GEOGRAPHICAL ASPECTS OF ORGANIC WASTE PRODUCTION AND MANAGEMENT IN GREECE[1]

K.E. LASARIDI[2]

ABSTRACT.

An estimated quantity of more than 23 million tons of organic waste is produced annually in Greece, of which agricultural waste of animal and plant origin constitute the main fraction with 15.8 and 5.4 tons respectively. Agricultural wastes have distinct geographic characteristics that determine the best practical management option for each category. Especially animal husbandry activity is concentrated in the prefectures of Thessaloniki and North Greece in general, Evia, Ioannina and Larissa, where construction of biological treatment facilities should constitute a high priority. The organic fraction of municipal solid waste and sewage sludge constitute the remaining of the organic waste stream, following the geographical distribution of the population in the country.

KEYWORDS: organic waste, manure, MSW, biosolids, composting, Greece

ΠΕΡΙΛΗΨΗ

Η εκτιμώμενη ποσότητα των οργανικών αποβλήτων που παράγονται κάθε χρόνο στην Ελλάδα ανέρχεται σε 23 εκατομμύρια τόνους, με τα αγροτικά απόβλητα ζωικής και φυτικής προέλευσης να αποτελούν το κύριο κλάσμα, με 15.8 και 5.4 τόνους αντίστοιχα. Τα αγροτικά απόβλητα παρουσιάζουν χαρακτηριστικές γεωγραφικές κατανομές που καθορίζουν τις βέλτιστες πρακτικές διαχείρισης ανά περίπτωση. Η κτηνοτροφική δραστηριότητα ειδικότερα συγκεντρώνεται κυρίως στους Νομούς Θεσσαλονίκης και στη Βόρεια Ελλάδα γενικότερα, Εύβοιας, Ιωαννίνων και Λάρισας, όπου η κατασκευή εγκαταστάσεων βιολογικής επεξεργασίας θα πρέπει να αποτελεί υψηλή προτεραιότητα. Το οργανικό κλάσμα των στερεών αστικών αποβλήτων και η ιλύς βιολογικών καθαρισμών συνιστούν το υπόλοιπο μέρος του ρεύματος των οργανικών αποβλήτων και παραγωγή τους επικεντρώνεται στα αστικά κέντρα ακολουθώντας τη γεωγραφική κατανομή του πληθυσμού στη χώρα.

INTRODUCTION

Organic wastes of any type contain organic matter, micro and macronutrients and are potentially useful for use on agricultural land, as they can enrich the soil with humus and enhance its productivity. Nevertheless, in Greece, like in many other Mediterranean countries, and despite a chronic deficiency of soil organic matter, organic wastes' recycling is not common. On the other hand, organic waste may also pose serious threats to the environment due to their high BOD and, mainly, nitrate content. As many areas of the world, including large parts of Greece, are considered sensitive for nitrates pollution of surface and ground water, the sustainable management of organic waste, especially manures and sludge, is becoming increasingly important.

All types of organic waste, with the exclusion of those containing hazardous contaminants (heavy metals, organic pollutants) share a common characteristic: while they are usually the cause of serious pollution if disposed of improperly, they can offer significant benefits to the agricultural land and reverse desertification effects that are intensified by modern agricultural practices. In traditional agriculture practices, organic waste and especially animal manures were valuable for land fertilisation and replenishment of soil organic matter. With modern agricultural practices, plant nutrients are provided through the application of inorganic fertilisers, leading to a depletion of soil organic matter and deterioration of its health. Controlled application of treated organic waste on land can

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close the loop, providing solutions to both problems and promoting sustainability in the agricultural sector.

During the last years the normative framework, regulating both waste management and fertilising, has deeply changed in several EU countries opening new perspectives in waste management and recycling. Indeed, latest laws and regulations, by setting out recycling targets, have played an important role on the growth of source collection systems for MSW. The restrictions posed by the Landfill Directive on the organic matter content allowed to the landfills (EC, 1999) and the ban of several categories of waste, have led to the development of alternatives, such as composting and anaerobic digestion, and the demand for the application of treated material on land. At the same time, in some countries new legislation on fertilisers considers quality compost as a fertiliser sharing the same fiscal advantages allowed to mineral fertilisers (Tittareli *et al.*, 2001).

This study examines the production and management practices for organic waste in Greece, with emphasis on their geographical patterns. The issue of compost quality and its potential uses in the different parts of the country is also discussed, along with selected case studies.

METHODOLOGY

The waste management sector is not served particularly well by statistics, and Greece does not constitute an exception. In spite of the horizontal actions taken at the EU level to improve the quality and reliability of waste related data and the great improvement of the situation in Greece well organised and reliable data on waste quantity and composition are still not available.

Data presented in this paper have been collected from a variety of sources: for municipal solid waste (MSW) and biosolids, data from special studies commissioned by the Hellenic Ministry for the Environment, Physical Planning and Public Works for the compilation of the National Waste Strategy have been used. For agricultural waste of plant and animal origin, data from the agricultural production statistics of the Ministry of Agriculture have been used (Anon 2000; 2001) along with literature values for the waste production coefficients adapted to the Greek conditions (Israelidis, 2001; Georgakakis *et al.*, 1994). Currently there are no available reliable collective official data for organic waste production and management in Greece. Waste management in Greece begun a process of gradual change from the mid-'90s, from a state of practically uncontrolled dumping to more sustainable practices, mainly under the policy pressure and funding from the EU, and this also reflects to the amount and quality of data available.

AVAILABLE QUANTITIES OF ORGANIC WASTE

Organic waste mainly fall into three large categories: agricultural waste of plant and animal origin, including some types of agroindustrial waste, the organic fraction of MSW, and sewage sludge or biosolids as it is preferably called nowadays. In each of the abovementioned categories, and for different reasons, only a fraction of the amount produced annually could be collected at a reasonable cost and be available for treatment. The amount of organic waste produced annually in Greece is summarised in Figure 1.

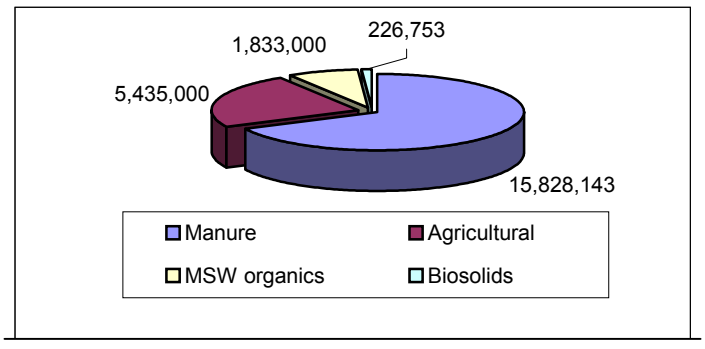

Figure 1: Quantities, in tons, of organic waste produced annually in Greece: manure – 15,828,143 t; agricultural waste of plant origin – 5,435,000 t; organic fraction of MSW – 1,833,000 t; biosolids – 226,753 t.

Agricultural waste

Manure

The quantities of animal manures can be calculated from the animal capital of the country, which is regularly recorded by the local Agricultural Directorates. The relevant data are cross-checked and compiled at Prefecture level by the Ministry of Agriculture. Data from the year 1996 were used, which reflect fairly well the current situation, as the animal capital of the country has not significantly changed since 1987 (Anon, 2000; 2001). The specific waste production is calculated from the values given in Georgakakis *et al.* (1994), assuming an average weight of 500 kg for cows of all types, 40 kg for sheep and goats, 1.5 kg for chicken and 200 kg for swine, considering a ratio of 9.6 pigs to 1 pig-mother in the total number of swine reported. Results are presented in Table 1.

The geographical distribution of the animal waste (liquid and solid excluding slaughter waste) produced by cows, swine, sheep & goats, and chicken is presented in Figure 2 (a-d, respectively). The total quantity of animal waste and the available quantity of manures (the solid fractione) by Prefecture is presented in Figure 2 (e and f). Because of the size and the type of animal raising units it would not be feasible to collect all the amount of waste produced. Cows for meet production are often raised in small units in open farms. This is especially true for goats and sheep, which are bread in small, disperse units, often in mountainous areas. Therefore, only a fraction of the waste produced could be collected and treated in central systems at a reasonable cost, which is the availability percentage. Waste is considered to be available for central treatment for units of more than 20 cows or pig-mothers, or for Municipalities with more than 10,000 sheep and goats (Anatoliki, 1999).

The highest quantities of animal waste are produced in Evia, North Greece and Epirus. The prefectures with the most waste are in descending order Evia, Atoloakarnania, Thessaloniki, Preveza, Larissa and Ioannina. Relatively small amounts of waste are found along the axis of Pindos, in Peloponnisos, Crete and the islands. Attiki is a relatively important producer, mainly for poultry and swine waste. There are distinct geographic trends in the type of animal husbandry exercised, and therefore the types of manures produced, in the different areas of the country. Cows, both for milk and meat production, are mainly raised in the North, i.e. in Macedonia and Thrace. Pigs are raised at modest numbers in most parts of the country, mainly in small units. More intensive pig husbandry is encountered in Evia, partly as a result of high state subsidies, and to a lesser extend in Preveza and Atoloakarnania. Chicken waste mainly arise in Attica, in the region of Megara, and Evia, and to a smaller degree in Thessaloniki and Ioannina, also important animal raising areas. Sheep and goats keeping is perhaps the most traditional animal raising activity in

Table 1: Production and characteristics of animal waste in Greece for 1996.

	Cows	**Swine**	**Sheep**	**Goats**	**Chicken**	**Total**
Number of animals	586,460	2,253,574	9,212,066	5,411,336	41,512,364	N/A
Specific waste production (kg/head/yr)	12,500	4,190	571	571	32	N/A
Waste production (t/yr)	7,330,750	9,442,250	5,260,090	3,089,870	1,328,400	26,451,360
Dry solids %)	13	10	25	25	27	N/A
Volatile solids (%)	82	80	85	85	74	N/A
Availability (%)	50	50	10	10	50	N/A
Available waste (t/yr)	3,665,375	4,721,125	526,009	308,987	664,200	9,885,696
Manure fraction	0.70	0.55	0.50	0.50	1.00	N/A
Manure production (t/yr)	5,131,525	5,193,238	2,630,045	1,544,935	1,328,400	15,828,143
Available manure (t/yr)	2,565,763	2,596,619	263,005	154,494	664,200	6,244,079

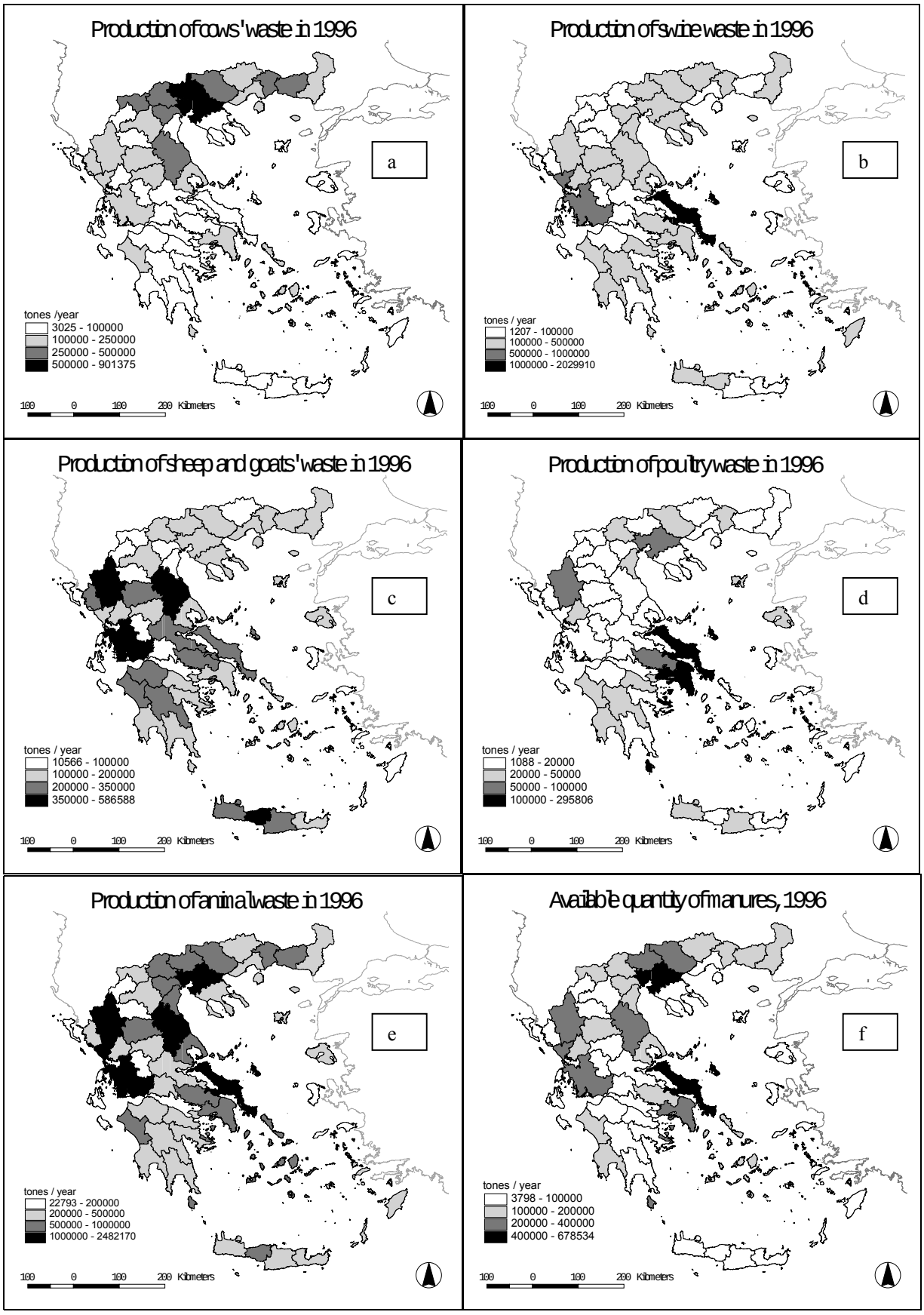

Figure 2. Production of liquid and solid waste in 1996 from (a): cows; (b): pigs; (c): sheep and goats; (d): chicken; (e): all of the above; and Figure 2f. Available quantities of manure (solid waste), in 1996.

Greece, and still today is fragmented in many small units found in all parts of the country. The type of units is also fairly traditional, with animals being often semi-free in mountainous areas, making waste collection and central management practically infeasible. High numbers of sheep and goats are found in Atoloakarnania, Ioannina, Larissa and Rethymni, but herds are raised in all parts of Greece, especially in Central and South Greece, including mountainous areas unsuitable for other types of animal husbandry. When the availability of the waste is taken into account, cow and swine waste are more heavily weighted resulting in the highest amounts of available manure, more than 400,000 tons/yr, in Evia and Thessaloniki. Considerable amounts are also produced in most parts of North Greece, West Greece, Larissa and Attica. These are the areas where central biological treatment facilities for compost and/or energy production from animal waste should be planned.

*Pla**nt residues***

Large quantities of plant residues are annually produced in Greece from the widely cultivated crops, such as cereal straws, corn and cotton stalks, cotton gin, olive-mill by-products, and juice and wine industry residues. Some of these by-products may find uses of higher value, such as fermentation for fodder production, or extraction of essential oils and other compounds, or may be used as fuel. However, because of the small size and disperse nature of most production units these options, even if technically available, are often economically infeasible. Therefore, the most common options for these wastes are disposal in often-unlicensed landfills, uncontrolled burning or simple on-site stockpiling.

In addition significant quantities, up to 1,000,000 t/yr of fruits and vegetables may be withdrawn, i.e. destroyed immediately after production without ever reaching the markets. However this quantity is falling as a result of the CAP agreements, and it is estimated to stabilise at about 400,000 t/yr (Ministry for the Environment, Physical Planning & Public Works, 2000). The average annual quantities of plant residues are summarised in Table 2 (Israelidis, 2001).

All of these wastes could be composted, on their own or in mixtures with other agricultural waste of plant or animal origin, to produce good quality, high value composts. Juice industry residues could also be treated anaerobically, and 2-3 such plants have been constructed, but never operated in the last 15 years.

Table 2: Average annual quantity of agricultural waste of plant origin.

Crop / waste	**Production (t/yr)**	**Waste ratio**	**Waste quantity (t/yr)**
Cereals / straw	2,600,000	0.55	1,430,000
Corn / stalks	2,000,000	1.16	2,320,000
Cotton / stalks / cotton gin waste	1,230,000	0.80	984,000 120,000
Olives / extracted press-cake			300,000
Citrus fruits for juice	330,000	0.53	175,000
Grapes / winery waste	525,000	0.20	106,000
TOTAL			5,435,000

Municipal solid waste

According to the Ministry for the Environment, Physical Planning and Public Works (2000), 3.9 million tons of MSW were produced in Greece in the year 1997, corresponding to a specific waste production of 0.97 kg/d/ca. Of these 47% is the putrescible organic fraction, while paper constitutes

another 20%. However, more recent studies indicate a lower percentage of organics, perhaps in the region of 35-40%. The geographical distribution of waste production by Prefecture is presented in Table 3. According to the Landfill Directive (EC, 1999), the amount of organics being landfilled should be gradually reduced by 65% to their 1995 quantity, i.e. alternative disposal routes should be found for about 1.2 million tons.

Table 3: Geographical distribution of MSW produced and their organic fraction, assumed to be 47% of the total (*Source*: Ministry for the Environment etc, 2000).

Administrational Region	% of MSW production	Organics (t/yr)	Administrational Region	% of MSW production	Organics (t/yr)
Attiki	37.87	694,190	Peloponnisos	4.87	89,300
Central Macedonia	18.74	343,570	Epirus	2.72	49,820
Thessalia	6.51	119,380	South Aegean	2.18	39,950
West Greece	5.77	105,750	West Macedonia	2.18	39,950
East Macedonia-Thrace	5.26	96,350	North Aegean	2.10	38,540
Sterea Ellada	5.21	95,410	Ionian Islands	1.62	29,610
Crete	4.97	91,180	TOTAL GREECE	100.00	1,833,000

Biosolids

In 1997 there were 138 wastewater treatment plants (WTP) covering 5,954,000 people and treating 970,085 m^3/d of municipal wastewater. Collectively, they produced 226,753 t/y wet weight or 58,993 t/y dry solids of sewage sludge, or as it is nowadays called, biosolids. Currently most of the biosolids are being landfilled and only minimal quantities are applied to land (Ministry for the Environment, Physical Planning & Public Works, 2000). However, the Landfill Directive (EC, 1999) also restricts the disposal of biosolids to landfills and alternative methods for the treatment and / or application of sludge to land should be adopted. Composting and anaerobic digestion are two options for good quality sludge, with low content in heavy metals. However, a large part of the biosolids produced may not conform to the new limits of heavy metals for agricultural land application, described in the proposed Sludge Directive.

MANAGEMENT OF ORGANIC WASTE

Potential environmental damage caused by organic waste may vary considerably, depending on the type of the waste. Adverse effects include contamination by human or plant pathogens, production of greenhouse gases – mainly methane during uncontrolled anaerobic digestion in landfills or waste ponds, leaching of nitrates resulting in nitrate pollution of potable water resources and eutrophication of sensible water bodies, nitrogen immobilisation in the soil and various types of phytotoxicity (Alexander, 1977; Inbar & Chen, 1993; Lasaridi & Stentiford, 1998; Zucconi *et al.*, 1985). However, if suitably treated and managed organic waste may be beneficially used to preserve soil health and productivity. Typically, biological treatment such as composting and anaerobic digestion is the most suitable for most types of organic waste. In certain cases, waste may need to undergo thermal treatment for sanitation, or simple drying may be sufficient. Composting may be performed in simple turned windrows, in aerated static piles or more complex reactor systems. Anaerobic digestion is performed in closed reactors-digesters of varying complexity. The degree of complexity usually determines the level of control of the process but also reflects to the costs.

Composting, mainly of manures, has been a very old farmers practice and the main way to preserve land fertility before the invasion of chemical fertilizers. Today though the intensification of agriculture necessitates more sophisticated management of the organic waste, to (a) certify that they have been adequately treated; (b) guaranty specific quality standards; and (c) monitor the soil to apply the exact quantities required.

Treatment of other types of organic waste, such as MSW and biosolids, requires higher levels of sophistication to avoid nuisances and guaranty the sanitary and environmental safety of the composts produced.

TRENDS AND DRIVES

As in most environmental issues in Greece, the main drive for change in the organic waste management comes from the EU, both in the form of legislation to which Greece must comply and available funding for waste treatment facilities.

In the field of MSW management the main driving force is the Landfill Directive (EC, 1999), which introduces a new framework for landfills operation, oriented to the effective protection of the environment. Organic waste is the main cause of environmental degradation caused by landfilling, as the biogas produced is a potent greenhouse gas, while leachate heavily pollutes ground-water. As a result, disposal of organic waste to landfills is restricted: the biodegradable fraction of MSW going to landfill should be reduced compared to 1995 levels by 25% in 5 years, by 50% in 8 years and by 65% in 15 years. In addition, some types of organic waste, currently allowed to landfills, such as biosolids, retreated produce and animal waste, will no more be acceptable. This poses enormous problems to countries heavily relying to landfill, such as Greece and the UK, especially when preparatory actions had not been taken. The option favoured by Greece is the mechanical separation and composting of the organic fraction of MSW, alone or mixed with biosolids or manures, depending on the region. The suitability of the compost produced this way for agricultural use remains to be proved, especially in the light of the proposed "Composting Directive" and the forthcoming amendment of the "Sludge Directive", which establishes strict standards for the heavy metal content and probably of an array of toxic organic pollutants.

The treatment of liquid and solid animal waste comes as a consequence of the need to protect surface and ground water from nitrification, as demanded by the Framework Water Directive (EC, 2000). As explained earlier agricultural waste of both animal and plant origin may be highly beneficial for the protection of soil fertility and the combat of erosion and desertification, when applied according to a good agricultural practice code. Composts and organic soil amendments currently enjoy high prices in the Greek market, and in many cases waste treatment plants for these types of material could be profitable. From Figure 2, it seems probable that central animal waste treatment facilities should be developed in Evia, Central Macedonia, Ioannina, Atoloakarnania, Thessalia and Attiki, and possibly in an array of other locations. Obviously this analysis serves only as a general overview and specific feasibility studies should be carried out on a case-by-case basis. It should be noted however, that in several cases private enterprises for compost production from manure have been developed in the aforementioned regions.

An extra drive for the sustainable management of organic waste comes from the area of combating global warming. In the UN Framework Convention on Climate Change in Kyoto in 1997, decided to reduce greenhouse gases emission by 5% on average during the period 2008-2012 compared to the 1990 level. On a voluntary basis EU Countries have decided to reduce emissions by 8% in the same period. There are two main options for reducing CO_2 levels in the atmosphere, which should probably be used in combination: a cut down on CO_2 emissions and enhancement of carbon sequestration in the terrestrial biosphere (Tittarelli *et al.*, 2001). The second option has been mainly discussed in relation to plants and forests. However, the soil is also an important part of the carbon cycle, actually representing the major terrestrial reservoir of organic C after fossil deposits. Processes regulating the carbon cycle are complex and not yet fully understood, involving soil, plants, the oceans and the atmosphere. A rough estimate of C reservoirs in different compartments would be: plants 600 Gt, living organisms in soil 50 Gt, fossils 4,000 Gt, soil organic matter 1,550 Gt and atmosphere 700Gt (Tittarelli *et al.*, 2001). It seems reasonable to consider that the great majority of Mediterranean soils that suffer from organic

matter depletion (e.g. less than 0.5% organic matter content in Crete) could behave as a substantial carbon sink. Carbon accumulation in soil depends on a greater addition of organic carbon and a lower decomposition rate, two processes strictly linked to each other and determinant of a sustainable management of soil fertility. The addition of treated organic waste to the soil could play an important role in this respect.

CONCLUSIONS

Of the 23 million tons of organic waste produced annually in Greece the largest fraction consists of agricultural waste of primary animal and secondary plant origin, and only a relatively small fraction is MSW and biosolids. Most agricultural waste is disposed of untreated, on-site or in dumps, causing substantial pollution of water, soil and air. However, under suitable treatment and management protocols, these wastes may constitute a valuable resource for sustaining the productivity of agricultural land, through the controlled addition of organic matter to the soil to combat erosion and desertification. Soil organic matter could thus play an important regulating role to the enhanced greenhouse effect, as a carbon sink.

The optimal geographic distribution for biological treatment facilities will be the outcome of detailed planning studies but it seems likely that North Greece, Evia, Epirus and Larissa are suitable candidates for central units treating animal waste.

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REFERENCES

[1]Alexander, M. (1977). *Introduction to Soil Microbiology*. 2nd ed. John Wiley & Sons, Toronto.
[2]Anatoliki (1999). Solid Waste Management Strategy for the Thessaloniki Prefecture. ANNATOLIKI S.A.
[3]Anon (2000). The Greek Agriculture in Numbers: basic characteristics. Ministry of Agriculture, Division of Agricultural Policy and Documentation, Athens.
[4]Anon (2001). The Geography of Greek Agriculture. Ministry of Agriculture, Division of Agricultural Policy and Documentation, Αθήνα.
[5]EC (1999). Council Directive 1999/31/EC of 26 April 1999 on the Landfill of Waste.
[6]EC (2000). Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy
[7]Georgakakis D., E. Papanikolaou, P. Koukoulakis, A. Papadopoulos, S. Raptis, C. Tsafaras, K. Thessalos, I. Papakostas, P. Kodakis (1994). Code of Agricultural Practice for the protection of waters from nitrate pollution of agricultural origin. Ministry of Agriculture, Division of Agricultural Applications, Athens.
[8]Lasaridi K.E. and E.I. Stentiford (1998). A Simple Respirometric Technique for Assessing Compost Stability. *Water Research,* **32**, 12, 3717-3723.
[9]Inbar, Y., Y. Chen (1993). Properties for establishing standards for utilisation of composts in container media. *In:* H.A.J. Hoitink and H.M. Keener (eds.). *Science and Engineering of Composting*. Renaissance Publications, Ohio, pp. 668-694.
[10]Israelidis K. (2001). Beneficial use of solid organic agroindustrial waste. *In:* K.E. Lasaridi and K. Pavlopoulos (eds.). Integrated Management of Organic Wastes and Residues. Harokopio University, Athens.
[11]Manios T., D. Kanakopoulos, D. Petounis V. Manios (2001). The organic waste management in Greece. International workshop on the "Management of

organic waste in rural Mediterranean areas", 22-23 February 2001, University of Navarra, Spain.
[12]Ministry for the Environment, Physical Planning & Public Works (2000). National Waste Strategy, Common Ministerial Decision 14312/1302/2000, FEK B723/9-6-00
[13]Tittarelli F., E. Favoino, P. Sequi (2001). Biodegradable waste management in rural Mediterranean areas of Italy. International workshop on the "Management of organic waste in rural Mediterranean areas", 22-23 February 2001, University of Navarra, Spain.
[14]Zucconi, F., A. Monaco, M. Forte, M. de Bertoldi. 1985. Phytotoxins during the stabilization of organic matter. *In:* J.K.R. Grasser (ed.). *Composting of Agricultural and Other Wastes*, Elsevier Applied Science, London, pp. 73-86.