Biochar in the UK: Understandings from the Agricultural Sector

(Photo courtesy of Simon Watchorn)

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Biochar DEMONSTRATOR

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Spreading biochar on stubble on a farm in Suffolk in autumn 2022 (Photo courtesy of Simon Watchorn).

Introduction

In October 2018, the UN's Intergovernmental Panel on Climate Change (IPCC) released its *Special Report: Global Warming of 1.5°C*. The report examines the impacts of global warming on 1.5°C above pre-industrial levels and the associated global greenhouse gas emission pathways. The report issues a stark warning about the scale and severity of the climate crisis. In order to limit warming to 1.5°C, urgent transitions are required in land, energy, urban and infrastructure, and industrial systems to ensure deep reductions in CO_2 emissions.[1] In order to reach these targets, rapid decarbonisation is required, and there is also the suggestion of the deployment of greenhouse gas removal (GGR) technologies.[2] [3] [4] [5]

Biochar is one of a growing number of GGR technologies that promise to remove carbon dioxide from the atmosphere. It is one of five GGR approaches currently part of a £30 million GGR demonstrator programme in the UK, funded by UK Research and Innovation (UKRI). Biochar is a carbon-rich substance produced by a thermochemical process called pyrolysis. Pyrolysis is the thermal decomposition of biomass which occurs at a very high temperature and under oxygen-deprived conditions. Three by-products are produced: biochar (solid), bio-oil (liquid) and syngas (gas).[6] [7]

Biochar can be produced from wood, agricultural residues, forestry wastes, food waste, animal waste, human waste, and fibres.[8] [9] Biochar stores the carbon from its original biomass source material in a stable form.[10] When applied to soils, the length of time biochar carbon

[1] IPCC, 'Special Report: Global Warming of 1.5°C', (IPCC, 2018): https://www.ipcc.ch/sr15/ (accessed 1 February 2022).
[2] Buck, Holly Jean. *After Geoengineering: Climate Tragedy, Repair, and Restoration*. London: Verso, 2019.
[3] Forster, Johanna, Naomi E. Vaughan, Clair Gough, Irene Lorenzoni, and Jason Chilvers. "Mapping Feasibilities of Greenhouse Gas Removal: Key Issues, Gaps and Opening up Assessments." *Global Environmental Change* 63 (2020): 1–13. https://doi.org/10.1016/j.gloenvcha.2020.102073
[4] IPCC, 'Special Report: Global Warming of 1.5°C'.
[5] Lawrence, Mathew, and Laurie Laybourn-Langton. *Planet on Fire: A Manifesto for the Age of Environmental Breakdown*. London: Verso, 2021.
[6] Otte, Pia Piroschka, and Jostein Vik. "Biochar Systems: Developing a Socio-Technical System Framework for Biochar Production in Norway." *Technology in Society* 51 (2017): 34–45. https://doi.org/10.1016/j.techsoc.2017.07.004
[7] Saxe, Jennie Perey, John H. Boman, Mick Bondi, Urszula Norton, Tara K. Righetti, Asif Hasan Rony, and Baharak Sajjadi. "Just or Bust? Energy Justice and the Impacts of Siting Solar Pyrolysis Biochar Production Facilities." *Energy Research and Social Science* 58 (2019): 1–12. https://doi.org/10.1016/j.erss.2019.101259
[8] Hansson, Anders, Simon Haikola, Mathias Fridahl, Pius Yanda, Edmund Mabhuye, and Noah Pauline. "Biochar as Multi-Purpose Sustainable Technology: Experiences from Projects in Tanzania." *Environment, Development and Sustainability* 23 (2021): 5182–5214. https://doi.org/10.1007/s10668-020-00809-8
[9] Otte and Vik, 'Biochar systems'.
[10] Shackley, Simon, Hans-Peter Schmidt, and Bruno Glaser. "Introduction." In *Biochar in European Soils and Agriculture: Science and Practice*, edited by Simon Shackley, Greet Ruysschaert, Kor Zwart, and Bruno Glaser, 1–16. Abingdon: Routledge, 2016.

remains ranges from decades to millennia,[11] although this is largely dependent on the type of feedstock used, the type of pyrolysis, and the settings used during pyrolysis.[12] [13] [14]

Agricultural land is likely to be one of the main sites of application for biochar. However, studies on farmers' perspectives on the adoption of biochar are scarce.[15] There is a lack of research investigating the socio-economic suitability of biochar for farmers in industrialised countries, and on the social, political, cultural, and environmental dimensions of biochar.[16] [17] Arguments have been made that decision-making about biochar production and deployment needs to be informed by as wide a range of stakeholders as possible - including farmers and others in the agricultural industry, researchers, policymakers, the biochar industry, and NGOs.[18] [19] To be effective, biochar discussion and decision-making need to be based on two-way communication and act as a learning process for all concerned.[20]

Aim

To address the identified knowledge gaps in relation to biochar, the Social Science researchers of the Biochar Demonstrator project are engaging with a wide range of stakeholders to gather views and opinions on biochar's potential contribution to climate change mitigation. Part of this research has involved interviews with a number of stakeholders including farmers and others in the agricultural industry, Government

[11] International Biochar Initiative, 'FAQs', (International Biochar Initiative, 2023): https://biochar-international.org/faqs/ (accessed 14 January 2023).
[12] Bruun, Esben, Andrew Cross, Jim Hammond, Victoria Nelissen, Daniel Rasse, and Henrik Hauggaard-Nielsen. "Biochar Carbon Stability and Effect of Greenhouse Gas Emissions." In *Biochar in European Soils and Agriculture: Science and Practice*, edited by Simon Shackley, Greet Ruysschaert, Kor Zwart, and Bruno Glaser, 165–83. Abingdon: Routledge, 2016.
[13] Hansson et al., 'Biochar as multi-purpose sustainable technology'.
[14] Lopez-Capel, Elisa, Kor Zwart, Simon Shackley, Romke Postma, John Stenstrom, Daniel Rasse, Alice Budai, and Bruno Glaser. "Biochar Properties." In *Biochar in European Soils and Agriculture: Science and Practice*, edited by Simon Shackley, Greet Ruysschaert, Kor Zwart, and Bruno Glaser, 41–72. Abingdon: Routledge, 2016.
[15] Latawiec, Agnieszka E., Jolanta B. Królczyk, Maciej Kuboń, Katarzyna Szwedziak, Adam Drosik, Ewa Polańczyk, Katarzyna Grotkiewicz, and Bernardo B.N. Strassburg. "Willingness to Adopt Biochar in Agriculture: The Producer's Perspective." *Sustainability (Switzerland)* 9 (2017): 1–13. https://doi.org/10.3390/su9040655
[16] Clare, Abbie, Andrew Barnes, John McDonagh, and Simon Shackley. "From Rhetoric to Reality: Farmer Perspectives on the Economic Potential of Biochar in China." *International Journal of Agricultural Sustainability* 12, no. 4 (2014): 440–58. https://doi.org/10.1080/14735903.2014.927711
[17] Otte and Vik, 'Biochar systems'.
[18] Pourhashem, Ghasideh, Shih Yu Hung, Kenneth B. Medlock, and Caroline A. Masiello. "Policy Support for Biochar: Review and Recommendations." *GCB Bioenergy* 11 (2019): 364–80. https://doi.org/10.1111/gcbb.12582
[19] Rittl, Tatiana Francischinelli, Bas Arts, and Thomas W. Kuyper. "Biochar: An Emerging Policy Arrangement in Brazil?" *Environmental Science and Policy* 51 (2015): 45–55. https://doi.org/10.1016/j.envsci.2015.03.010
[20] Shackley, Simon. "Shifting Chars? Aligning Climate Change, Carbon Abatement, Agriculture, Land Use and Food Safety and Security Policies." *Carbon Management* 5, no. 2 (2014): 119–21. https://doi.org/10.1080/17583004.2014.912827

Departments, NGOs, the biochar industry, carbon trading companies, the forestry industry, local authorities, and academics. We wish to understand how stakeholders view the opportunities, risks, and uncertainties of biochar, along with stakeholder views on different types of governance arrangements (including market measures, public policies and regulations), that may be required to support the widespread deployment of biochar for carbon storage.

To address the issue of ensuring two-way communication, and to share knowledge and experience of biochar use and application, on Thursday 4th May 2023, an Agricultural Biochar Knowledge Exchange event was held at The Allerton Project, Loddington, which brought together over fifty stakeholders including farmers and others from the agricultural industry, representatives from the biochar industry, policymakers, and academics. As part of this event, a deliberation session took place which encouraged all attendees to put forward their views and opinions on biochar.

In the deliberation session, two questions were asked:

1) What are the key opportunities related to using biochar in agriculture?
2) What are the key concerns related to using biochar in agriculture?

Responses were recorded on flip charts and subsequently transcribed and imported into the *NVivo* 12 software package to undertake coding. Coding enables data to be analysed for themes and patterns. The coding framework was developed iteratively, and inductive coding was used to identify all of the different themes mentioned by attendees. All statements or words in the transcribed data that revealed an understanding about biochar were coded, resulting in an extensive and diverse set of themes. The identification of sub-themes within the main themes enable finer level details to be revealed.

The number of codes identified for each theme and sub-theme were noted (see Tables 1 and 2). These are discussed further in the Findings section, however, the quantification is simply to provide an initial indication of the level of interest in the different themes. The total refers to the number of times the same statement or word was mentioned in the data, and this was noted once the coding had been completed.

The findings which emerged from the analysis are described in the section which follows.

Findings

In total, 76 responses were analysed, and 7 main themes emerged from the analysis (Table 1). 14 sub-themes provide finer level detail (Table 2). The key main theme emerged as the ‘environmental’ theme with 32.9% of responses. This was followed by ‘agriculture and food production’ with 21% of responses, ‘economics and incentives’ with 13.2% of responses, ‘feedstocks’ with 11.8% of responses, ‘governance’ with 9.2% of responses, ‘technical’ with 6.6% of responses, and ‘communication’ with 5% of responses (Figure 1).

Main theme	Total
Agriculture and food production	16
Communication	4
Economics and incentives	10
Environmental	25
Feedstocks	9
Governance	7
Technical	5

Table 1 The main themes identified in the analysis.

Main theme	Sub-theme	Number of responses coded
Agriculture and food production		16
Communication		4
Economics and incentives		
	Carbon trading	6
	Cost	4
Environmental		
	Carbon sequestration	3
	Ecosystem services	15
	Energy	3
	Forestry	1
	Pollution	3
Feedstocks		
	Competition	3
	Quality	3
	Residues	3
Governance		7
Technical		
	Commercial availability	2
	Data	1
	Definition	1
	Research	1

Table 2 The sub-themes identified in the analysis.

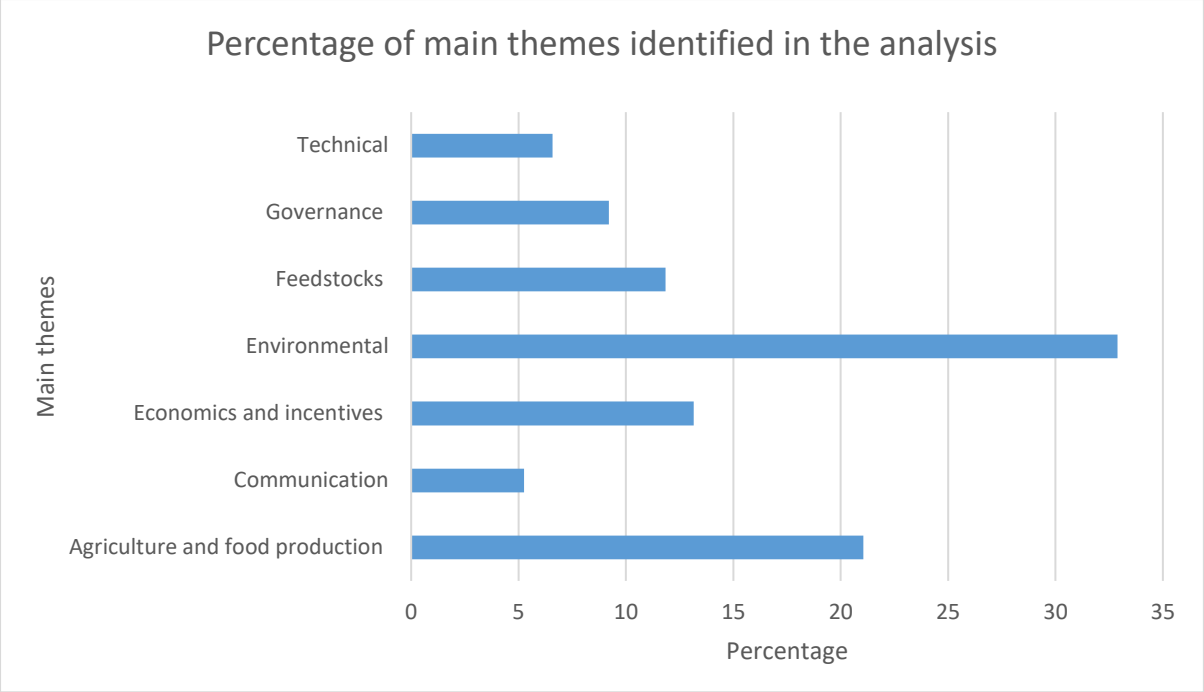

Figure 1 The percentage of main themes identified in the analysis.

Table 2 details the breakdown of responses coded for the sub-themes within the main themes. Within the environmental theme, 15 responses were coded for the ecosystem services sub-theme. The prominence of this sub-theme is striking. Carbon sequestration was noted as a separate sub-theme within the environmental theme, and this generated 3 responses. This indicates that whilst carbon sequestration was recognised by attendees as a potential benefit of biochar, other ecosystem services were more likely to be perceived as potential benefits from the application of biochar to agricultural land.

At the opposite end of the scale, 4 responses were recorded for communication. The range of sub-themes shows an awareness by the attendees of the various dimensions associated with biochar. This awareness is not just technical or scientific but also relates to issues of governance and economics amongst others.

The main themes and sub-themes which emerged from the analysis reveal the complexity of current biochar understandings. In the section which follows, each sub-theme identified in the analysis is described.

Overview of main themes and sub-themes

In this section, an overview is provided of the 7 main themes and the 14 sub-themes which emerged from the analysis.

Agriculture and Food Production

Biochar's potential to replace or assist the use of chemicals in agriculture was considered an opportunity, especially if it could be used as an alternative to inorganic fertilisers. The potential for biochar to be mixed with organic fertilisers such as poultry manure and co-composted was also considered as a potential 'win'. This creates a high-nutrient slow release manure. However, concerns were raised around the ability of biochar to lock-up pesticides,

herbicides and nitrogen, and for manganese deficiencies to occur in soils. In livestock farming, biochar was viewed as an approach to reduce methane in cattle, and could be used as an animal feed as well as for bedding. However, when biochar is used in chicken bedding, a crust may form and this may be harmful for chickens.

Communication

Positive PR around biochar was being conducted by biochar producers to promote their products to the agricultural community. This was being carried out to increase sales. However, negative PR around biochar may make the agricultural community reluctant to apply biochar to land. Both positive and negative PR may result in greenwashing or miscommunication. One suggestion put forward to address the issue of miscommunication was to develop a hub which could be used to communicate information about biochar. Done correctly, this could also help prevent greenwashing.

Economics and Incentives

Carbon trading
Carbon trading was viewed as a potential incentive to encourage the use of biochar. This could potentially increase income for farmers through the sale of carbon credits. However, uncertainties were raised around the use of carbon trading of biochar including the ethics of doing so. Carbon trading of biochar is likely to enable companies outside of agriculture to continue using fossil fuels, facilitating business as usual and failing to cut carbon emissions. The question of who owns the carbon credits associated with biochar was also raised. There are uncertainties around whether it is biochar producers or farmers applying biochar to their land that own biochar carbon credits.

Cost
Biochar was viewed as having the potential to reduce costs for farmers by potentially being a replacement for inorganic fertilisers. It was also seen as a low-cost greenhouse gas removal technology. On-farm biochar production was viewed as a financial opportunity for agricultural businesses as it may enable farmers to work together in clusters. This could enable mixed farming and a circular economy. However, if biochar was produced on an industrial scale, concerns were raised around high biochar production costs. These costs are passed on to those who wish to apply biochar, making the product too expensive for users.

Environmental

A number of sub-themes emerged and these were carbon sequestration, ecosystem services, energy, forestry, and pollution.

Carbon Sequestration
The use of biochar for carbon sequestration was viewed as an opportunity. However, there was a concern about the residence time of biochar in soil and the stability of carbon. The length of time biochar carbon remains in the soil is determined by the type of feedstock used, the type of pyrolysis, and the settings during pyrolysis. There is also difficulty in establishing the amount of carbon already stored in soil as there is no UK soil carbon code (work is ongoing to establish a soil carbon code).

Ecosystem Services
In the sub-theme of ecosystem services, the use of biochar was viewed as an opportunity with one exception.

Biochar was perceived as being able to increase soil moisture. Its ability to increase water holding capacity would assist with drought resistance. As biochar can act as a filter, it was also viewed as having the ability to slow down water movement. There was a perception that biochar could improve soil health, along with building the soil food web and increasing microbial diversity. Biochar was also viewed as having the ability to act as a pH buffer and to lower nutrient loss. There was also a perception of the potential of improvements to river health and cleaner rivers through the use of biochar bunds to prevent pesticide leaching.

The one concern which arose was that the application of biochar was an irreversible process. Once applied to land, it is impossible for biochar to be removed. Uncertainties remain around potential adverse effects to soil after the application of biochar. If any adverse effects did arise, it is not possible to remove biochar to prevent any further harms occurring.

Energy
Biochar production plants may create opportunities around energy generation and the production of heat. However, questions were raised about the amount of energy required to produce biochar and whether biochar was actually a carbon negative product.

Forestry
The production of biochar was perceived as a potential opportunity for woodland management.

Pollution
Concerns emerged around the use of contaminated feedstocks for the production of biochar. Biochar could potentially add metals, persistent organic pollutants, and polycyclic aromatic hydrocarbons to the soil, thereby contaminating land.

Feedstocks

Three sub-themes emerged around feedstocks and these were competition, quality, and residues.

Competition
Concerns were raised around the competing use of land for food production or for biochar feedstock production. Linked to this was the growing of monoculture biomass crops which would be required for the production of biochar. There was also a perception of competition for feedstocks. This could come from biomass specifically grown for feedstocks (competition between use in bioenergy with carbon capture and storage (BECCS) and in the production of biochar). Alternatively, competition may arise with residues such as straw as this material can be used for animal feed and bedding as well as in biochar production.

Quality
As the quality of the feedstock determines the quality of biochar, concerns emerged around this issue. The variability and inconsistency of feedstocks may potentially make it difficult to produce uniform batches of biochar. Feedstock sources may prove difficult to trace and it may not be possible to establish their origin.

Residues
Biochar produced from residues was perceived as potentially adding value to low value crops such as agricultural straw or coppice. The use of other (non-agricultural) residues as biochar feedstocks could also potentially divert material away from landfill. However, it was also viewed that biochar should not be produced from residues due to issues around contamination, and the quality and variability of biochar, and should instead be produced from virgin wood.

Governance

A number of concerns were raised around the regulation of biochar. The lack of regulation around biochar was problematic, as was the absence of a biochar standard. However, the point was made about whether there is currently enough data to enable the development of effective biochar regulation. The need for understanding how the application of biochar impacts Red Tractor auditing was also raised. Additionally, supermarket contracts may mean biochar is unable to be applied to agricultural land.

Technical

A number of technical concerns were raised and these were spread over a number of issues.

Commercial Availability
The point was raised that if farmers wish to produce their own biochar, no pyrolysis machines are available that are a suitable size. Those that are available are either too small or too large. In addition, currently, there is no commercially available spreadable product that can be applied at farm scale.

Data
Concerns around a lack of data were raised. More data are required about biochar and biochar application before it is deployed.

Definition
The lack of a definition of what biochar is was a concern. Biochar is not one thing and is determined by what it is produced from.

Research
Concerns were raised around the lack of collaboration between biochar researchers. This should happen to ensure results are produced more quickly.

Other issues arising

Although only mentioned once, issues around distributive injustice and food supply were raised. From interviews we have undertaken with the wider biochar community, and with the agricultural community, we are aware these are matters of concern.

Distributive Injustice
The application of biochar to agricultural land was viewed as the risks from any harms being closer and stacked towards farmers. If farmers are asked to apply biochar to agricultural land, they are carrying the burden of risk if biochar is used in a greenhouse gas removal strategy.

Food Supply
The issue of consumers being unwilling to purchase food grown on land with biochar applied was raised. If contaminated biochar was applied to agricultural land, this may lead to carcinogens entering food supplies.

Summary

Even though this report is based on one knowledge exchange event it has highlighted the complexity of current biochar understandings within the agricultural sector. As the themes illustrate, opportunities and concerns were identified which extend beyond scientific or technical matters.

Whilst biochar can be defined as a material that is produced from biomass through pyrolysis, because of the many types of feedstocks it can be produced from, different types of biochar can be produced. The lack of a firm definition of biochar was raised as a concern by attendees. This is an issue that requires further investigation and clarification as farmers will need to have confidence in any biochar products they apply to land.

The key theme which emerged from the analysis was the environment and particularly the potential environmental benefits arising from biochar (although some concerns for the environment were also expressed). Whilst carbon sequestration was identified as a sub-theme within the environmental theme, it was not viewed as the main opportunity associated with biochar application to agricultural land. Instead, there were a range of other ecosystem services which were perceived as potentially benefiting from the application of biochar to agricultural land.

Whilst this report has provided an overview of the understandings of biochar from members of the agricultural community at the Biochar Knowledge Exchange Event, it is only one part of the social science research within the Biochar Demonstrator Project. Other research activities are ongoing and are detailed below.

Next steps for the Social Science research:

- We continue to interview members of the agricultural community so that we can develop a deeper understanding of the variety of views and opinions both positive and negative relating to the production of biochar by farmers together with the use and application of biochar in agriculture. If you would be willing to be interviewed, or know someone who would, please get in contact.
- Further agricultural knowledge exchange events will be held to enable researchers to present ongoing biochar research to the agricultural community. These events also enable researchers to learn from the experiences of the agricultural community in producing, using and applying biochar in agriculture.

If you have any suggestions as to what would be helpful for the agricultural community in respect of biochar (e.g. reports, events, fact sheets), please get in contact.

Please contact Catherine Price via email. Email address: catherine.price@nottingham.ac.uk

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We would like to thank all those who attended the Biochar Knowledge Exchange Event at the Allerton Project in May 2023, and for their participation in the deliberation session.

Appendix

Final programme of the Agricultural Biochar Knowledge Exchange Event, Allerton Project, Loddington, Thursday 4th May 2023

Time	Activity	Presenter / lead
10-10.30	Arrivals	
10.30-10.45	Welcome and introduction: purpose of event; people involved; overview of the day; introduction	**Joe Stanley**, GWCT Allerton Project **Dr Catherine Price**, School of Geography, University of Nottingham
10.45-11.05	Biochar Demonstrator – *Assessment of biochar as a means of long-term carbon sequestration* Q&A	**Professor Colin Snape & Dr William Meredith**, Faculty of Engineering, University of Nottingham Chaired by Joe Stanley
11.05-11.35	Biochar science 1. Biochar Demonstrator – *Biochar in UK Soils* 2. AgriCaptureCO2 project Q&A	 **Dr Tom Bott**, School of Biosciences, University of Nottingham **Joe Stanley**, AgriCaptureCO2 Chaired by Catherine Price
11.35-12.00	Biochar – farmer experiences and perspectives 1. *Biochar: A Trial Farmer's Experiences and Perspectives* 2. *Potential for Biochar production and use within Agroforestry systems* 3. *Experiences from the AgricaptureCO2 project* Q&A	 **Simon Watchorn** **Oliver Kynaston** **Joe Stanley** Chaired by Alice Midmer GWCT
12.00-12.25	*Experiences from the AgricaptureCO2 Lancashire Biochar Pilot* Biochar producer (Dark Black Carbon) perspectives Q&A	**Nik Bruce,** Lancashire County Council **Liz Casely,** Dark Black Carbon Chaired by Joe Stanley
12.30-1.15	Lunch	

1.15 – 1.35	The regulatory perspective: • Our regulatory role – where we fit in & why • Our research & science – what we're doing to understand the risks • Our view on the opportunity & risks based on what we've seen so far Q&A	**Ross Lowrie,** Net Zero & Decarbonisation Senior Advisor, Environment Agency Chaired by Catherine Price
1.35 - 2.30	Discussion / deliberation session	Catherine Price
2.30-3.30	Farm walk	Joe Stanley
3.30	Tea and Departure	