The City and the Agricultural Sector Inter-relationship: Environmental costs and benefits.
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Abstract

Both the urban and the agricultural sectors use natural resources and produce wastes using environmental resources.
From an economic perspective, each and every stage of production, use and disposal of goods (or services) should also incorporate (internalize) the associated environmental costs, quantified whenever possible. It has by now been universally accepted that in searching for optimal means for the solution of solid waste, comparing and selecting disposal alternatives, an explicit cognizance must be taken of environmental costs. This will render the different alternatives comparably and thus enable a more comprehensive search for an optimal solution.
The co-existence of the urban and agricultural sectors is essential. For generations, the agricultural sector supplied goods to the city and obtained industrial products, central services etc. Presently, food can be imported and supplied from far away. However, the new role of the agricultural sector is to provide environmental services to the growing cities. One aspect of this will be demonstrated and analyzed here: the agricultural sector as an acceptor of wastes from the cities: municipal waste, wastewater and sludge from wastewater treatment plants. The paper will discuss the two sides of the equation describing the inter-relation between the city and the agriculture section, for the case of municipal solid wastes
Quantification of the external costs (or benefits) and adopting a wide range of administrative, legal, and, in particular, decentralized economic instruments in policy making could create a new market equilibrium that will reflect the desired adjustments in terms of volumes of waste, toxicity and other externalities generated by the community. This methodology could also determine the cost sharing between the city and the agricultural sector.
Introduction

The activity of the modern society is associated with nuisance and damage of the environment (i.e., noise, water bodies contamination, air pollution etc.). The modern development is characterized, among other things, with massive urbanization, rise in standards of living (and wastes produced accordingly).

The increasing amounts of waste are a serious environmental threat: waste is dumped and cover large parcels of land; leachates, produced when water pass through waste dumps, are a major source of water and soil pollution; fires and generation of different landfill gases threat air quality; the accumulated waste and its by-product endanger human health and environmental quality. In addition, the waste dumped by society represents a waste of resources, some of which are not regenerated. The disposal of construction waste in Israel, for example, affect the environment both through the problems associated with the disposal process as well as by the need to extract more sand, affecting landscape, beaches stability and destroying important eco-systems.

The agricultural sector, being in an economic crisis for the past years, is characterized with massive land use and intensification of the agriculture, both leading to immense use of resources (water, fertilizers, pesticides etc.) as well as land erosion, and desertification. There is a need to preserve the agriculture sector not only as a supplier of food, but also as a supplier of environmental benefit (i.e. supplier of oxygen and a carbon dioxide sequestration mechanism, increased infiltration and water drainage to ground water). In dense countries like Israel, the agriculture sector serves also as a guard of open spaces and as a site of nature, landscape and even an attraction for eco-tourism.

There is a logical, environmental and economic rational to combine the wastes produced in the city with the needs of the agricultural sector. The city can supply the agricultural sector with organic solid wastes, as well as sewage sludge and treated wastewater to the mutual benefits of both sides. However, it should be emphasized that this mechanism should be based on mutual commitment and on economic efficiency (including environmental considerations). There is a need to put the environmental benefits and burdens into perspective and to analyze their relative importance. Due to the fact that direct costs are given in monetary terms, it is reasonable to assign monetary values to the environmental costs as well, and the optimal solution will be chosen according to cost-benefit analysis or economic efficiency (Tietenberg, 1992; Turner et al., 1994).

The aim of this presentation is to indicate the economic and environmental benefits and costs of a cooperation in which the agriculture sector serves as an acceptor of municipal wastes.

1. The City

1.1 Reduced direct and environmental costs of waste transportation and disposal in landfills.

Each inhabitant in a modern city produces 0.7-1.5 kg of solid waste every day. Even if all waste produced in the city is disposed of in sanitary engineered
landfills, there are still environmental burdens associated with it. Transportation to and from the landfill (including road congestion, accidents, air pollution, noise etc.), leachates, release of landfill gas [landfill gas systems can recover only 40-90% of the emitted gas (White et. al., 1995)], etc. The main environmental burdens are due to the presence of organic materials in the waste. In Israel, for example, the organic fraction of the waste is a contributor of more than 12% of greenhouse gases emissions (Ayalon et al, in press). The significant contribution of this sector is similar in many countries, especially in developing countries. Even in Europe, where waste is being handled under more strict legislation, the international concern about global warming is the driving force in recent legislation to reduce the amount of biodegradable organic fraction of waste entering landfills (Petersen, 1997) with Germany leading (Stegmann, 1997). Several states in the US have adopted and enforced new legislation concerning the biodegradable fraction of the municipal waste (i.e., Friesen, 1999). The inability to dispose of the organic waste introduces a serious additional expense on the city.

In order to minimize the amount of organic waste landfilling, there is a need for pre-treatment of the waste. This can include incineration, aerobic composting or anaerobic digestion (AD). The advantages and disadvantages of these alternatives are discussed elsewhere (Ayalon et. al., 1999). Here, we shall focus on the alternative of aerobic composting (it should be noted that if the AD is adopted, the final stage of the treatment will be aerobic composting). If the organic fraction (with or without source separation of the waste) is composted, the city will gain reduced operational and environmental costs associated with waste disposal in landfills. In several studies conducted in Europe and in Israel, the external costs of landfilling due to leachates and landfill gas emissions were evaluated to be in the range of 5-10 US$/ton waste (DoE report, 1993, Coopers & Lybrand, 1996, Enosh, 1996). Another benefit from waste composting is associated with reduced transportation to the landfill and operational costs at the site as well as reduced land needed for landfills.

1.2 Avoided environmental costs through agricultural land use
Plants and agriculture crop serve as a sink sequestering carbon dioxide emissions. The production of one ton of dry vegetative matter leads to the sequestration of 2 tons carbon dioxide. A world market for trading CO2 emission permits among countries is presently proposed. It is estimated, at this point, that an average value of 25$ per ton carbon is a reasonable figure (Bertram, 1996; Cansier & Krumm, 1997).

In arid regions in general and in dense countries like Israel, in particular, agriculture is also essential as the ‘final frontier’ guarding open and green spaces and help to encounter desertification. The use of compost has a high potential to increase productivity of land in the frontier between desert and arable land.

1.3 Need for separation of wastes.
In order to ensure high quality compost, there is a need to separate the waste at the source, i.e. at identified sources of organic wastes (markets, restaurants etc.)
and in homes. The separation of the waste should not make the operational costs of collection of the waste more expensive. A governmental technical committee appointed in Israel in 1996, found that separation of MSW at the source to a clean organic stream and a dry stream, will not induce higher collection costs (Ministry of Agriculture, 1996). However, source separation requires a different infrastructure and the use of two different containers at home and at the curb and massive public education. There are additional external costs born by the citizens who are required to devote time and efforts to separate the waste.

1.4 Environmental damages from near-by located composting systems.
The composting process entails environmental problems such as odors, flies, dispersion of fungi and actinomycetes spores, emission of N₂O, a potent greenhouse gas (Dalemo & Oostra, 1997) as well as the formation of leachates and fires. All of these can be minimized or eliminated by the proper management of the composting plant (including the use of bio-filters, preventing desiccation of the compost to prevent dust formation, leachates collection and treatment etc.)

2. The agricultural sector

2.1 Agro-technical benefits
The agriculture sector role, as presented here, is an acceptor of municipal wastes. The compost, the end product after composting organic residuals, will be used in farmland and it has agro-technical advantages. In a dozen field studies (Avnimelech, 1995) it was shown that the addition of compost resulted a significant improvement of soil chemical composition, soil structural properties, increased water holding capacity (and less demand for irrigation) and increased crop yield. The use of compost was shown to be a very essential soil amendment in the Mediterranean, arid and semi arid regions soils, especially in cases when salinity is a problem. Under such conditions, application of compost (at rates of 20-40 m³/ha) leads to a 10-20% crop yield increase, or an approximate gross contribution of 20-40$/ton of compost (10-20$/ ton of waste) in the Israeli case (Avnimelech, 1995).

2.1 Increased plant resistance to diseases.
The use of composts results another benefit to the agriculture sector - increased plant resistance to diseases caused by pathogens (Hoitink & Fahy, 1986). Eventually, this role of organic matter will also reduce pesticide use.

2.3 Possible soil and crop pollution.
The application of compost may pollute soils if the compost is polluted with heavy metals, chemicals and even glass. According to a number of surveys all over the world, compost made from source separated municipal solid waste is well within the environmental standards. A clean organic waste is needed to produce high quality compost, compost that can be used without any suspected soil, water and crop contamination. If the organic fraction is separated at the source, even very high application rates of municipal composts from should not
lead to any problems of heavy metals accumulation in soils or plants in neutral and calcareous soils (Stilwell, 1993).

3. Economic considerations

The agreement between the municipal and the agricultural sectors should be based on economic efficiency. The agricultural sector will accept all wastes supplied if the benefits are higher than the costs. Part of the costs will be covered by the city (collection and treatment of the wastes) and parts by the farmers. In addition, environmental assets (i.e., open spaces) should be taken into account.

In order to assess the economic costs and benefits from the above-suggested agreement between the city and the agriculture sector, we have calculated the costs of waste management in a model city of 100,000 inhabitants, producing 150 ton of waste per day. Costs of collection and disposal of waste were obtained from municipalities in Israel, average tipping fees from plants in Europe and USA (Coopers & Lybrand, 1996, White et. al., 1995, Glenn, 1998).

The alternatives analyzed- landfilling of all the waste and composting the organic fraction (comprise 50% of the waste) and landfilling the inorganic fraction. The results are given in table 1.

TABLE 1
Discussion

In general, the agriculture sector is an essential element contributing significantly to the quality of life in the densely populated urban sector. It supplies oxygen, natural landscapes and other environmental services. In addition, the agriculture sector is a potent acceptor of increasing amounts of municipal wastes. Both partners gain economic and environmental benefits, but they could lose if several principals are not kept. The organic waste should be separated at source in commercial places like markets, supermarkets, restaurants etc., as well as separation of yard waste and organic residues at home, this will ensure the production of a clean compost. The composting process should be well managed in order to minimize dust and odors from the plant.

It will also be fair to state that the agriculture sector should be compensated for its services to the society, as long as this sector is committed to use water, fertilizers, pesticides and other resources according to national and international regulations and agreements.

Both the urban and the agricultural sectors can gain from a cooperation where waste produced in the city is utilized as a resource in farmland. It was shown that the main benefit from the suggested cooperation is environmental. Under the conditions and considerations discussed, there is a direct, insignificant, reduction of waste management costs to the city (17.5$ instead of 20$ per ton); a direct benefit of 5$ to the agricultural sector and an environmental benefit of 8$ per ton of waste. The total cost of implementing this city-agriculture waste cooperation will cost only 4.5 $ instead of 20$ per ton of waste, compared with the ‘traditional’ landfilling. This benefit can determine the cost sharing between the city and the agricultural sector and can create a market between the agricultural sector, a supplier of environmental services to the urban society, and the sustainable city.

Conclusions

It was demonstrated that both the city and the agricultural sector could gain from a cooperation in which the agricultural sector serves as an acceptor for the increasing amounts of the wastes produced in the city. It was demonstrated that a reduction in costs of municipal solid waste management and a significant environmental benefit could be achieved if the organic fraction of the waste is separated and composted and used in the agricultural sector. The specific gain was calculated for typical waste composition and agriculture in arid or semi-arid soils, areas threatened by shortage in water, desertification etc. It is plausible that different specific values will be relevant elsewhere, yet, the suggested approach should be valid nonetheless.
References


Ministry of Agriculture, 1996. Conclusions of the governmental technical committee for analyzing the use of compost from municipal solid waste (Hebrew).


Table 1: Direct and environmental costs and benefits of waste management.

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>landfill</th>
<th>compost + landfill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collection costs in the city</td>
<td>equal</td>
<td>=</td>
</tr>
<tr>
<td>Transportation to plants</td>
<td>equal</td>
<td>=</td>
</tr>
<tr>
<td>Cost of landfilling</td>
<td>20$/ ton of waste</td>
<td>3000$ 1500$</td>
</tr>
<tr>
<td>Cost of incineration</td>
<td>50$/ ton of waste</td>
<td></td>
</tr>
<tr>
<td>Cost of composting</td>
<td>15$/ ton of waste</td>
<td>1125$</td>
</tr>
<tr>
<td>Total direct costs to the city</td>
<td>3000$</td>
<td>2625$</td>
</tr>
<tr>
<td>(per 150 tpd produced)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total direct costs to the city</td>
<td>20$</td>
<td>17.5$</td>
</tr>
<tr>
<td>(per 1 ton of waste)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value of compost use</td>
<td>crop increase- 10$/ ton of waste</td>
<td>(-)10$ (*)</td>
</tr>
<tr>
<td>Cost of compost, transportation &amp; spreading</td>
<td></td>
<td>5$</td>
</tr>
<tr>
<td>Total direct benefit to agriculture</td>
<td></td>
<td>(-) 5$</td>
</tr>
<tr>
<td>Value of CO2 sequestration</td>
<td>22.5 ton dry composted matter/ day</td>
<td>(-)3$</td>
</tr>
<tr>
<td>45 ton CO2 sequestered</td>
<td>10$/ ton CO2</td>
<td></td>
</tr>
<tr>
<td>Avoided CH4 emissions from landfills</td>
<td>5$/ ton waste</td>
<td>(-)5$</td>
</tr>
<tr>
<td>Total environmental benefits</td>
<td></td>
<td>(-)8$</td>
</tr>
<tr>
<td>Unknown (costs and benefits):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation externalities (assumed to be equal in both alternatives). Soil and crop pollution. Increased water-holding capacity and plant resistance. Public opinion (NIMBY, positive responses to recycling). Reduced costs for open-spaces development and maintenance.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total costs (per ton of waste)</td>
<td>20$</td>
<td>4.5$</td>
</tr>
</tbody>
</table>

(*) Values having a negative sign represent a benefit.