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

LIFE LIVE-WASTE

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• The estimated total livestock heads in Cyprus in 2011 were more than 4,400,000; which would mean that around 1,850,000 tons of manure.

• Cyprus faces water shortage problems ⇒ seasonal rainfall disparity, seawater penetration into the island’s water table and lack of natural water retention areas.

• Cyprus has few indigenous energy sources ⇒ its power system depends on imported oil.
<table>
<thead>
<tr>
<th>Number of animals</th>
<th>Manure production factor</th>
<th>Total manure production</th>
<th>Direct application</th>
<th>Anaerobic lagoons</th>
<th>Anaerobic digestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>(head)</td>
<td>(t/head·year)</td>
<td>(t/year)</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Cattle</td>
<td>55,975</td>
<td>10.8</td>
<td>604,530</td>
<td>93%</td>
<td>7%</td>
</tr>
<tr>
<td>Pigs</td>
<td>437,420</td>
<td>1.89</td>
<td>826,724</td>
<td>70%</td>
<td>30%</td>
</tr>
<tr>
<td>Sheep</td>
<td>255,540</td>
<td>0.64</td>
<td>163,546</td>
<td>100%</td>
<td>-</td>
</tr>
<tr>
<td>Goats</td>
<td>214,720</td>
<td>0.64</td>
<td>137,421</td>
<td>100%</td>
<td>-</td>
</tr>
<tr>
<td>Poultry</td>
<td>3,440,000</td>
<td>0.034</td>
<td>116,960</td>
<td>89%</td>
<td>11%</td>
</tr>
</tbody>
</table>
Objective: Comparison of the environmental profile of different options for the management of livestock waste in Cyprus

Materials and methods

Goal and scope definition

Inventory data collection

Interpretation

Impact assessment

<table>
<thead>
<tr>
<th>Environmental results</th>
<th>Impact categories</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change</td>
<td></td>
<td>10</td>
<td>60</td>
<td>-1</td>
</tr>
<tr>
<td>Acidification</td>
<td></td>
<td>5</td>
<td>15</td>
<td>-5</td>
</tr>
<tr>
<td>Eutrophication</td>
<td></td>
<td>0.8</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Inputs from technosphere

- Electricity: 1000 kWh
- Chemicals: 50 kg

Outputs to Environment

- CH₄: 60 kg
- N₂O: 0.1 kg

Conclusions

Recommendations

Improvement options

Raw materials, fossil fuels and water

Emissions to air, water and soil

Identification of environmental hotspots

Environmental credits ➔ resources recovery
Materials and methods

Scenario 1

Animal waste production → Anaerobic lagoon

Scenario 2

Animal waste production → Solid/liquid separation → Anaerobic lagoon → Solid storage → Land application

Avoided mineral fertilisation

Life
Scenario 3

Animal waste production → Storage → Transport → Land application → Avoided mineral fertilisation

Scenario 4

Animal waste production → AD → Storage → Bioenergy production → Electricity → Avoided electricity production

Life

LIVEWASTE
Materials and methods

Scenario 5 – LiveWaste project

Animal waste production

Anaerobic digestion

BTF

Solid/liquid separation

BF + AC

Biogas upgrading

Struvite reactor

SBR

Compost unit

Effluent reuse

Land application

Avoided natural gas use

Avoided water use & mineral fertilisation

Avoided peat use & mineral fertilisation

Natural gas grid

Avoided water use & mineral fertilisation
Materials and methods

Functional unit:

1 ton of livestock waste treated

System boundaries:

- Production of inputs and energy: electricity, transport, infrastructure and chemicals.
- Direct emissions: transport, CHP, storage, land application.
- Environmental credits: electricity production and manure and digestate applied on land can replace electricity from fossil fuels and mineral fertilisers.
Materials and methods

ReCiPe Midpoint Methodology

Characterisation results
- Climate change (CC)
- Ozone depletion (OD)
- Photochemical oxidant formation (POF)
- Fossil depletion (FD)
- Water depletion (WD)
- Terrestrial acidification (TA)
- Freshwater eutrophication (FE)
- Marine eutrophication (ME)
Comparative results - characterisation

**Climate change**

- **Scenario 1**: 500 kg CO$_2$ eq/FU
- **Scenario 2**: 200 kg CO$_2$ eq/FU
- **Scenario 3**: 100 kg CO$_2$ eq/FU
- **Scenario 4**: 50 kg CO$_2$ eq/FU
- **Scenario 5**: 0 kg CO$_2$ eq/FU

**Ozone depletion**

- **Scenario 1**: -2.0E-06 kg CFC-11 eq/FU
- **Scenario 2**: 0 kg CFC-11 eq/FU
- **Scenario 3**: 2.0E-06 kg CFC-11 eq/FU
- **Scenario 4**: 8.0E-06 kg CFC-11 eq/FU
- **Scenario 5**: 6.0E-06 kg CFC-11 eq/FU

**Photochemical oxidant formation**

- **Scenario 1**: 0.20 kg NMVOC/FU
- **Scenario 2**: 0.10 kg NMVOC/FU
- **Scenario 3**: 0.00 kg NMVOC/FU
- **Scenario 4**: 0.10 kg NMVOC/FU
- **Scenario 5**: 0.20 kg NMVOC/FU

**Fossil depletion**

- **Scenario 1**: -10 kg oil eq/FU
- **Scenario 2**: -5 kg oil eq/FU
- **Scenario 3**: 0 kg oil eq/FU
- **Scenario 4**: 5 kg oil eq/FU
- **Scenario 5**: 10 kg oil eq/FU

*Life* program and *LIVEWASTE*.
Comparative results - characterisation

**Water depletion**

- Scenario 1: 0 kg m$^3$/FU
- Scenario 2: -0.05 kg m$^3$/FU
- Scenario 3: -0.1 kg m$^3$/FU
- Scenario 4: -0.15 kg m$^3$/FU
- Scenario 5: -0.2 kg m$^3$/FU

**Terrestrial acidification**

- Scenario 1: 0.5 kg SO$_2$ eq/FU
- Scenario 2: 1 kg SO$_2$ eq/FU
- Scenario 3: 1.5 kg SO$_2$ eq/FU
- Scenario 4: 2 kg SO$_2$ eq/FU
- Scenario 5: 3 kg SO$_2$ eq/FU

**Freshwater eutrophication**

- Scenario 1: 0.5 kg P eq/FU
- Scenario 2: 0.2 kg P eq/FU
- Scenario 3: 0 kg P eq/FU
- Scenario 4: 0 kg P eq/FU
- Scenario 5: -0.1 kg P eq/FU

**Marine eutrophication**

- Scenario 1: 0.8 kg N eq/FU
- Scenario 2: 0.6 kg N eq/FU
- Scenario 3: 0.4 kg N eq/FU
- Scenario 4: 0.2 kg N eq/FU
- Scenario 5: 0 kg N eq/FU
Comparative results – normalisation

- **Scenario 1**: 1.48
- **Scenario 2**: 0.68
- **Scenario 3**: 0.12
- **Scenario 4**: 0.09
- **Scenario 5**: 0.03
Production of **valuable products** (bioenergy and organic fertilisers) helps to offset environmental burdens \(\rightarrow\) replacement of potentially polluting processes.

- **Anaerobic lagoons** are a source of pollutants. In addition, this waste disposal process does not produce any valuable product.

- **Direct application** achieved intermediate results since a fraction of the nutrients present in the manure are uptaken by the plants and thus avoiding mineral fertilisers.

- **Biogas plant** exhibited the best environmental results in terms of energy-related categories since it avoids the production of electricity. However, environmental burdens were identified in TA due to the large content of ammonium in the digestate.

- **LiveWaste system** attained the best global environmental results since it reduces pollution and produces several valuable products from the gas, liquid and solid streams.
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