Management and monitoring of agricultural waste disposal by local and regional authorities

M.K.Doula[1*], A.Hliaoutakis[2], N.S.Papadopoulos[2], A.Kydonakis[2], L.Argyriou[2] and A.Sarris[2]

1. Benaki Phytopathological Institute, Department of Phytopathology, Laboratory of Non-Parasitic Diseases, 8 Stef. Delta, 14561 Kifissia, Greece.

2. Foundation for Research & Technology-Hellas (F.O.R.T.H.), Institute for Mediterranean Studies, Laboratory of Geophysical-Satellite Remote Sensing, Nik. Foka 130, Rethymno, 74100, Crete, Greece,

Corresponding author E-mail: mdoula@otenet.gr, Tel. +30 210 8180232, Fax: +30 210 8077506

Abstract. Agricultural wastes (AW) are produced in huge quantities worldwide and may cause detrimental effects on environmental quality, affecting soil, water and air quality. Purpose: Given the need for more food of good quality and therefore the intensified agriculture, it is important to develop recycling plans even for those types of treated AW (e.g. composts) that are not considered hazardous. Apart from developing a strategy for safe AW disposal, reuse or recycling, authorities (local, regional, governmental) should periodically monitor these areas, which must be selected considering many factors and parameters (e.g. geomorphological, climatic, hydrological, societal, and others). The purpose of this study is to provide guidelines to authorities for the development of sustainable management and monitoring strategies for areas where AW are applied on soil. Method: A holistic approach is developed based on experience and knowledge gained through the cooperation with local and regional authorities as well as on the results of two European LIFE projects, i.e. AgroStrat and Prosodol. Results: Scientific and technical guidelines are provided to authorities, organized into eight concrete steps to facilitate the design and implementation of sustainable strategies for AW reuse or disposal. Web based applications developed in the framework of the two LIFE projects are presented to assist authorities to implement effective monitoring and also to provide consultancy to farmers, landowners and waste users for safe reuse or disposal considering geomorphological characteristics, soil properties, waste composition and legislative restrictions. Conclusions: The integrated strategy of these eight steps provides the general but still the required means, actions and measures to be adopted by authorities and individuals in order to develop local or regional strategies/action plans, fully conformed to local/regional peculiarities.

Key words: agricultural wastes; soil; sustainable waste management; Web based decision-making tools

1. Introduction

Although Agricultural Wastes (AW) are produced in huge amounts worldwide, no common strategic framework exists for safe reuse of AW in agricultural sector, for soil disposal and for development of actions plans by local/regional authorities to exploit AW in agriculture or for soil improvement.

Agricultural wastes are produced from many different processes throughout the entire year and from the processing of plenty of different crops. Therefore, they substantially vary in composition and in amount, making their management difficult. Moreover, in the most of the cases, AW is not considered by the waste producers as hazardous or potentially hazardous and discharged, often untreated, on soil or in water bodies. It is true, however, that some types of AW are indeed non-hazardous, as for instance composted materials, however, other types, as for example, olive mill wastes (OMW), may cause adverse effects on the environment or to human/animal health if discharged untreated.

Doula et al. [1] developed and published a strategic approach for managing AW at local/regional level that can be implemented worldwide. Depending on wastes' properties and their hazard potential, two approaches for safe and sustainable landspreading were proposed, i.e. an approach appropriate for traditionally used wastes (mainly manures and composts) and an approach for wastes that are hazardous and should be reused under specific restrictions. Eight concrete and detailed steps were proposed for the these two types of AW, six of them common for both types, that can be adopted and incorporated into regional plans or may take the form of legislative framework for agricultural waste landspeading.

In this study, these eight steps are analyzed further and explained, focusing also on decision-making tools for monitoring disposal areas. Specific actions that authorities should design and undertake in order to implement each one of the eight steps are presented and explained, providing also technical consultancy on developing the required databases and GIS maps.

2. Steps for developing a strategy for agricultural waste management-Guidance for implementation

The proposed strategic framework considers two categories of AW [1]:

i. Traditionally used wastes (i.e. AW-type1) applied and used mainly as soil improvers/additives. This category includes mainly solid waste and especially manures (after stabilization or not) and composts, which are traditionally used by farmers for thousands of years. Some types of wastewater of low organic load, as for example water used for washing crops before or during processing, are also included in this category.

ii. Potentially-hazardous or hazardous wastes (i.e. AW-type2) disposed on land. This category includes wastewater and also solid waste, e.g. OMW, waste from livestock farming, wastewater and sludge from food processing, and others. These types of AW may contain a plethora of potential hazardous constituents, as for example polyphenols, pesticide residues, heavy metals and also pathogens.

Table 1 includes the eight steps proposed for the development of strategic plans for AW management at local and regional level.

Table 1 The eight steps of the strategic framework proposed for sustainable management of AW at local and regional level [1].

<table>
<tr><th>Traditionally used wastes (AW-type1)</th><th>Potentially-hazardous or hazardous wastes (AW-type2)</th></tr>
<tr><td colspan="2">• Step 1: Development of regional action plans and establishment of quality criteria
• Step 2: Physical, chemical, biological characterization of the organic materials
• Step 3: Adoption of soil quality indicators and thresholds
• Step 4: Development of Land Suitability Maps</td></tr>
<tr><td>• Step 5: Soil characterization-analyses</td><td>• Step 5: Assessment of risk level and development of remediation or landspreading plan</td></tr>
<tr><td>• Step 6: Quantification of cultivation targets and definition of cultivation practices</td><td>• Step 6: Quantification of landspreading-Doses estimation</td></tr>
<tr><td colspan="2">• Step 7: Ensure safe reuse/disposal-Health protection and safe production
• Step 8: Periodical monitoring and risk evaluation during and after landspreading</td></tr>
</table>

2.1. Common initial steps 1-4

2.1.1. Step 1: Development of regional action plans and establishment of quality criteria

Authorities should develop local/regional plans covering a period of, at least 5 years, preferably in cooperation with the interested stakeholders (farmers and their associations, representatives of market and productive sectors, citizens associations). Before this, authorities should have defined and recorded areas' current status by creating relative databases (inventories), which can be also accessible through GIS web-applications to the governmental agencies and to the public. The definition of current status includes the evaluation of many parameters, e.g. natural areas' characteristics (hydrogeology, physiography, geomorphology, soil structure, texture, water permeability, porosity, presence and depth of impermeable soil layers, etc.), history of the different sites, current and past land uses, environmental status with regards to soil, water and air quality (e.g. extent and types of contaminants that potentially exist, known/anticipated presence and behavior of receptors, areas of waste production, types and quantities of waste disposed on soil or in aquatic receptors, soil degradation extent), socio-economic parameters (e.g. economic development, infrastructure, agricultural and touristic development), aesthetic of the areas, social life and others that are of environmental, economical and societal interest.

Since the parameters are too many and of different significance for each area, the involved parties should set local or regional priorities, set quantified targets for each one of the parameters of priority and establish appropriate indicators which will be monitored during the period of the Action Plan. The evolution of the indicators should be evaluated in relation to the targets and to the sustainable development of the areas of interest. Indicators' values should be monitored periodically during the implementation of the Action Plan and their temporal change could be included in the web GIS application. Therefore, the most appropriate land use for each one of the regional areas can be defined as well as the level of quality for some significant parameters of the areas (e.g. soil, water, air, social life, etc.) that must be kept constant or to be improved during an time period agreed by the involved stakeholders. This procedure is anticipated to assist authorities to define areas that may be appropriate for AW reuse or disposal.

In terms of soil and water quality, an initial regional soil and water survey should be performed and be available for the future monitoring. Soil sampling should take place at three depth increments (0-30 cm, 30-60 cm and 60-90cm) in order to define the current situation in representative, benchmark soils of the area. Emphasis should be given to identify control soils i.e. soils that have never accepted AW or other waste types as well areas, where AW have been disposed for long time. A similar, well-organized sampling campaign should also be undertaken in order to identify the current quality status of the regional aquatic systems. Current disposal areas (licensed and as many as possible non-licensed) must be defined and recorded in the inventory.

Following soil sampling, complete physicochemical analysis and identification of the organic and the inorganic soil constituents are strongly recommended as well as the development of soil thematic GIS maps for all measured parameters. An example of such maps can be found on the web site of LIFE-AgroStrat project [2]. These maps can be further used for the most of the following steps and for both types of AW. Thematic maps may be produced also for other parameters that are considered important, e.g. Land use change, land cover, economic development, waste disposal areas, etc.

Another GIS application that could be used for this step, is the one developed during LIFE-Prosodol project [3], and is presented in the Online resources of the recent work of Doula et al. [1]. The tool as developed during the project enables the evaluation of location suitability for olive oil production facilities installation and further, the evaluation of suitable waste disposal areas depending on several anthropogenic (residential areas, road network), environmental and societal (slope, degradation, archaeological sites, lake and rivers area, NATURA areas, land use-Corine), as well as geological (hydrolithology, geology, faults) criteria-factors. The tool's outputs depend on the criteria and priorities set by the authorities; therefore it can be used to achieve the targets of this Step 1.

2.1.2. Step 2: Physical, chemical, biological characterization of the organic materials

Waste producers are, in general, responsible for describing their waste in detail and informing local/regional authorities. On the other hand, authorities should establish an easily understandable and applicable, but still official procedure that waste producers must follow in order to collect and fill all appropriate documents that are required to be submitted to the authorities. In case of already established procedure (e.g. by national laws), authorities should provide all appropriate means that will facilitate the procedure. It is also strongly recommended to establish a web-based procedure for data collection from the producers that will automatically feed the inventories of the authorities. Submitted documents must include background information on the source and origin of the waste and specific physical, chemical and biological test data as imposed by the national legislative framework (unless there is a justifiable reason why testing is not required). For example, for European Member States, wastes must be classified using the List of Wastes (LoW) (formerly commonly identified using the European Waste Catalogue10 (EWC)) and assessed in accordance to national standards [4].

A sampling plan must be developed by the waste producers in accordance with the national legislative framework. In the United Kingdom, for example, waste producers should use Best Practice to sample the waste using the national standard BS EN 14899:2005 [5].
Authorities should provide assistance to the waste producers and in any case must inform, educate and assist them by providing technical guidance for sampling plan development and implementation. This is important in order to ensure that samples are representative and are collected by implementing generally accepted sampling

methodologies. On EU level various standards for sampling of waste exist such as EN 14899 “Characterization of waste-Sampling of waste materials - Framework for the pre- paration and application of a Sampling Plan”, CEN/ TR 15310-1-5 “Characterization of waste-Sampling of waste materials” and EN 14735 “Characterization of waste - Preparation of waste samples for ecotoxicity tests”.

As regards AW-type1, waste producers that wish to dispose or reuse them, they must still fully characterize them to prove that are not hazardous and to ensure sustainable reuse/disposal. Recently, the EU published a proposal for a Regulation laying down rules on the making available on the market of CE marked fertilizing products. The document defines that the materials’ producers (organic amendments, organic fertilizers, composts) must provide to the authorities supporting documents with the results of a series of tests; tests are included in the respective Annex of the Proposal [6].

Authorities should be notified by the waste producers or/and users regarding the characterization and the amounts of the materials to be spread on soil, which should be accompanied by the chemical analysis and the respective evaluation of the materials.

For AW-type2, a more detailed monitoring plan should be put in force, including a well-designed waste sampling strategy, which could be implemented by the waste producers, however, due to the particularity of this waste type, it is recommended to be performed by experts.

Waste sampling must consider the legislative framework, if existed, or the standard sampling methods. Data must be stored in the inventory of Step 1 and also feed the GIS database of the area.

According to the results of this assessment and the national/European/international legislative restrictions, the competent local/regional/governmental authority may permit (or not) landspreading.

2.1.3 Step 3: Adoption of soil quality indicators and thresholds

As regards soil and after having identified which areas could be potentially appropriate for waste reuse or disposal as well as, which type of wastes produced in the region can be spread on soil, authorities should establish a set of soil parameters (i.e. soil indicators) that will be monitored periodically to assess soil quality. This step requires a scientific work to be done and a sampling strategy should be designed and implemented by experts. Therefore, the strategy has to objectives:

1. identification of background levels of key soil parameters by using soil survey data of Step 1. By considering also legislative restrictions and literature data, authorities can establish a list of thresholds for soil parameters (through statistical processing), which will be the most appropriate for the specific region. An example of such a list with thresholds for soil parameters has been published by Doula et al. [7].
2. definition of the soil parameters that are most likely to be affected by waste reuse/disposal. These parameters can be used as indicators for soil quality monitoring. This definition, however, requires the collection of additional soil data from areas that already accept waste for almost one or two years. Soil sampling should be performed every 2-3 months from these areas in order to ensure that all activities, which could have a detrimental effect on soil parameters will be recorded and assessed. A methodology for the definition of soil parameters at waste disposal areas have been developed by Doula et al. [8]. Changes in soil quality can be assessed by measuring the soil indicators and comparing them with critical limits or thresholds at different time intervals, for a specific use in a selected area-system [9]. An issue for consideration is that the soil parameters that are anticipated to be affected when waste are disposed on soil are dependent on waste type. For example, when manures or composts are applied on agricultural land, soil electrical conductivity and nitrates may be significantly increased, however when OMW are applied on soil the parameters that are mainly affected are soil pH, electrical conductivity, organic matter, total nitrogen, polyphenols, available phosphorus, exchangeable potassium and available iron [8]. For pistachio wastes, electrical conductivity, organic matter, total nitrogen, polyphenols, available phosphorus, exchangeable potassium, available copper, and available zinc were defined as the most appropriate soil indicators [10]. If such a methodological study could not be performed, then it is recommended to identify the most appropriate soil parameters by assessing quality parameters of the surrounding area (collected during Step 1) and start monitor them over time. Some common and sensitive soil parameters can be used in this case, as for example, soil pH, electrical conductivity, polyphenols, total organic carbon, nitrogen, phosphorus, zinc and copper.

2.1.4 Step 4: Development of Land Suitability Maps

This step will provide authorities with data to define which areas among the potentially appropriate (Step 1) are indeed suitable to accept waste, in terms of soil quality, site characteristics and targets established during Step 1 (e.g. economic, aesthetic societal). By developing specific GIS-Land Suitability Maps (LSM), authorities will be able to know which is the degree of suitability of each site to accept waste. The theoretical base for the production of LSM is the one developed by the United Nations Food and Agriculture Organization-FAO [11] and foresees the categorization of the areas of interest into suitability classes. Adapted FAO [11] suitability classes are presented in Table 2 [1, 12]. Criteria that will be set up and then evaluated as a second stage, are specific for each area or region and therefore, no specific methodology can be provided for this.

Table 2 Land Suitability Classes [11].

Suitability Classes	**Description**
S1 Highly Suitable	Land having no significant limitations to sustained application for waste disposal or reuse or only minor limitations. Nil to minor negative economic, environmental, health and/or social outcomes.
S2 Moderately Suitable	Land having limitations which in aggregate are moderately severe for sustained application of waste. Appreciably inferior to S1 land. Potential negative economic, environmental, health and/or social outcomes if not adequately managed.
S3 Marginally suitable	Land having limitations which in aggregate are severe for sustained application of waste. Moderate to high risk of negative economic, environmental, health and/or social outcomes if not adequately managed.
N1 Not Suitable	Land having limitations, which may be insurmountable. Limitations are so severe as to preclude successful sustained waste disposal or reuse. Very high risk of negative economic, environmental and/or social outcomes if not managed.
N2 Not Suitable	Land having limitations which appear so severe as to preclude any possibilities of successful sustained waste disposal or reuse in the given manner. Almost certain risk of significant negative economic, environmental and/or social outcomes

Such LSM have been developed for pistachio waste, studied in the framework of the LIFE-Agrostrat [10]. The factors considered for land evaluation were (1) physical and chemical characteristics of the area and soils (i.e. drainage, slope, soil depth, infiltration rate, erosion level, texture, salinity, exchangeable sodium percentage and cation exchange capacity); (2) soil indicators that have been developed during AgroStrat Project for the evaluation of soil quality at pistachio cultivation and pistachio waste disposal areas, and (3) wastewater and solid waste properties [13]. Table 3 includes the parameters considered for the evaluation of land suitability to accept solid pistachio wastes. Similar evaluation table has been developed for the disposal of wastewater derived from pistachio processing, however the rating of the parameters was stricter (data not shown). Parameters 9-15 are the soil indicators defined for pistachio disposal. The consideration of soil indicators in the evaluation system ensures that the most important soil chemical parameters will be kept within the acceptable concentration range. However, in case that the indicators have not been determined (Step 3) then parameters 1-8 can be used. Tables 4 and 5 include the rating system adopted to evaluate the parameters of Table 3.

Table 3 Parameters for land evaluation for pistachio solid waste/sludge disposal

	Property/parameter	**Suitability Classes**				
		S1	**S2**	**S3**	**N1**	**N2**
1	Drainage	A, B	C	D, E	F	G
2	Slope, %	A, B	C	D	E	E
3	Depth	6, 5, 4	3	2	1	1
4	Erosion	0, 1	2	3	4	4
5	Salinity, dS/m	< 2	2-4	4-8	>8	
6	Infiltration rate, cm/h	2-8	0.1-2.0 8-16	<0.1 16-50		
7	Cation Exchange Capacity (CEC), meq/100g	>15	8-15	<8		
8	Exchangeable Sodium Percentage (ESP), %	0-6	6-10	10-15	15-25	>25
9	Total Nitrogen, %	<0.1	0.1-0.3	>0.3		
10	$N\text{-}NO_3$, mg/kg	<10	10-20	20-30	>30	
11	P-Olsen, mg/kg	<10	10-28	28-40	40-59	>59
12	Exchangeable K, cmol(+)/kg	<0.26	0.26-1.2	1.2-2.0	>2.0	>2.0
13	DTPA Cu, mg/kg	<3	3.0-10	10-20	>20	
14	DTPA Zn, mg/kg	<2.9	2.9-8.1	8.1-13	> 13	
15	Polyphenols, mg/kg	<50			>50	

Table 4 Soil: categorization in rated classes of drainage, slope, depth, erosion level and Exchangeable Sodium Percentage (ESP)-referred to Table 3 [13-15].

Parameter	Classes and rating						
Drainage	A Excessively drained	B Somewhat excessively drained	C Well drained	D Moderately well drained	E Somewhat poorly drained	F Poorly drained	G Very poorly drained
Slope	A 0-30	B 3-6%	C 6-12%	D 12-15%	E >15%		
Depth (cm)	10-15 Very shallow	15-30 Shallow	30-60 Slightly shallow	60-100 Moderately deep	100-150 Deep	>150 Very deep	
Erosion	0 Non eroded	1 Slightly eroded	2 Moderately eroded	3 Highly eroded	4 Very highly eroded		
ESP (%)	< 6 Non sodic	6-10 Sodic	10-15 Moderate sodic	15-25 alkaline	>25 degraded/ heavily degraded		

As regards soil salinity, land constrained by soil salinity is defined as landscapes that have very high electrical conductivity (EC) (> 4dS/m) or could be at extremely high salinity risk (>4dS/m) as a result of the proposed waste management scenario [7].

Infiltration is the process by which water on the ground surface enters the soil. Infiltration rate is a measure of the rate at which soil is able to absorb rainfall or irrigation. The rate decreases as the soil becomes saturated. If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier. It depends on soil pore space, size, shape, and distribution. Fine textured soils generally possess slow or very slow infiltration rate, while for coarse-textured soils the rate ranges from moderately rapid to very rapid. A medium-textured soil, such as a loam or silt loam, tends to have moderate to slow infiltration rate. Therefore, since infiltration rate reflects also these soil properties, as texture and size, for the development of the suitability criteria, only infiltration rate is considered [16].

Cation exchange capacity (CEC) is a measure of soil's ability to hold positively charged ions. It is a very important soil property influencing soil structure stability, nutrient availability, soil pH and the soil's reaction to fertilizers and other ameliorants [17]. The CEC of soils varies according the clay %, the type of clay, soil pH and amount of organic matter, for instance, pure sand has very low CEC, less than 2 meq/100 g. For waste disposal areas, it is desirable to select areas with as high CEC as possible in order to ensure retention by soil particles of cations added with wastes, although high values of CEC are associated with high clay content, which in turn reduces significantly soil permeability.

Table 5 Proposed indicators and the respective thresholds for pistachio waste disposal areas used for the development of Table 3 [3, 8, 18].

Soil Indicator	Low	Normal	High	Very high	Excessive
Total N, %	< 0.1	0.1-0.3	> 0.3		
Available P, mg/kg	< 10	10-28	28-40	40-59	> 59
Exchangeable K, cmol/kg	< 0.26	0.26-1.2	1.2-2.0	> 2.0	> 2.0
Available Cu-DTPA, mg/kg	< 0.8	0.8-3.0	3.0-20	> 20	
Available Zn-DTPA, mg/kg	< 2.9	2.9-8.1	8.1-13	> 13	
Total Polyphenols, mg/kg	<50			> 50	

It is also recommended that legislative and other generally accepted restrictions for waste landspreading (e.g. for soil heavy metals) to be taken into consideration [10, 19]. The evaluation may also include data from the soil thematic maps of Step 1 in order to identify areas with prohibitively high values of some soil parameters that make them unsuitable to accept the particular waste type as characterized in Step 2.

2.2. Differentiated steps 5 and 6 for the two types of AW

2.2.1 AW-type1

In case for reuse of AW-type1 in agriculture, two steps are proposed as mandatory, which are under the responsibility of the farmers, however, technical assistance is proposed to be provided to them by the Authorities. In brief:

Step 5: Farmers must perform chemical analyses to define the level of soil fertility as well as the nutrients that should be supplied for a specific type of cultivation. 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 AW use.

Step 6: Quantification of cultivation targets and definition of cultivation practices. Knowing the level of soil fertility, farmers should define and quantify their targets for the season or/and for longer period. Therefore, they will be able to estimate the amount of nutrients that must by supplied in order to achieve the defined targets, considering also the concentration of the nutrients in soil. For example, for 50 years-old pistachio trees and for yield target 5 tn/ha, the nitrogen supply must be 140 kg/ha, potassium 100 kg/ha as K_2O and phosphorus 2.25 Kg/ha as P_2O_5. Considering the needed amount per unit area of each nutrient, the amount of waste that is theoretically needed to fulfill each nutrient requirement can be calculated. The calculation is repeated for each one of the nutrients (e.g. N, P, K) and the amount for distribution is the lowest among these. However, before taking the final decision regarding the amount to be distributed, some critical waste' s and soil's parameters should be taken into account. These are the ones defined by national laws and especially heavy metals in waste and in soil. By considering these two parameters, the maximum permitted waste amount that can be spread on soil can be calculated. The calculations are repeated for all heavy metals defined in the respective law. The lowest amount of this procedure is then compared to the one resulted from the first calculation (i.e. considering only the nutrients). If the nutrients-calculated amount is lower than the metals'-calculated amount, then the first one can be spread on soil. Otherwise the optimum amount is the one calculated according to the legislation. Having defined the final optimum amount of waste to be reused on soil, all nutrients that will be provided due to application of this waste amount are recalculated. If any of the nutrients is not covered by this waste amount, then mineral fertilizers are applied in application rates according to the defined nutrients needs [1].

Nutrients contained in irrigation water (mainly P, N, S, B) should be also taken into account. If the nutrient content of the irrigation water is considerable, then the nutrients amounts should be extracted from the total estimated nutrients supplement.

The estimation of appropriate nutrients input can be assisted by decision-making tools, such as the "Cultivation Management Software" (Fig. 1), which has been developed in the framework of the LIFE-AgroStrat Project [20]. The software has been developed for the purposes of the project and includes GIS maps and data from the project pilot area, i.e. Aegina island, Greece, however, it can be used to any other area. Following all the above steps, authorities can make their data, in the form of a GIS-LSM, available to the system.

The functionality of the software:

- The users identify their cultivated areas by inserting the corresponding coordinates or by identifying the relevant fields using the embedded map. By inserting the results of the chemical analysis for a specific field, the software provides consultancy on the quality of soil, irrigation and organic materials/waste and also fertilization scenarios ensuring sustainable use of mineral fertilizers and soil amendments.
- For the consultancy, the software may also retreive data from the thematic GIS maps (step 1), in case there are missing soil parameters from the chemical analysis. For example, if potassium is missing from the chemical analysis, the software by using the respective field coordinates finds the value of soil potassium from the respective thematic map.
- The software also includes a feature to facilitate sustainable reuse or disposal of AW, as described below:
    - The user inserts the results of the waste's chemical analysis. Different types of organic materials can be inserted, as for example, pistachio waste, olive mill waste, manures, a.o.
    - The software evaluates the appropriateness of the material for soil disposal, considering the European and the national legislative frameworks.
    - By using Land Suitability Maps (step 4), the software evaluates the corresponding area for its suitability to accept solid waste or wastewater. For the suitable areas, the recommended amount of waste that is allowed to be discharged, is calculated considering the level of suitability, soil properties and waste's composition.
    - For fertilization purposes of the AW, then the appropriate amount is calculated considering soil nutritional status, irrigation water quality and trees needs. Detailed instructions are provided to the user on how to use and apply the materials in combination with mineral fertilizers.

2.2.2 AW-type 2

The two intermediate steps for AW-type2 are:

Step 5: Assessment of risk level and development of remediation or landspreading plan. During this Step, authorities should undertake all appropriate actions to precisely define which areas should be considered or not for landspreading and what is the optimum landspreading plan. This is because, it is very likely, some areas (although being of low or negligible pollution/degradation risk) to be inappropriate to accept wastes disposal due to their specific characteristics or to require alternative landspreading practices. In general, wastes can be applied without limitations in areas characterized as S1 and a management plan should be developed and implemented under the supervision of local authorities and the responsible governmental agencies.

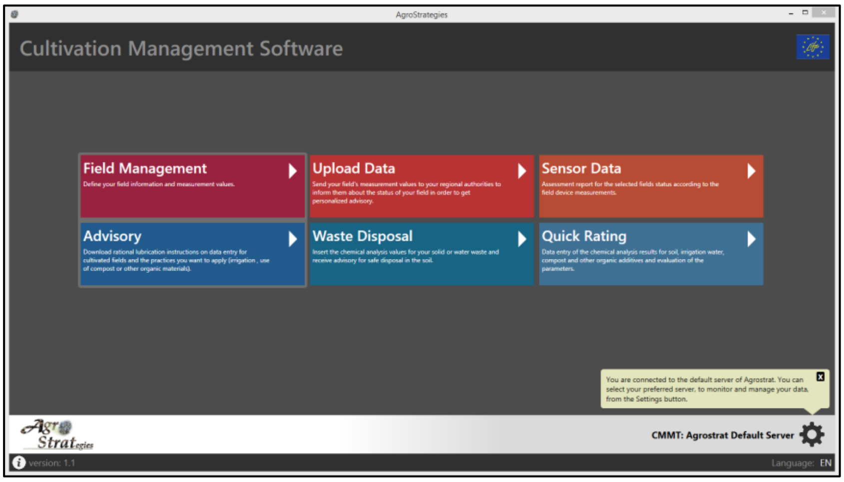

Fig. 1 Home page of the Cultivation Management Software developed in the framework of LIFE-Agrostrat project

For areas belonging to S2, S3, N1 and N2 suitability classes, performance of a risk assessment study is recommended. In simple words, risk assessment is the scientific process addressing the informal questions "how risky is it?" or "what is the chance of a bad outcome?" [21]. Most countries have a well-established framework for contaminated/degraded land risk assessment procedures, although terminology and matters of detail can vary substantially between countries. Differences mainly can be found at the endpoints of the studies. Studies usually start with suspicion about presence of soil or water bodies pollution/degradation while the endpoints mainly considered are human health, ecological risk, risk to water resources and risks for construction materials. Authorities should cooperate with experts on land/soil risk assessment and provide data and criteria collected during all previous steps in order the risk level to be defined [21].

For areas characterized as S2 and S3 and following the results of the risk assessment and the definition of the degree of limitations as well as the restricted factors, authorities can decide if these areas can be included in the landspreading plans or if a remediation plan should be developed and applied.

It is also recommended that N1 and N2 areas must be excluded from the landspreading plans due to the high risk of degradation while an improvement or remediation plan should be developed and implemented.

Step 6: Quantification of landspreading-Doses estimation. Having identified the suitable areas and ensured that no legislative restrictions exist for wastes landspreading, authorities, in cooperation with experts, should estimate the optimum amount of each waste type that can be distributed at the suitable areas. Doula et al. [1] described the calculation methodoly and proposed that the optimum waste amount is the one that ensures that the upper thresholds of the soil indicators (Step 3) will not be exceeded. Therefore, the concentration of indicators in soil, in waste as well as the respective indicators' threshold should be known. Especially for nitrogen, the maximum amount that is allowed by the relevant legislation for NO_3^- addition on soils (e.g. the "Nitrates Directive" 91/676/EEC of the EU which defines 170 Kg N/ha/y or other amounts as defined by national laws) should be considered as the upper limit of the element in soil.

2.3 *Common final steps 7 and 8*

2.3.1 Step 7: Ensure safe reuse/disposal-Health protection and safe production

Authorities should adapt and implement all appropriate measures foreseen in the national legislative framework to ensure safe products and at the same time safeguards public's and workers' health. A vital priority when considering reuse or disposal of AW on soil is the protection of workers' and citizens' health during and also after landspreading. The users should handle wastes by following the specific instructions given for the specific type of waste, while 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.
Safe food production must be ensured for AW-type1 by implementing national legislation and by conducting all appropriate food samplings and measurements. On the contrary, since AW-type2 is rarely used for the production of food for human consumption, but may be used for the production of animal food, the respective standards for the production of safe animal food must be taken into consideration [1].

2.3.2. Step 8: Periodical monitoring and risk evaluation during and after landspreading

The final Step foresees the monitoring of the impact of AW disposal on soil through a systematically planned sampling scheme and aims to identify and continuously record the impact of waste landspreading on soil quality and the environment in the short and in the long term.

For AW-type2 this Step must have a rigorous implementation to ensure environmental sustainability over time. On the contrary, for AW-type1, the implementation can be less strict and more adapted to local and societal particularities. Nevertheless, all information regarding waste types and amounts applied on soil, time and practice of application as well as, other relative information should be available to the authorities at any time so as to be able to implement monitoring strategies and assess the collected data.
In brief, authorities in cooperation with scientists and local waste users:

- Must design an effective monitoring strategy and implement it.
- Monitor soil quality indicators once a year and preferably before wastes distribution. For this, landowners or land users must perform soil sampling and chemical analysis annually. The results of the chemical analyses should be evaluated by experts (e.g. agronomists, soil scientists, environmentalists) and a technical report should be submitted to the responsible authorities. The report should also include a detailed description of the wastes' distribution plan (amount, timing, equipment used). Depending on the evaluation results, the responsible authorities may permit wastes disposal or not.
- Establish a specific inventory (i.e a database) of each disposal site, which will be updated annually with all data submitted by the owners or/and the results of surveys performed by the authorities. This will facilitate the immediate identification of risky areas as well as, will provide data regarding history of the site, specific local geomorphological characteristics, amounts of waste that have been disposed each year, results of waste and soil chemical analyses and any other data that are considered useful and necessary for the effective protection of soil quality and function.

To facilitate this step, a GIS-based web application, namely "Central Management Monitoring Tool" (CMMT) has been developed in the framework of LIFE Agrostrat project [22]. CMMT system is a free web application that enables the establishment of a Management-Monitoring Center, which can assist authorities with the management and monitoring of cultivated areas on a regional scale, by connecting them with farmers, landowners, and waste users (Fig. 2). It facilitates the monitoring of cultivated fields or waste disposal areas, using soil, water and organic materials/waste parameters integrated within a geographical Information System (GIS). Individual users may upload their fields and corresponding chemical analysis to the CMMT system through the "Cultivation Management Software" (server-client model architecture).

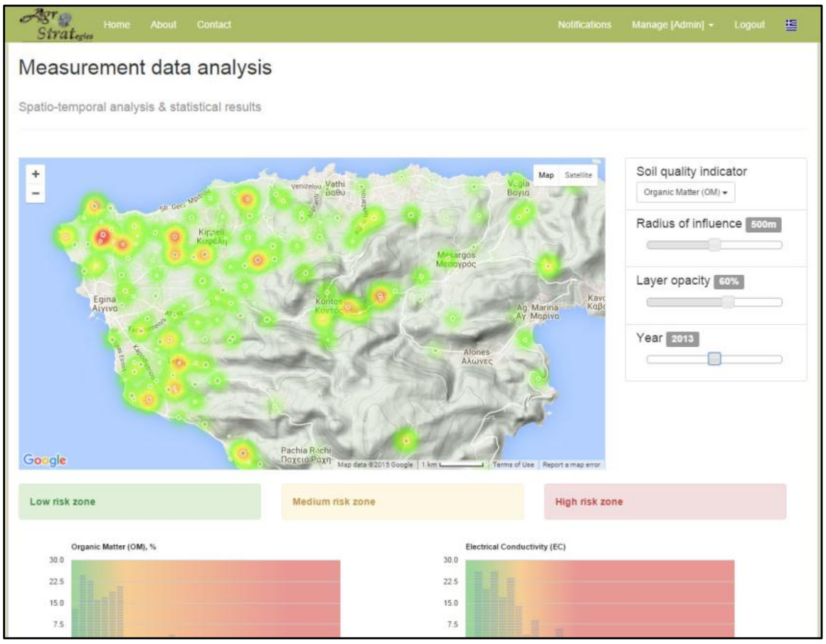

Fig. 2 Central Management - Monitoring Tool (CMMT) of LIFE AgroStrat project: On-line collection and mapping of soil data by monitoring authorities

Therefore, all data described during previous steps can be sent to the authorities. The application provides essential monitoring features, such as temporal evaluation of the cultivated areas through comprehensive charts, or statistical data analysis on a spatial scale analysis. The CMMT system also provides the potential to visualize the analysis results and produce local/regional maps, as illustrated in Fig. 2. Essentially, the CMMT allows individual users to communicate through the "Cultivation Management Software" with the responsible local/regional authority and request directives and guidance about their cultivated fields or discharge areas.

Another web GIS-based monitoring tool that has been developed in the framework of LIFE-Prosodol project [23], and can be also used in combination with the CMMT, enables mapping of soil constituents' distributions vs. time, and depth. An example of these maps was presented by Doula et al. [1]. Through this tool, local and regional authorities will have the opportunity to map and screen disposal areas rapidly, identify potential risky conditions, carry out systematic monitoring of the areas of interest and facilitate decision making on the appropriate measures to be taken at field or regional scale. The tool, which was developed for the case of OMW, monitors the eight soil indicators selected for this type of waste (i.e. soil pH, electrical conductivity, organic matter, total nitrogen, polyphenols, exchangeable potassium, available phosphorus and available iron) and integrates the continuous monitoring of the OMW disposal areas into the regular activities of local/regional authorities and thus, allows the proper and continuous monitoring of such areas. Nevertheless, the tool can be adapted to any type of AW and conformed easily to any local/regional peculiarities.

The adoption and application of such a tool, however, requires the cooperation of the disposal areas' owners, since repeated soil samplings at various sites are necessary for maps creation and update. The proposed application tool uses interpolation surfaces that indicate the distribution of the different physical and chemical parameters in the area of interest, so the user can rapidly obtain an idea of the possible diffusion of the chemical parameters and the degree of risk in the vicinity of the waste disposal areas.

3. Conclusions

Sustainable management of agricultural waste and especially reuse in agricultural sector and/or discharge on soil requires a well-designed strategy that will ensure that all three components of sustainability, i.e. environmental protection, economic growth and societal well-being are fulfilled. At local and regional level, authorities have to play a very significant role in the management of agricultural waste. The eight steps-integrated strategy proposed provides the general but still the required means, actions and measures to be adopted by authorities and individuals in order to develop local or regional strategies/action plans, fully conformed to local/regional peculiarities.
Decision making tools and Web-GIS applications may significantly assist authorities and individuals to make the correct decision while at the same time contribute to the (1) visualization of wastes areas quality, (2) selection according to specific criteria of the most appropriate areas for wastes reuse, (3) continuous monitoring and (4) estimation of correct doses of wastes application considering many factors, as soil and irrigation water parameters.

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