limits or thresholds at different time intervals, for a specific use in a selected area system. A critical limit or threshold level is the desirable range of values for a selected indicator that must be maintained for normal functioning of the ecosystems health. Within this critical range, the system performs its specific functions in natural ecosystems (Arshad and Martin, 2002).

Thus, when a set of indicators is proposed, this list should be accompanied by thresholds levels for each one of the indicators in order to assist evaluation of collected data and of the chemical analyses results. The thresholds could be identified based on EU directives, on national laws, but also on the international literature, mainly for as far as soil is concerned.

The peculiarity of soil indicators appropriate for waste reuse or disposal areas is that they mainly correspond to soil properties associated with fertility and not to pollutants in the classical sense, such as heavy metals and are therefore not included in national laws or EU directives. Nevertheless, international literature can provide general limits as these properties have been extensively studied for many years. Given the complexities of setting limits and the uniqueness of each targeted area/region, it may be more efficient to develop guidelines that can help in setting up limits under certain land and environment conditions (Doula et al., 2013).

Although a general definition of soil indicators thresholds could be performed after searching in international literature and national or EU legislative frameworks, it should be highlighted that the definition of indicators' thresholds would be more effective and representative of each target area if they would be determined after evaluation of data collected from the areas of interest and by taking into account local characteristics and values of the indicators of representative control samples.

c) Periodical soil and water quality monitoring

The next step is monitoring the impact of AW reuse on soil, water bodies and the environment under the specific bio-climatic conditions of the Mediterranean areas through a systematically planned sampling scheme combined with different eco-bio-toxicological tests.

Regarding the soil, an initial geo referenced grid or free (based on the main soil types of each target area) soil sampling should take place at depth increments in order to define the current situation in representative, benchmark soils of the area. Emphasis should be on identifying control soils, i.e. soils that have never accepted AW or other wastes in the area as well as soils in which AW have been applied intensively. It is recommended that for the initial characterization of the area, the collected soil samples should be analyzed for all soil physicochemical properties.

After the initial characterization of the area, soil samples should be collected annually from hot spots, which would have been identified during the initial characterization of the area, and be analyzed only for the soil quality indicators.

For the annual monitoring of the area, a geo-referenced soil sampling scheme should be planned and implemented by local authorities or via them by areas owners, while the collected data is recommended to be stored and evaluated through geographic information systems (GIS) as this would facilitate data management by local authorities.

2.5 WasteReuse Decision Making Tool(WDMT)

The WasteReuse Decision Making Tool (WDMT) is an online guide and planner, based on empirical research from a range of relevant experiments and demonstrations in selected Mediterranean countries and is free for producers to figure the most suitable compost type to be used for a specific crop in a certain area and climate conditions and to learn about important aspects of the different types of organic waste. The WDTM is the WasteReuse country-level database regarding the composition, restrictions of use, price and producers of different types of composts, as well as of the cultivations for which these composts are appropriate.

The WDMT was developed by the WasteReuse Project to help farmers understand the sustainable treatment and use of agricultural waste in an effort to promote the use of organic wastes as alternative to mineral fertilizers and to foster and disseminate cultivation practices related to the circular economy.

Decision Making Tool

It also enables the research community to use the WDMT as a wiki platform to benchmark and include their relevant findings for other countries, crops or types of wastes in a unified and accessible online database for all European countries. An additional use of this tool is to assist policy makers to assess and measure the effectiveness and impact of cultivation practices integrating the reuse of agricultural wastes.

The WDMT will be available in the website after the end of the project, for further updates from scientists, researchers and practitioners working with the agricultural waste field and the beneficiaries of WasteReuse project will continue their efforts to integrate it as a practice from different stakeholders seeking information to make informed decisions by scientific evidence.

2.6 Conclusions and recommendations

Public interest focuses more and more on the production of safe and high quality agricultural products while safeguarding the environment during the process. Agricultural waste is a key factor in this regard. Not only because the amount of waste produced should be as low as possible, but also because of what proper management, recycling and reuse of this waste could mean in terms of environmental and economic impact.

Now, intensive farming systems often use excess amounts of water and fertilizers while nutrients are introduced through irrigation systems immediately after transplanting in order to produce strong and healthy plants. This results in excessive use, e.g 20% to 30%, of fertilizers and almost doubles the amount of water actually needed by the crop. Apart from the high production cost and the low product competitiveness there are also serious environmental problems caused by these practices, such as useless water consumption, increased risk of desertification due to increased soil salinity, soil pollution/degradation, water pollution through leaching of the excess nutrients and soil biodiversity loss.

The WasteReuse project achieved to develop new and alternative agricultural practices with the use of agricultural waste (AW), which affects, besides the production itself, the quality of soil, water and air by considering the effect of the significant parameters as soil properties, soil-climate relation and environmental conditions.

Due to this four-year work performed, a set of policy recommendations and conclusions were derived:

A. POLICY RECOMMENDATIONS

Promote the use of organic wastes

The use of organic wastes as alternative to commercial chemical fertilizers constitutes an energy saving apart from the benefit of avoiding soil erosion and degradation and loss of soil fertility. Because organic wastes represent a potential source of considerable agronomic, energy and economic value, their proper and efficient use as fertilizers should be promoted by national and EU authorities in developing strategies for increasing agricultural productivity and improving sustainability. The use of organic wastes as alternative to mineral fertilizers will help to reduce natural resources consumption and energy costs, as well as the risks of groundwater contamination derived from inorganic fertilization.

Introduce a common legal framework on the reuse of AW at EU level

At the moment, the rules and standards for the use of compost vary considerably across Member States. Some countries have a dense and coherent net of regulations on national and/or on provincial level, while other allow for compost to be used without any legal directions. As coherent approaches to policy, standards, quality assurance and market development have produced in many relevant environmental, health and safety and industrial fields positive outcomes, it would be highly beneficial for the agricultural sector and for the environment to create a coherent EU regulatory framework for compost.

Regulate and control composting areas and facilities

Permits for on-farm composting operations are generally not required for small to medium size facilities that do not sell finished compost products on a wholesale or retail basis. Nevertheless, a well-run facility must operate in compliance with the national and local regulations pertaining to surface water, ground water and odors. A site for an agricultural composting facility must therefore provide the required area and conditions for all weather composting as well as limit the environmental risk associated with odor, noise, dust, leaching, and surface water runoff. In order to be able to steer and monitor the choice for composting areas and facilities clear and transparent regulation, on all levels ranging from local to European, would be of high importance in order to control the environmental impacts.

Encourage regular soil analysis for the safe use of AW

Prior to the selection and application of any cultivation practice, the soil to be cultivated should be analysed for a series of parameters that determine its quality and fertility. The use of AW makes this analysis even more important in order to define any potential adverse effects caused to soil health due to previous practices or waste use. Soil analysis is therefore a practice that should be adopted by farmers, who need to be properly informed and encouraged by competent authorities in all EU countries to regularly analyse the soil of their cultivations in order to determine its level of available nutrients before establishing the baseline level of micronutrients.

Implement a comprehensive monitoring system for AW reuse

Monitoring of AW reuse should be performed by local, regional or governmental authorities, but farmers could also play a significant role in monitoring and maintaining soil and water quality. An effective monitoring system has to consider the geomorphology, the hydrology, the soil types of the application area, the peculiarities and the characteristics of the produced AW as well as, the local meteorological conditions.

It is, therefore, recommended that a monitoring tool fully suited to AW reuse in the agricultural sector would be implemented and should include:

- An optimized set of soil quality indicators;
- Threshold values for the quality indicators;
- Periodical soil and water quality monitoring.

Include by products in the waste regulations

Until now by products can be freely recycled as soil improvers and fertilizers, but these materials should be subject to overall generic controls and there should be further specific controls for each group according to their properties and progressively detailed information should be required according to the class of waste. Therefore, prior spreading by products on land, their suitability should be proved and checked by a competent authority.

Suitable wastes need to be defined through an appropriate chemical/physical characterization and, if appropriate, grouped into broad categories to make for a workable classification for use across the EU. This classification is considered fundamental for the collection of coherent information and for making sensible comparisons and it should be somehow regulated and harmonized throughout the EU.

Standardize the composition and application of compost

The application of compost has to respect environmental parameters. Many of the maximum loads of PTEs to the soil defined in European standards and regulations are stemming from traditional sewage sludge regulations or are calculated from quantitative compost limitations multiplied by heavy metal threshold values. In this respect it is considered as highly beneficial, for both end users and for the environment, if metal loads on soil will be laid down according to specific standards that should be adopted in all Member States.

Furthermore, a common framework for the chemical composition, testing, certification and use of compost in the EU should take into account various parameters, such as the acceptable quantities of foreign matter in compost, the required hygiene and related worker safety standards, the PTEs specific to compost, the pesticide and especially herbicide residue content of organic wastes, and the phytotoxicity tests.

Assign the ECOLABEL brand to composts

WasteReuse provided indications about the possibility to use composts for the cultivation of some key crops defining amounts that can be applied in order to assure a correct establishment of the crop. From an ecological point of view, the use of compost can have an important added valued due to the possibility of being assigned the ECOLABEL brand that is recognized at EU level.

Encourage plant-based composts for the production of peat-based growing media

The use of plant based composts can represent a key element in the production of peat-free products (mainly growing media) that have a broad variety of applications for plant cultivation and that can be partly or integrally constituted by recycled/processed wastes and by products coming from different productive sectors.

Take into account toxicity for the treatment and use of AW

Toxicity is a very significant parameter for the characterization of AW and it should be taken into account before and after treatment to i) select the most appropriate treatment technologies which should reduce the toxicity of treated AW to acceptable levels, ii) define the use of the final products and iii) define the optimum management strategy of the secondary wastes produced in order to eliminate adverse impacts on humans and environment. Pre-treatment of AW, careful application on soils, use of standardized procedures to evaluate toxicity and determination of the fate of contaminants in soil and water will maximize sustainability in agriculture and minimize impacts on ecosystems.

B. CONCLUSIONS

WasteReuse showcased that increasing the recycling of nutrients and water with the application of sustainable methods and appropriate technologies for the reuse of AW could have various and multiplied environmental and economic benefits. On the condition that all necessary measures are taken to ensure safe and effective use of AW the potential of the tested methodologies and technologies is great, both for farmers and for the environment. In order to maximize the positive impacts of reusing AW and to mainstream its application, the research conducted in the WasteReuse project concluded that further action is needed in this field, that could be summarized in the following points:

a. Create a coherent regulatory framework for compost, similar to sewage sludge, by harmonizing current national rules or by enacting a common legal framework on a EU level for the content, handling, storage and use of compost;

b. Promote the use of organic wastes as alternative to mineral fertilizers and revise accordingly the European Fertiliser Regulation (463/2013) in order to align the policies on treatment of agricultural waste with the circular economy strategy of the EU and to reduce the use of fertilizer through the recycling of agricultural wastes;

c. Foster and disseminate cultivation practices related to the circular economy and based on the recycling of different types of AW after their careful characterization;

d. Promote the use of zeolite in improving plant growth and preserving soils and water bodies from the negative effects deriving from high nitrate concentration;

e. Assign the ECOLABEL brand to composts;

f. Encourage plant-based composts for the production of peat;

g. Take into account toxicity for the characterization of AW before and after treatment with a view to i) select the most appropriate treatment technologies which should reduce the toxicity of treated AW to acceptable levels, ii) define the use of the final products and iii) define the optimum management strategy of the secondary wastes produced in order to eliminate adverse impacts on humans and environment;

h. Reduce carbon footprint of agricultural production through proper recycling of nutrients;

i. Promote the reduction of pesticide use by exploiting biological control of plant pathogens and suppressive properties of selected compost;

j. Engage with all key stakeholders in Europe to disseminate successful practices for reusing AW and for receiving feedback and listening their concerns about the use of compost;

k. Promote a renovated approach to agricultural production based on a more aware use of resources.

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