The influence of fertiliser rates on UK biomass crop sustainability

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Why should we address sustainable biomass production?
UK’s renewable energy strategy

Bioenergy and energy crops are an important part to reach GHG reduction target of 80 % by 2050

By 2020, renewable electricity up to 30 % from 5.5 % today and renewable heat up to 12 % from today

Substantial amounts of indigenous and imported biomass

- 2.2 Mha of energy crops by 2030 (16,000 % increase of miscanthus from existing 7500 ha) (E4Tech summary for DECC)
Biomass sustainability beyond GHG’s

Renewable Energy Directive (RED) and Cramer framework consider the following sustainability issues:

- Preservation of biodiversity – biomass should strengthen not endanger biodiversity
- Monitoring of biomass cultivation by the EC to ensure agricultural productivity is maximised (inc land-use change, food production and biodiversity)
- Quality of soil, water and air is retained or increased
- Loss of carbon in soil is accounted for in GHG calculations and considered when converting land
Therefore...

When considering large-scale biomass cultivation in the UK...

- We should consider beyond GHG’s when evaluating sustainability
- Examine biodiversity as recommended by the developing legislation

This study assesses the life-cycle environmental impact of energy crop production and considers acidification and eutrophication as well as the impact of global warming
What is a Life Cycle Assessment?
Life Cycle Assessment

Assesses the **environmental impacts** of a product or process from cradle-to-grave

The four key steps are:
- Goal and scope
- Inventory analysis
- Impact assessment
- Interpretation

Use SimaPro 7.1 and Ecoinvent database
Goal and Scope

Determine environmental impacts for large-scale biomass cultivation under UK agronomic practice, using different fertiliser options for crop nutrition

Sensitivity analysis assessed:
- Impact of $N_2O$ emissions on total GHG emissions
- Influence of crop yield per unit area, which could be expected to fluctuate in response to N fertiliser, crop breeding and climate change

Emission allocation from waste disposal was investigated
- It can be argued that emissions released from sewage sludge application should be attributed to either the wastewater treatment companies or the grower
The functional unit in this study was 1 MJ biomass delivered to end user
• Compared to 1 MJ natural gas delivered to the UK

In practice, the biomass and natural gas would be utilised by the end-user
Overview of Bioenergy system
System definition and inventory

Ground preparation (primary and secondary) → Planting → Harvesting and restoration → Transportation of biomass → Utilisation of biomass

- Glyphosate, Diesel
- Cuttings, Rhizomes, Sewage Sludge, NPK Fertiliser, Pesticide, Diesel
- Airborne Emissions
- Potential Leaching, Emissions to Biosphere
- Airborne Emissions
- Airborne Emissions
Fertiliser application scenarios

For both crops, the following fertiliser scenarios were assessed:

• No fertiliser
• Inorganic fertiliser
• Sewage sludge as digested cake

Sewage sludge is a “co-product” of waste disposal

• Allocation typically based on mass, economic or energy ratios

Defra indicate 30 % of N in sludge available as crop nutrient over 3 years

• Sensitivity analysis considers 3 emissions allocation factors (0, 30 and 100 %)
Results of impact assessment
Impacts considered for assessment

Global Warming Potential (GWP)
- Measurement of a greenhouse gas contribution to global warming, kg CO$_{2eq}$

Eutrophication Potential (EP)
- Change in the amount of chemical nutrients in the surrounding land and water
- P and N contribute from fertiliser application
- Decrease of biodiversity and increase algae

Acidification Potential (AP)
- Measures damaging effects of the conversion of SO$_2$ and NO$_x$ into acids
- Cause nutrients to be washed out of soils, change soil pH levels and result in an increase in soil heavy metal content
Miscanthus impact assessment

![Graph showing Miscanthus impact assessment](image)
Global Warming Potential

Substantial reduction in GWP compared to delivery of 1 MJ natural gas

Small difference between different agronomic variations

Applying inorganic fertiliser, GWP increases by 2% compared to zero fertiliser control due to ammonium nitrate production
- Sewage sludge less extent – less intensive to produce

Assumes land-use reference system of arable land
- No carbon credit or penalty for land-use change
- RFA and RED do not currently include credits for land-use systems
Eutrophication and Acidification Potential

Applying inorganic fertiliser increases EP by 450 % for miscanthus
- Leaching of nitrates and phosphates
- Variation in these levels expected with soil and drainage conditions

Assuming 30 % of emissions from sludge application were allocated to grower
- AP would increase by 650 % compared to inorganic fertiliser application
- Volatilisation of NH$_3$

Compared to land-use reference system, biomass cultivation may improve EP and AP
Emissions factor for $\text{N}_2\text{O}$

$\text{N}_2\text{O}$ has 298 times more impact to GWP compared to $\text{CO}_2$, over a 100 year period.

When applying fertiliser, $\text{N}_2\text{O}$ emissions from soil contribute to GWP. Influenced by:

- Environmental factors (climate, soil organic C content, drainage and soil pH)
- N management (fertiliser type, application rate and crop type)

$\text{N}_2\text{O}$ emission factor varied from 0 - 3 % to comply with IPCC upper uncertainty range.

- Results in a maximum 1.2 % change in GWP for miscanthus with sewage sludge.
- Insignificant compared to the large reduction against fossil fuel equivalent.
GWP savings per unit area

If yield increase from applying fertiliser, amount of crop harvested per unit area increases

- Also, GWP savings per unit area may increase

Requires marginal yield increase $< 0.2 \text{ t/ha}$ from use of additional 25 kg/ha N fertiliser for the benefit of increased yield to outweigh the GWP cost of applying fertiliser

- Grower applies N fertiliser based on economics of yield increase
- If financially worthwhile, also achieve optimum yield and optimum GWP savings
Conclusions

• Miscanthus and SRC willow grown under typical UK conditions have substantial GWP savings compared to fossil fuel alternatives

• Applying fertiliser results in large increase in EP and AP

• Considering GWP per unit area means only small yield increase required for application of N fertiliser to be beneficial for GWP savings

• Varying IPCC N$_2$O emissions factor had marginal impact on results

• Emissions allocation split between wastewater treatment and crop growth is significant for EP and AP
  – Should be considered when developing legislation for bioenergy