Environmental impacts of different options for management of livestock waste in Cyprus

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In Cyprus the introduction of intensive farming operations has increased the amount of animal waste generated. The environmental problems derived from the concentration of animal waste in specific areas, marked by the insular nature of the country, require the development of sustainable solutions. These specific environmental impacts largely depend on the livestock production system, the management system and the environmental conditions. Conventionally, animal manure is widely applied on land as an organic fertiliser without further pre-treatment. In addition, anaerobic lagoon systems are relatively common at large livestock farms in Eastern European countries such as Cyprus. In this type of treatment, animal slurries, either before or after solids separation, are sent to anaerobic lagoons, where organic material is decomposed under anaerobic conditions, releasing polluting emissions to the atmosphere. In recent years, the treatment of animal waste in biogas plants notably increased in Europe. These plants use the anaerobic digestion process in order to partially convert the organic matter of the substrate into biogas (a gas rich in methane). This biogas can be employed in several ways. It can be directly burnt in a boiler to produce heat, used to co-generate both heat and electricity, upgraded for the natural gas grid or used as a fuel for vehicles. In addition, not only biogas is produced, but also a digested substrate, commonly referred as digestate. It is a nutrient-rich stream that can be also used as organic fertiliser for crop cultivation. Anaerobic digestion of animal manure offers several environmental advantages compared with conventional management such as i) lower dependence on fossil fuels through bioenergy production from biogas, ii) considerable reduction of odours, iii) and inactivation of pathogens.

The main objective of this study is to compare the environmental profile of different options for the management of livestock waste by means of Life Cycle Assessment (LCA) methodology. The animal waste considered in the evaluation consists of 94% pig slurry and 6% chicken manure. Four different scenarios have been considered in the study. In Scenario 1, animal waste is directly applied on land as an organic fertiliser; thus, avoiding mineral fertilisation. Scenario 2 includes the management of livestock waste in an anaerobic lagoon, without any pre-treatment. Scenario 3 separates the animal waste into its liquid and solid fraction. While the liquid fraction is sent to an anaerobic lagoon, the solid fraction is stored and applied on land as an organic fertiliser. Environmental credits due to avoided mineral fertilisation were also taken into account in this scenario. Scenario 3 comprises an anaerobic digestion plant, where animal waste is converted into biogas in order to produce electricity and heat. The total electricity produced is assumed to be supplied to the Cypriot national grid, whereas heat is used for self-consumption. Therefore, environmental credits due to avoided electricity production have been also considered in this scenario. In addition, the produced digestate is stored and applied on land as an organic fertiliser, avoiding the use of mineral ones. All processes included in the scenarios under study can be found in **Figure 1**.

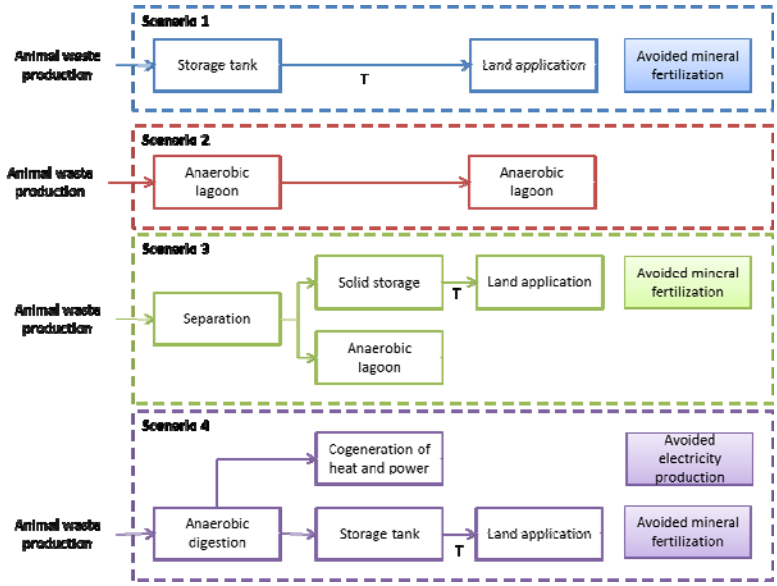

Figure 1. Flowchart of the scenarios under assessment

The environmental profile of the four management options have been obtained using the characterisation factors from ReCiPe Midpoint methodology in terms of 6 impact categories: climate change (CC), ozone depletion (OD),

terrestrial acidification (TA), freshwater eutrophication (FE), marine eutrophication (ME) and fossil depletion (FD). In addition, the Endpoint methodology has been used in order to obtain the single score of each scenario.

The results obtained highly depended on the impact category under study. Regarding CC, Scenario 2 achieved the worst result (396 kg CO_2 eq per ton of waste). The reason behind this was the high methane emissions that occurred during the anaerobic degradation of the organic matter in the anaerobic lagoon, which similarly occurred in Scenario 3 (173 kg CO_2 eq per ton of waste). However, the separation into solid and liquid fractions allowed that a lower amount of slurry went to the anaerobic lagoon. Scenario 1, achieved an intermediate position (60 kg CO_2 eq per ton of waste). The main contributor in this scenario was the emissions of methane produced in the storage tank of the farm. Finally, Scenario 4 achieved good results in this impact category (-39 kg CO_2 eq per ton of waste). These environmental benefits were achieved not only due to the environmental credits not only provided by avoided mineral fertilisation but also by the avoided electricity production from the grid, since the Cypriot electric profile is highly dependent on fossil sources. A similar behaviour was found in other energy-related categories such as OD and FD. All scenarios that used the animal waste or digestate as an organic fertiliser ended up in environmental benefits because of credits accrued from the avoided use of mineral fertilisers. Therefore, the worst results were achieved by Scenario 2, where all the animal waste was sent to an anaerobic lagoon. Scenario 4 reached the worst environmental result regarding TA (3.8 kg SO_2 eq/ton of waste), due to ammonia emissions from the storage and application of digestate. The reason behind this result was that, since during the anaerobic digestion process the organic nitrogen of the substrate is converted into ammonia nitrogen, the digestate content in ammonium nitrogen was slightly higher compared with the slurry. A similar result was achieved by Scenario 1 (3.7 kg SO_2 eq/ton of waste), because of high emissions of ammonia emitted during the storage and application of slurry. Scenario 2 and 3 released high emissions of nitrogen-based compounds in the anaerobic lagoon. However, only about half of this nitrogen was in the form of ammonia, the other half is mainly in the form of nitrogen gas, which is not detrimental to the environment. Therefore, the results regarding TA were around 2.5 kg SO_2/ton of waste for both scenarios. Regarding FE, phosphate emissions occur during the application of both organic and mineral fertilisers on land. Therefore, the results in this impact category were guided by the high avoided production of mineral phosphorus fertiliser. Since Scenario 1 and 4 applied all the substrate (animal slurry and digestate) on land, they achieved the best environmental results. The environmental impacts produced in ME were mainly due to emissions of nitrogen-based compounds such as nitrate. Nitrate leaching occurred after the application of organic and mineral fertiliser. Therefore, Scenarios 2 and 3 achieved better environmental results in this impact category since they applied less amount of substrate on land.

As shown, the environmental results high varied depending on the impact category. Therefore, the single score of the Endpoint methodology was used in order to identify the best animal waste scenario. Results obtained are shown in **Figure 2**.

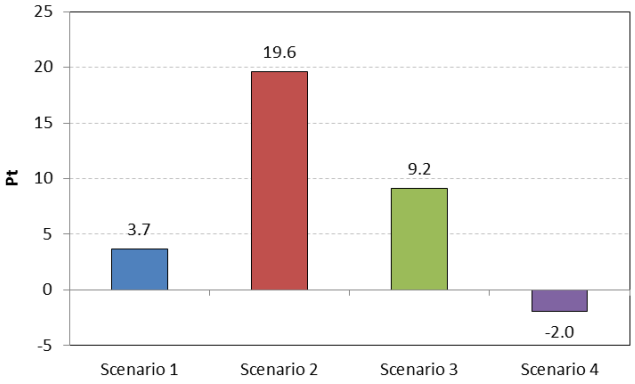

Figure 2. Single score obtained for each scenario under assessment

As shown in **Figure 2**, the worst management option from an environmental point of view was achieved when anaerobic lagoons were included (Scenarios 2 and 3). The best results were obtained when the animal waste was used as an organic fertiliser, but also as a source of bioenergy (Scenario 4).

The LIVE-WASTE project aims at minimising the environmental impacts associated to the management of animal waste in Cyprus, while producing different valuable products, such as biogas rich in hydrogen, high quality compost, struvite and a reusable effluent. Further research is being performed in order to assess the environmental performance of this innovative system and to compare the results with the abovementioned more conventional options of animal waste management.

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