Nutrient recycling from bio-digestion waste as green fertilizers

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INTRODUCTION

In the transition from a fossil to a bio-based economy, it has become an important challenge to maximally recuperate valuable nutrients coming from waste streams. Nutrient resources are rapidly depleting, significant amounts of fossil energy are used for the production of chemical fertilizers, whereas costs for energy and fertilizers are increasing. In the meantime, biogas production through anaerobic digestion produces nutrient-rich digestates. In high-nutrient regions, these products cannot or only sparingly be returned to agricultural land in its crude unprocessed form. The consequent processing of this digestate requires a variety of technologies producing a lot of different derivatives, which could potentially be re-used as a green substitute for fossil-based mineral fertilizers. This sustainable development strategy is completely in line with the **cradle-to-cradle approach** (Figure 1): Waste turns into secondary resources.

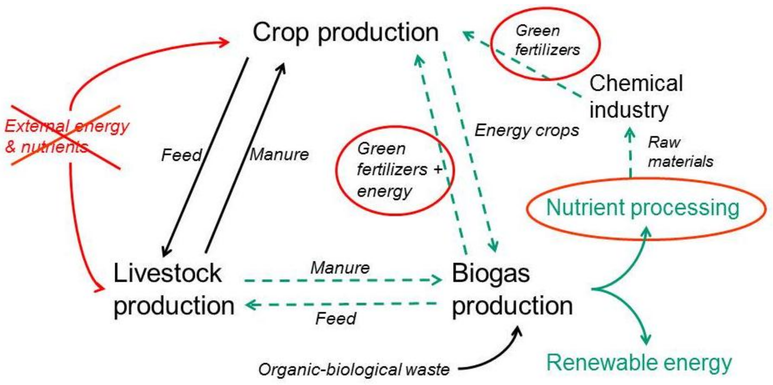


Figure 1. Visualization of the cradle-to-cradle approach

OBJECTIVES

This research aims:

1. To create a **systematic overview of the available technologies** for nutrient recuperation, as well as to sort the diverse digestate streams (end- and side products) into different **classes**.

2. To construct diverse **pilot plants** for nutrient recuperation: at least one for separation, struvite production and NH_3-stripping.

3. To characterize the **physico-chemical properties** of the various digestate derivatives, with attention for general conditions, conductivity and pH, macronutrients and their speciation, essential and non essential trace elements, organic carbon and nutritive ratios.

4. To identify **potential bottlenecks for agricultural re-use** of these products.

5. To assess **field experiments** in order to evaluate the impact on soil and crop production in a concept of cradle-to-cradle re-use of valuable macro- and micronutrients. Hereby, **nutrient balances** will be set up.

6. To study the **legislative aspects** for application of these nutrient streams as artificial fertilizer directly on agricultural fields or as raw resource for the chemical industry in and outside Flanders.

7. To explore and frame the different **pathways for marketing**, as well as to evaluate the **marketing value**.

RESULTS (1)

Physico-chemical analysis of potential green fertilizers

- **Concentrates from membrane filtration (RO) of the liquid fraction of digestates**

Fertilizer value:
  - N-content: 6.4±0.4 kg t^{-1} FW (> animal manure)
  - Nitrogen Uptake Efficiency: 82 % (> animal manure)
  - K_2O-content: 5.2±3.2 kg t^{-1} FW (> animal manure)

  → **Potential N-K green fertilizer**

Potential bottlenecks for agricultural re-use:
  - Salt content: risk for soil degradation
  - Sodium adsorption ratio: risk for soil compaction
  - K-content: risk of head-illness in cattle

- **Waste water from acidic air scrubbers for ammonia removal**

Fertilizer value:
  - N-content: 23±9 kg t^{-1} FW (> animal manure)
  - Nitrogen Uptake Efficiency: 100 % (> animal manure)
  - S-content: ± 34 kg t^{-1} FW (> animal manure)

  → **Potential N-S green fertilizer**

Potential bottlenecks for agricultural re-use:
  - Salt content: risk for soil degradation
  - H_2S-formation: toxic at low concentrations
  - Corrosive and acidifying properties

- **Comparison green and conventional fertilizers**

Fertilizer	N/P/K	C/N	Nitrogen Uptake Efficiency	Sodium Adsorption Ratio
Animal manure	8.8/1/1.6	4.9	60%	0.12
Digestate	2/1/1.6	11	81%	1.5
Liquid fraction digestate	8.8/1/7.1	2.2	77%	3.2
Concentrate	15/1/8.6	2.7	82%	2.1
Air scrubber water	-	-	100%	-

RESULTS (2)

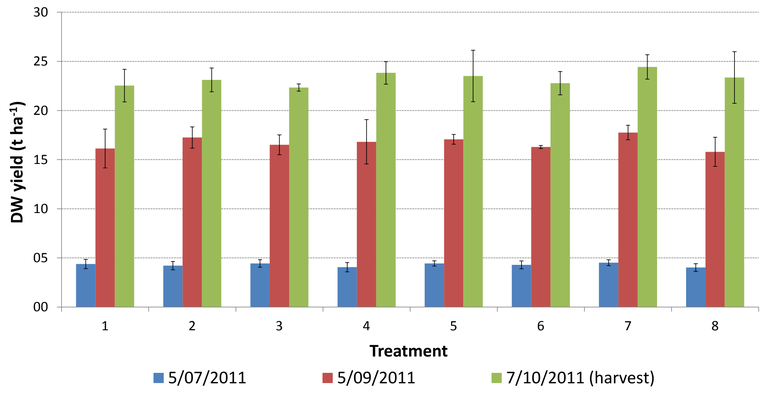
Field experiment

- **Treatments (n=4)**

Object	Start fertilizer	Animal manure	Artificial N	Air scrubber water	50% digestate 50% LF* dig.	LF* digestate	Artificial K_2O
1	X	X	X	-	-	-	X
2	X	X	-	X	-	-	X
3	-	X	-	X	-	-	X
4	X	-	X	-	X	-	X
5	X	-	-	X	X	-	X
6	-	-	-	X	X	-	X
7	X	X	-	-	-	X	X
8	-	X	-	-	-	X	X

*LF = Liquid Fraction

- **Dry weight biomass yield (t ha^{-1}; n = 4)**



Fertilization
29/04/2011

Energy maize ± 30 cm
19/06/2011

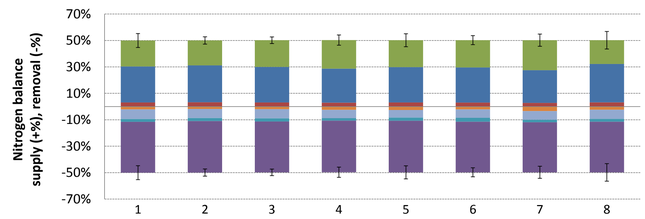
Energy maize ± 3.6 m
20/08/2011

RESULTS (3)

Nutrient balances (2011)*

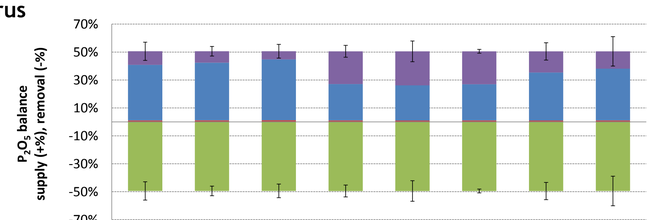
* Nitrogen modeling was conducted with NDICEA 6.0.16 (Van der Burgt et al., 2006)

- **Nitrogen**



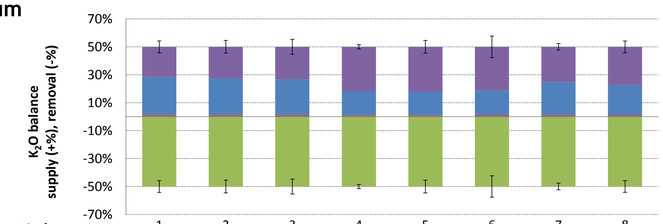
kg N ha^{-1}	1	2	3	4	5	6	7	8
Decomposition organic matter	156	145	162	182	165	169	206	142
Manure supply	216	216	216	217	217	217	225	230
Deposition	25	25	25	25	25	25	25	25
Removal with products	-306	-301	-309	-329	-317	-313	-344	-303
Volatilization	-17	-18	-19	-16	-19	-24	-17	-17
Leaching/denitrification subsoil	-58	-53	-56	-53	-47	-52	-60	-55
Denitrification topsoil	-17	-14	-16	-21	-21	-18	-31	-19

- **Phosphorus**



kg P_2O_5 ha^{-1}	1	2	3	4	5	6	7	8
Calculated deficit	27	22	15	67	72	68	46	35
Manure supply	108	108	108	74	74	74	105	105
Deposition	3	3	3	3	3	3	3	3
Removal with products	-135	-130	-123	-141	-146	-142	-151	-140

- **Potassium**



kg K_2O ha^{-1}	1	2	3	4	5	6	7	8
Calculated deficit	144	157	163	268	279	254	185	209
Manure supply	181	181	181	145	145	145	173	166
Deposition	8	8	8	8	8	8	8	8
Removal with products	-333	-346	-352	-420	-431	-406	-366	-383

CONCLUSIONS AND FUTURE PERSPECTIVES

- Concentrates from membrane filtration of the liquid fraction of digestates show potential as green N-K fertilizer, whereas waste water from ammonia air scrubbers shows potential as formulated N-S fertilizer.
- For the field experiment, no significant (α = 0.05) differences were observed in the dry weight biomass yield for the different treatments during the harvest, nor in the dry weight content itself (± 28-29 %).
- Nitrogen balances are roughly similar for each scenario and in equilibrium. In all scenario's the crop demand was covered by the availability of N.
- Significantly less P_2O_5 was applied to the soil in scenario's 4, 5 and 6, yet a higher P_2O_5 uptake by the crops was observed in these scenario's.
- The crop K_2O uptake was significantly (α = 0.05) higher for scenario 4, 5 and 6 compared to the reference, while approximately three times less artificial K_2O was used in these scenarios.
- No significant (α = 0.05) differences in soil salt content, sodium adsorption ratio, pH-H_2O and pH-KCl were observed at the end of the growing season.
- Substitution of conventional fertilizers by membrane filtration concentrates or air scrubber water theoretically results in significant economic and ecological benefits for the agriculturist.
- Nutrient balances were modeled with one year data. Further field research is on-going in order to evaluate the impact on soil quality, fertility and chemistry by application of these new green fertilizers in the longer term.

CONTACT

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