The influence of fertiliser rates on UK biomass crop sustainability

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for Climate Change Research

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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)*

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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

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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

Functional unit

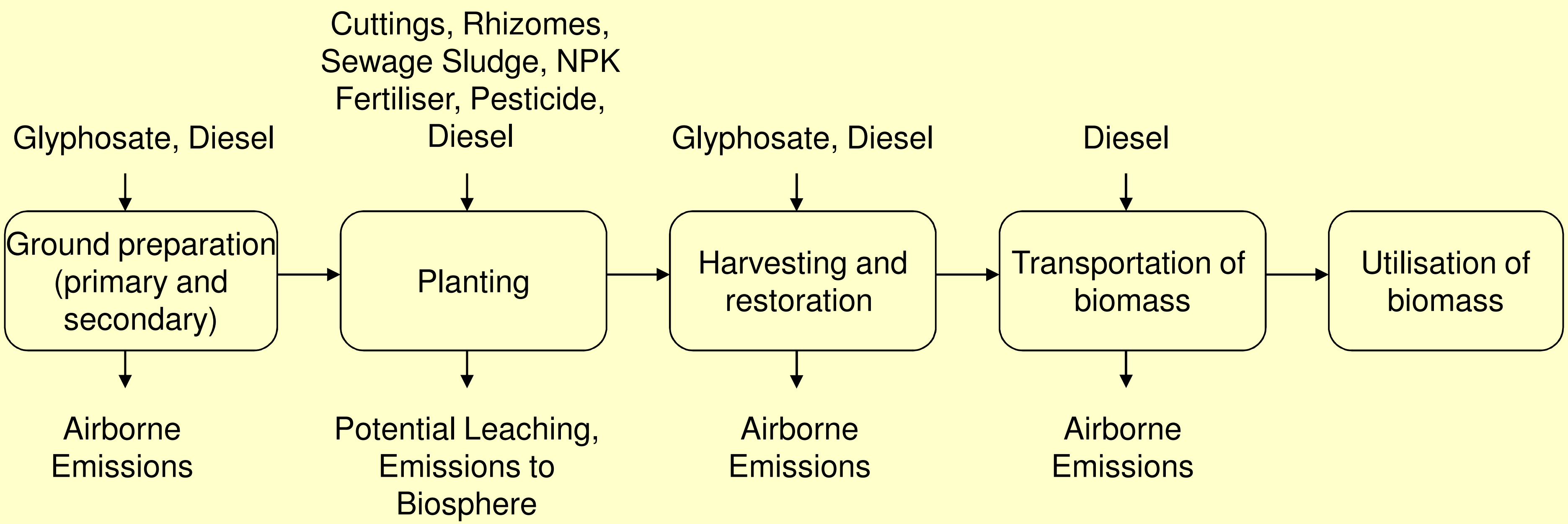
The functional unit in this study was 1 MJ biomass delivered to end user

- 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



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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 %)

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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

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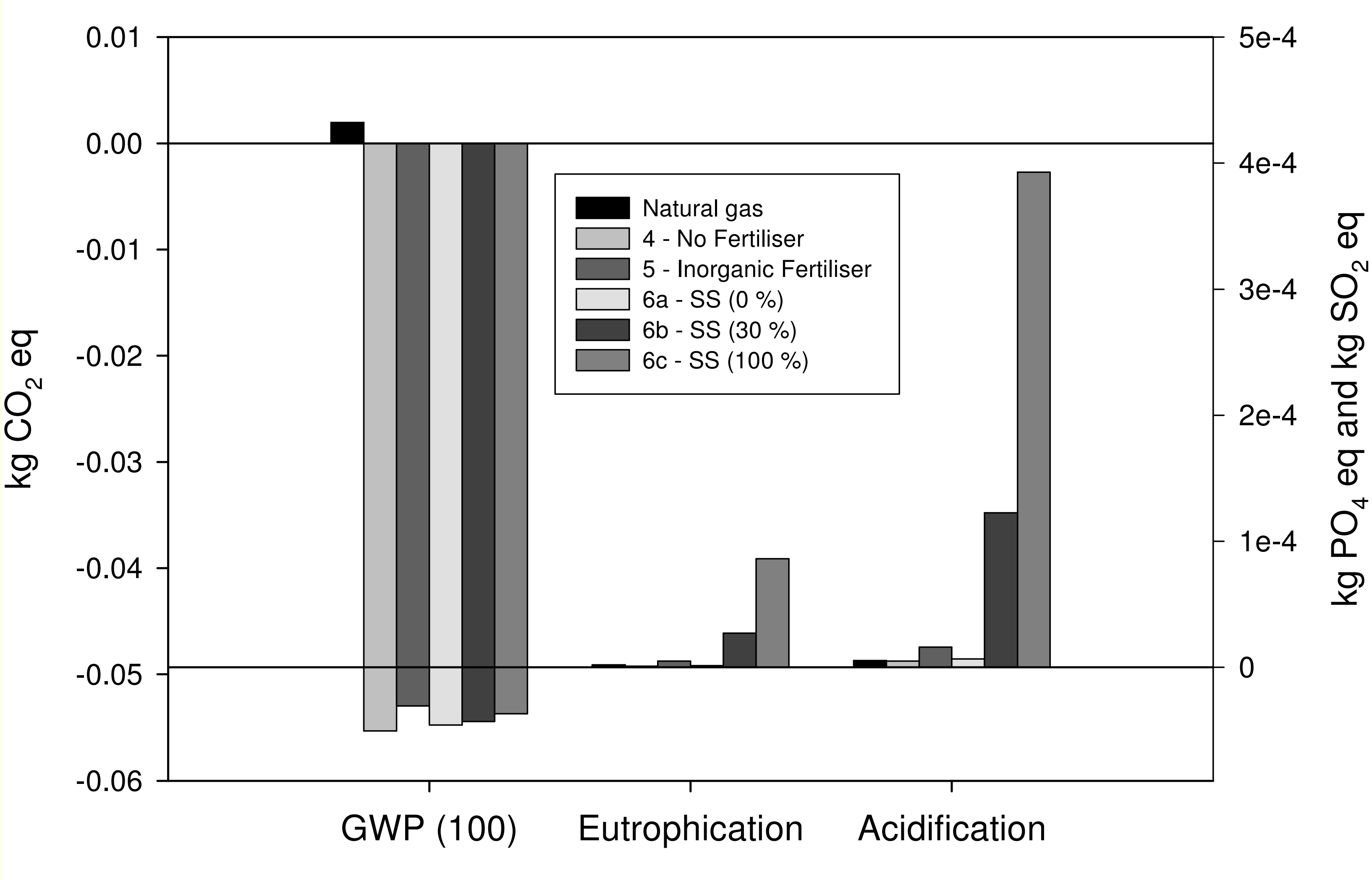
Miscanthus impact assessment



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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

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Emissions factor for N_2O

N_2O has 298 times more impact to GWP compared to CO_2, over a 100 year period

When applying fertiliser, N_2O 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)

N_2O 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

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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 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_2O 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