NATURAL ENVIRONMENT RESEARCH COUNCIL

Centre for Ecology & Hydrology
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Early Career Researchers' Bioenergy Symposium

21st and 22nd March 2013

Centre of Ecology and Hydrology
Lancaster Environment Centre
Lancaster, UK

Abstracts and Event Programme

Bioenergy Symposium 2013
CEH Lancaster, UK
21st/22nd March 2013

Land use change for perennial energy crops

Amy Thomas - *School of Environmental Sciences, University of East Anglia, Norwich Research Park, Norwich, Norfolk, NR4 7TJ* - Amy.Thomas@uea.ac.uk

Mapping for England indicates 2,409,541 ha suitable for cultivation of miscanthus within 40km of co-firing or CHP potential end uses. Of these 63% is currently used for arable crops. Where perennial bioenergy cultivation replaces annual crops, cessation of tillage may have significant effects on soil atmosphere exchanges. These impacts will also be affected by soil texture and drainage.

There is often a focus on potential for increased C storage under no till conditions, however some field studies have measured increased N_2O. Given the high global warming potential of N_2O, impacts on nitrogen cycling must therefore also be considered to assess whether the GHG emissions savings promised by bioenergy can be fulfilled. Structural changes to soil can cause significant change in N_2O balance, and it is useful to predict these using modelling approaches.

Modelling of tillage is usually either by application of factors to alter rates of processes, or via a change in bulk density to simulate these changes indirectly. The DayCent model has been developed to give improved simulation of tillage regime using existing equations as appropriate. The process is complicated by the need to fit with existing structure of the model, and the absence of equations to represent impact on certain properties such as macropore network tortuosity.

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Analysis of the plant cell-wall glycome to optimise bioenergy and biorefining applications of biomass feedstocks

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Background

Today's increasing demand for fossil fuels is putting a massive strain on a resource that is finite by nature. Lignocellulosic biomass, including that from the energy crop *Miscanthus*, is one of the most abundant renewable resources available, and its energy rich polysaccharides can be converted into biofuels and a whole range of biomaterials. However, despite its potential use as a widespread feedstock, lignocellulosic biorefining is hampered by the cell-wall recalcitrance to saccharification. By deepening our knowledge of the intricate cell-wall composition and organisation, lignocellulosic biorefining efficiency will be improved.

Methodology

Different composition and concentrations of cell-wall polysaccharides and phenolic compounds results in variable levels of biomass digestibility. In order to uncover which factors actually influence this variability we selected twenty-five *Miscanthus* genotypes representing a wide range of compositional variability, performance in saccharification trials and yield, to conduct an in-depth analysis of its lignocellulosic biomass, with a particular focus on the cell wall glycome. A combination of cell biological and biochemical approaches will be applied, which among others include the analysis of cell-wall polysaccharides using glycan microarrays and a variety of chromatography based hyphenated techniques for the quantification of structural carbohydrates and phenolics. The obtained information will then be integrated with saccharification and fermentation data in order to link the cell-wall composition with its performance in downstream processes.

Outcomes

This study will provide a detailed understanding of how different compositional characteristics, including that of the cell-wall glycome, link to the saccharification of cell-wall biomass. This is essential for the tailoring of more effective biorefining treatments to specific cell-wall types, and also for the breeding of biomass feedstocks with desired characteristics for conversion to biofuels and biomaterials.

Characterising the functional role of mycorrhizal fungi in *Miscanthus* bioenergy cropping systems

Caitlin Burns - *School of Life Sciences, Gibbet Hill, University of Warwick, Coventry, CV4 7AL* - C.Burns@warwick.ac.uk

Arbuscular mycorrhizal fungi (AMF) live in symbiosis with around 80% of plant species, and broadly increase plant yield, biomass, disease resistance and shoot P. Plants exchange carbon sugars for nutrients scavenged by AMF, including phosphate. There is little known about AMF in association with *Miscanthus*, a productive bioenergy crop grown in the UK and abroad. My hypotheses are, 1) AMF are present in *Miscanthus* in UK bioenergy cropping systems, 2) AMF are beneficial for plant growth and nutrition. Field samples from Lincolnshire were analysed using molecular and staining techniques. AMF were found to be present in *Miscanthus* roots. Miscanthus was then grown in the glasshouse, with field soil and commercial rhizomes. There were two treatments; ‘Mycorrhizal’ and ‘Fungicide reduced-mycorrhizal’. After 6 months growth, ‘Mycorrhizal’ *Miscanthus* had significantly greater biomass. Future experiments will be conducted to determine if AMF inoculation improves *Miscanthus* growth, and which AMF species colonise *Miscanthus* best. AMF are present, and may benefit *Miscanthus* growth and nutrition.

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A new method of measuring trace gas emissions from bio-energy crops

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Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the most important biogenic greenhouse gases (GHGs).

Net ecosystem exchange (NEE) is quantified by measuring all sources and sinks, which exist in soils and vegetation and are highly heterogeneous.

Existing small-scale techniques for measuring GHG fluxes, such as chamber methods cannot sample from over tall vegetation. Eddy covariance is used to measure landscape fluxes of CO_2, but is rare for CH_4 and not available for N_2O. It is subject to stringent fetch limitations and cannot resolve down to the plot scale.

We will describe the development of a new technique able to measure NEE of CO_2, CH_4 and N_2O from tall vegetation at high frequency and high spatial resolution allowing manipulative field experiments to be conducted on a plot scale.

The Impact of *Miscanthus* on Soil Carbon

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Bioenergy crops have a unique role in the provision of renewable energy and it is expected to make a considerable contribution as an alternative to fossil fuel. The growing of energy crops to replace fossil fuels has been widely suggested as a key strategy in mitigating anthropogenic CO_2 emissions. However, in order for the production of energy crops to be truly sustainable, the energy balance needs to be favourable. This cannot be assessed without taking into account the full lifecycle of these crops. Many studies have been carried out with regard to both above ground and below ground impacts, but few consider the above and below ground impacts simultaneously.

The Ecosystem Land Use Modelling (ELUM) project, commissioned and funded by the ETI (Energy Technologies Institute), aims to provide the data required for a full life cycle assessment associated with the sustainability of bioenergy crop deployment with land use change across the UK. The project focuses on soil organic carbon (SOC) beneath bioenergy crops in order to determine C dynamics, and the potential ability to sequester C below these crops.

The aim of my project is to investigate the impact of the energy crop Miscanthus on soil carbon and greenhouse gas (GHG) fluxes. My project focuses on the processes by which energy crops interact with SOC, with an emphasis on different Miscanthus genotypes. This is predominantly a field based project working on up to 14 different genotypes of Miscanthus all in triplicate plots as well as some glass house experiments. Above ground characteristics such as yield, litter drop and crop establishment are being assessed in order to determine any correlation with GHG soil fluxes, root activity and soil content. It is expected that due to the variety of genotypes and their physical differences, that there will be differences below-ground, but will these differences depict a potential winner in C sequestration potential?

This data will contribute to a UK-wide modelling of soil carbon under Miscanthus to provide a comprehensive source of evidence-based information for use by policy makers.

Land Use Change to Bioenergy: A quantitative analysis using meta-analytical methods

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There is an ever increasing need to address the current state of energy use in the UK to move towards a cleaner and more sustainable alternative to fossil fuels. Bioenergy is one of the proposed solutions which could provide a carbon neutral source of both electricity and liquid transport fuels by negating any emissions produced from burning the gases by sequestering them throughout their life time of growth. In order to meet our energy needs from bioenergy, land will need to be converted to allow for mass cultivation which will cause changes in the GHG balance of the land. Through an extensive literature analysis and meta-analysis of the current literature, this talk will address how much we currently know about land use conversions to bioenergy and where future research will need to be targeted to better our understanding.

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The understanding of biodiversity in mycorrhizal associations within bioenergy crops is essential in understanding ecosystem functioning

Chris Barnes - *School of Life Sciences, Gibbet Hill, University of Warwick, Coventry, CV4 7AL* - C.J.Barnes@warwick.ac.uk

Bioenergy crops occupy a growing proportion of farmland within the UK. Yet little is known about their effect on biodiversity. Mycorrhizal fungi are soil fungi that form symbiotic associations with plant roots, including those of energy crops. Their presence can influence plant diversity and vitality, by assisting their host in gathering nutrients. In return however, the plant sacrifices significant proportions of its carbon resource. Given the importance of mycorrhizal fungi within an ecosystem the area is relatively understudied. Are they diverse given that the aboveground system is homogenous? If so, do they follow traditional ecological rules, such as seasonal cycling and succession patterns? Do they respond to environmental parameters? In this presentation I will be answering these questions and explaining how these may effect *in situ* ecosystem functioning.

The Feasibility of Anaerobic Digestion of Species-Rich Upland Meadow Grass

Lynda Sainty - *CNAP (M2), Department of Biology, University of York, Wentworth Way, York, YO10 5DD* - rs32@york.ac.uk

Poor soil fertility and traditional agricultural management support meadows of high species richness in the UK uplands. These meadows are rare habitats, protected for their plant diversity and heritage. However, due to low farm incomes and a long downward trend in grazing animal numbers, concerns have been raised that they could be abandoned.

Therefore this research is investigating the technical, environmental and economic feasibility of using species-rich upland meadow grass as a feedstock for anaerobic digestion (AD), with the aims of energy production and habitat conservation.

AD is a complex microbiological process, breaking down organic feedstocks in the absence of oxygen to produce biogas, which contains 55-70% methane. The methane can be used to produce energy or fuel.

The research is broken into 3 sections: (i) AD of upland species-rich and species-poor grass, assessing methane production; (ii) life cycle assessment to compare the environmental effects of present land use and land managed for AD; (iii) economic analysis of setting up and running an AD plant in the uplands, to include subsidies required and jobs created. Data will be presented from section (i); sections (ii) and (iii) are yet to be performed.

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Biochar effects on soil invertebrate communities and soil processes in a temperate mesocosm experiment

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Production of biochar, the recalcitrant residue formed by pyrolysis of plant matter, is suggested as a means of increasing stable carbon (C) storage in the soil[1]. Biochar has also been shown to increase the productivity of certain crops due to its ability to reduce nutrient leaching and improve soil water-holding capacity. However, the response of soil carbon pools to biochar addition is not yet well understood. Studies have shown that biochar has highly variable effects on microbial C cycling and thus on soil C storage[2,3,4]. This discrepancy may be partially explained by the response of soil invertebrates at higher trophic levels which regulate microbial activity. This research aims to understand the role of soil invertebrates (i.e. Collembola and nematode worms) in biochar-mediated changes to soil C dynamics and greenhouse gas emissions across a range of plant-soil communities. An open-air, pot-based mesocosm experiment was established in May, 2011 at the Centre for Ecology and Hydrology, Edinburgh. Three treatments were included in a fully-factorial design: biochar (presence [2 % w/w] or absence), soil type (arable sandy, arable sandy loam, grassland sandy loam), and vegetation type (Hordeum vulgare, Lolium perenne, unvegetated). Monitored parameters include: invertebrate and microbial species composition, soil C fluxes (CO_2 and trace gas evolution, leachate C content, primary productivity and soil C content), and soil conditions (pH, moisture content and water-holding capacity). Preliminary results and future experiments are discussed.

1. Lehmann, 2007. A handful of carbon. *Nature* **447**, 143-144.

2. Liang et al., 2010. Black carbon affects the cycling of non-black carbon in soil. *Organic Geochemistry* **41**, 206-213.

3. Van Zwieten et al., 2010. Influence of biochars on flux of N2O and CO2 from Ferrosol. *Australian Journal of Soil Research*, **48**, 555-568.

4. Wardle et al., 2008. Fire-derived charcoal causes loss of forest humus. *Science* **320**, 629.

Greenhouse Gas Balance in the Transition from Semi-improved Grassland to *Miscanthus*

Jon McCalmont - *Institute of Biological, Environmental and Rural Sciences, Edward Llwyd Building, Aberystwyth University, Aberystwyth, SY23 3DA* – jpm8@aber.ac.uk

Understanding carbon stocks and their dynamic over time is a key issue in policy making with regard to encouraging alternative energy technologies. In an attempt to quantify the impact on these carbon stocks of a land use change from poor quality agricultural grassland to a bioenergy crop, Aberystwyth University has commissioned a commercial scale (6 ha) field of *Miscanthus x giganteus* (Asian Elephant Grass) on University land and established a comprehensive suite of meteorological and scalar sensing equipment at the site. Fast response gas analysers and sonic anemometers are being used to monitor real time ecosystem exchange of CO2 between the land and atmosphere, when coupled with high quality meteorological data these provide 20 Hz snapshots of gas flux; results are combined with biomass sampling and regular soil respiration measurements in an attempt to build a coherent picture of how various components of the carbon story in this particular field combine and whether they produce a net gain or loss of carbon from the system during the development of the crop. 2012 has been particularly challenging for field work in Wales with 268 days of rain recorded at the field site; data loss from open path sensors has been a serious issue through this first year of establishment though much remains to provide important parameters for ecosystem exchange modelling which is the primary aim of the project.

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Partitioning belowground CO_2 emissions for a *Miscanthus* plantation in Lincolnshire, UK

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Miscanthus is a lignocellulosic crop that uses the Hatch-Slack (C4) photosynthetic pathway as opposed to most C3 vegetation native to the UK. *Miscanthus* can be grown for a number of practical end-uses but recently interest has increased in its viability as a bioenergy crop; both providing a renewable source of energy and helping to limit climate change by reducing carbon (C) emissions associated with energy generation. Recent studies have shown that *Miscanthus* plantations may increase stocks of soil organic carbon (SOC), however full greenhouse gas (GHG) budgets must be calculated. Consequently, we monitored emissions of N_2O, CH_4 and CO_2 from *Miscanthus* roots, decomposing plant litter and soil individually to quantify and partition these emissions and better understand the influence of abiotic factors on SOC and GHG dynamics under *Miscanthus*.

We hypothesised that the high C input treatments would stimulate large outputs but also increase soil C stocks. However, whilst CO_2 efflux varies significantly between treatments, results from the first two years of the experiment do not suggest that any increase in SOC is significant. Four years of continuous monitoring, chemical and physical soil fractionation and ecosystem C cycle modelling will allow a more comprehensive analysis to partition belowground trace gas efflux by plant input and over time.

Drivers of potential GHG fluxes under bioenergy land use change in the UK

Kim Parmar - *Centre for Ecology and Hydrology, Lancaster Environment Centre, Library Avenue, Bailrigg, Lancaster, LA1 4AP* – kimpar70@ceh.ac.uk

The greatest contributors to global greenhouse gases (GHG's) are CO_2 emissions from fossil fuel use and following land use change (LUC). Globally, soils contain three times more carbon than the atmosphere and have the potential to act as GHG sources or sinks. A significant amount of land may be converted to bioenergy production to help meet UK 2050 renewable energy and GHG emissions reduction targets. This raises considerable sustainability concerns with respect to the effects of LUC on soil carbon (C) conservation and GHG emissions.

Forests are a key component in the global C cycle and when managed effectively can reduce atmospheric GHG concentrations. Together with other dedicated bioenergy crops, Short Rotation Forestry (SRF) could be used to meet biomass requirements. SRF is defined as high density plantations of fastgrowing tree species grown on short rotational lengths (8-20 years) for biomass. As SRF is likely to be an important domestic source of biomass for energy it is imperative that we gain an understanding of the implications for large-scale commercial application on soil C and the GHG balance.

We utilized a paired-site approach to investigate how LUC to SRF could potentially alter the underlying processes of soil GHG production and consumption. This work was linked to a wider soil C stock inventory for bioenergy LUC, so our major focus was on changes to soil respiration. Specifically, we examined the relative importance of litter, soil, and microbial properties in determining potential soil respiration, and whether these relationships were consistent at different soil temperatures (10 °C and 20 °C).

Soils were sampled to a depth of 30 cm from 30 LUC transitions across the UK and incubated under controlled laboratory conditions, with gas samples taken over a seven day enclosure period. CO_2, N_2O and CH_4 gas fluxes were measured by gas chromatography and were examined together with other soil properties measured in the field and laboratory.

LUC to SRF resulted in a significant reduction in CO_2 fluxes overall at 0-15 cm (on both a soil mass and carbon mass basis). Furthermore, this response of CO_2 flux to LUC was similar at both 10 °C and 20 °C. Reductions in CO_2 flux at 0-15 cm are significantly related to decreased bacterial biomass, as measured by Phospholipid Fatty Acids (PLFA), soil pH and bulk density. These patterns suggest that changes in the quality and quantity of organic inputs under SRF may drive a reduction in soil respiration. While changes in soil C were limited, reduced respiration was supported by the increase in litter C stock under SRF. These findings indicate that LUC to SRF can strengthen the soils potential as a C sink whilst contributing successfully towards meeting GHG emissions reduction targets.

- Thursday 21st March 2013 -

12:30 – 13:30	Lunch in meeting Rooms A and B
13:30 – 15:00	Welcome and introduction to proceedings Session #1 Land use change for perennial energy crops **Amy Thomas (University of East Anglia)** Analysis of the plant cell-wall glycome to optimise bioenergy and biorefining applications of biomass feedstocks **Ricardo da Costa (Aberystwyth University)** Characterising the functional role of mycorrhizal fungi in *Miscanthus* bioenergy cropping systems **Caitlin Burns (University of Warwick)** Guest speaker **CEH Lancaster**
15:00 – 15:30	Tea/Coffee and biscuits
15:30 – 17:00	Session #2 A new method of measuring trace gas emissions from bio-energy crops **Ben Keane (University of York)** The impact of *Miscanthus* on soil carbon **Alice Massey (Aberystwyth University)** Land Use Change to Bioenergy: A quantitative analysis using meta-analytical methods **Zoe Harris (University of Southampton)** Guest speaker **CEH Lancaster**
17:00	Discussion and end of presentations
19:00	Networking dinner at the Gatehouse restaurant

- Friday 22nd March 2013 -

9:30 – 9:45	Convene in Meeting Rooms A and B
9:45 – 10:45	Session #3 The understand of biodiversity in mycorrhizal associations within bioenergy crops is essential in understanding ecosystem functioning **Chris Barnes (University of Warwick)** The feasibility of anaerobic digestion of species-rich upland meadow grass **Lynda Sainty (University of York)** Guest speaker **CEH Lancaster**
10:45 – 11:00	Tea/Coffee and biscuits
11:00 – 12:00	Session #4 Biochar effects on soil invertebrate communities and soil processes in a temperate mesocosm experiment **Sarah McCormack (CEH Edinburgh)** Greenhouse Gas Balance in the Transition from Semi-improved Grassland to *Miscanthus* **Jon McCalmont (Aberystwyth University)** Guest speaker **CEH Lancaster**
12:00 – 13:00	Lunch in meeting rooms A and B
13:00 – 14:00	Session #5 Partitioning belowground CO_2 emissions for a *Miscanthus* plantation in Lincolnshire, UK **Andy Robertson (CEH Lancaster)** Guest speaker **CEH Lancaster** Drivers of potential GHG fluxes under bioenergy land use change in the UK **Kim Parmar (CEH Lancaster)**
14:00 – 15:00	Discussion and end of day 2

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