

In this issue:

Editorial	1
The effects of empty fruit bunch biochar on crop performance and nitrous oxide emission in maize cropping system	2
Effect of biofilms and biochar on soil aggregation stabilization	2
Impact of biochars on soil biota and microbial activities	3
Effect of biochars on crop yields and N uptake	3
Short-term incubation studies on degradation of biochar in soil	4
Welfare analysis	4
Biochar network	5
Contributions	6

Editorial

Dear Reader,

Welcome to the fourth and last issue of the SAW-Biochar Public-Newsletter. We thank all partners of the consortium for their contributions to this very successful research network. Some of the results are still in the publication process, please check the website for updates: www.atb-potsdam.de/biochar

International biochar symposium

In May 2015 ATB organized an international biochar symposium "Biochar Contribution to Sustainable Agriculture" in Potsdam, where results of the research network were presented and discussed with more than 100 scientists from more than 20 countries world-wide.

The result showed promising perspectives as well as limitations of biochar use in agriculture in the tropics and the temperate zones.

All abstracts of the international biochar symposium are online available under the following link: http://www.atb-potsdam.de/fileadmin/docs/BABs/BAB_Heft89_k.pdf.

The final results in the project "Biochar in Agriculture"

This issue summarizes the respective research progress of the project partners in Germany and Malaysia. We present results of the impact of biochars, digestate and fertilizer add-ons on soil fertility in terms of yield potential, nutrient dynamics, greenhouse gas emissions and soil biology.

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The effects of empty fruit bunch biochar on crop performance and nitrous oxide emission in maize cropping system

Sherwin Lee Chan Kit, Rosenani Abu Bakar, Azni Idris, Che Fauziah Ishak, Khairuddin Abdul Rahim (Universiti Putra Malaysia)

A field experiment was conducted to determine the effects of different application rates of oil palm empty fruit bunch biochar (0, 5, 10, 20 and 40 Mg ha⁻¹) on maize yield, N uptake, N₂O emission, and soil properties in an Oxisol. The experimental layout was randomized complete block design (RCBD) with 5 replicates, each plot measuring 6 m by 4 m. Empty fruit bunch biochar (EFBB) was distributed evenly before mixing with the top soil. A separate EFBB was weighed and applied in a 1 m by 1 m microplot, bordered with PVC plastic sheet. The microplot was randomly placed around the centre area of each plot for gas, soil, and plant tissue sampling. Maize seeds were sown and two split applications of fertilizers were applied at the rate of 180 kg N ha⁻¹ (ammonium sulphate), 60 kg P₂O₅ (triple superphosphate), and 120 kg K₂O (muriate of potash). Gas sampling was done weekly for N₂O flux measurement, collected in a static gas chamber, till harvesting period (80 days after sowing). Maize tissue samples were harvested for dry matter weight and nutrient content analysis (N, P, K, Ca, and Mg), while soil was collected for pH, CEC, total C, total N, and exchangeable cations (K, Ca, and Mg).

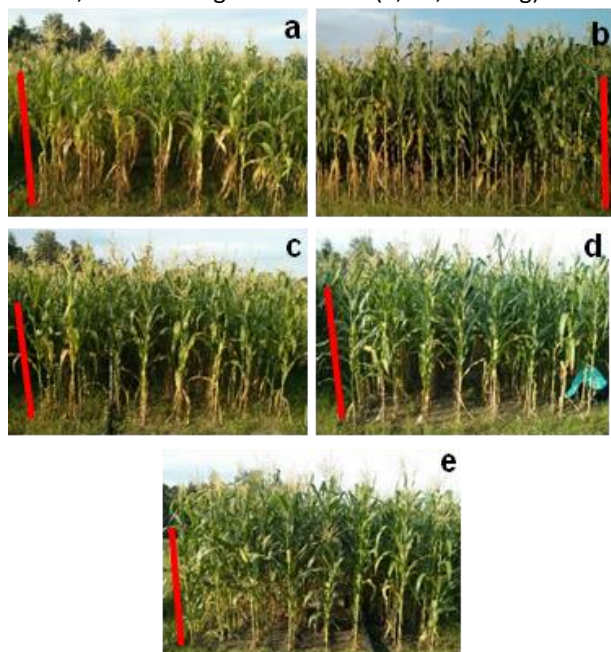


Fig. 1 The maize growth performance with different EFBB rates; (a) 0 (control), (b) 5, (c) 10, (d) 20, and (e) 40 Mg ha⁻¹. The red bar is 2 metres tall as reference.

Results showed that addition of EFBB significantly increased maize yield and total dry matter weight up to 74% and 46% respectively, compared to plots without biochar. The crop uptake of N and K were significantly improved by 38% and

65%, respectively. For soil properties, EFBB increased soil pH, extractable P, and exchangeable K, but no significant difference for other elements.

There were mixed results in emissions of N₂O, where some treated plots had higher flux rate than the control, while some were lower. As a result, the total N₂O emission for this planting season was insignificantly different among the treated and non-treated plots. High variability and low number of replications made it difficult to test the effect of biochar on N₂O emission in the field. Increasing gas chamber size and number of replication may be able to remediate this issue.

In conclusion, EFBB has significant effect on maize yield and dry matter weight but has no effect on N₂O emission. An additional planting season may be required to further investigate the impact of EFBB amendment on crop performance, N uptake, and soil N₂O emission.

Effect of biofilms and biochar on soil aggregation stabilization

Frederick Büks, Martin Kaupenjohann (Technische Universität Berlin)

As biofilms are supposed to play a major role in aggregate stabilization, our work focused on bacterial extracellular polymeric substance (EPS).

In the first trial, EPS contained in soil aggregates from the field trial in Berge was pretreated with different concentrations of α -glucosidase, β -galactosidase, lipase and DNA. These enzymes are known to destabilize EPS by digesting biofilm components. A measured decrease of aggregate stability as well as an increase of bacterial cell release after these treatments indicate a stabilization of soil aggregates by bacterial biofilms.

In the second trial, mechanically disaggregated soil from the field trial in Berge containing 5% pyrogen biochar was incubated with 2 different microbial communities, one extracted from the soil and dominated by *acidobacteria*, *actinobacteria* and fungi, the other one derived from air-born bacteria and dominated by β -*proteobacteria*. Contrary to our expectations, different biofilm populations did not develop different aggregate stability, although there is a tendency to higher aggregate stability in samples containing a fungal population.

In the third trial, influence of grazers on aggregate stability was measured. Soil aggregates from the field trial in Berge were incubated for 14 days with high concentrations of the soil nematode *Acrobeloides buetschlii* grazing on bacterial biofilms. Aggregate stability, development of nematode population (brightfield microscopy counting), metabolic activity of microorganisms (soil respiration in control) as well as fatty acid concentrations (PLFA) were measured

during the experiment. Results show no influence of nematode feeding and motion on aggregate stability, which is probably due to inaccessibility of biofilms within the soil aggregates.

In a separated trial, soil from the field trial in Berge was incubated for 35 day in 8 variants (with/without biochar x sterile/unsterile x addition of lime/no addition). The data are currently evaluated and shall give insight in the influence of pyrogen biochars on manganese cycling and heavy metal mobilization.

In conclusion, we found evidence for bacterial biofilms being aggregation agents in sandy agricultural soils. This property is not necessarily influenced by biofilm microbial composition. Also, biofilms seem to be protected against grazing nematodes due to their position inside the aggregate's micro-pore system.

Impact of biochars on soil biota and microbial activities

Peter Lentzsch, Monika Joschko, Stephan Wirth, Philip Rebensburg (Leibniz Centre for Agricultural and Landscape Research)

According to our planning, soil microbiological studies were started with samples from the Berge field experiment in September 2012, followed by annual samplings in August 2013, November 2014 and finally April 2015. Soil microbial biomass and basal respiration were highly variable, due to unexpectedly high spatial variability and trends of soil properties across the site which were a major problem to identify impacts of different treatments at the field scale. Accordingly, a model prediction of microbial biomass carbon using soil parameters was highly correlated to the field measurements, showing the same spatial variability. Additional laboratory experiments were performed to reveal effects of chars on soil microbial properties and soil microbial communities under controlled conditions.

Concerning our soil zoological studies in the field experiment Berge, we found spatially and temporally highly variable abundances of earthworms ranging from 20 to 84 individuals (mainly *Aporrectodea caliginosa*), in 2013 and 2014, however, impacts of biochar on the abundance of earthworm were detected in a low-fertile subarea of field site. The analysis of carbon transfer between biochar and earthworms was postponed until evidence of biochar impacts from isotopic studies of other WPs is provided.

A solution was found for studying microbial population parameters by dividing the field in two subareas and by using discriminant analysis including a pre-monitoring data set. On this basis, we found taxa-specific reactions in 2013 but not in the following years.

With regard to biochar as constituent of soil organic matter (SOM) and potential primary organic matter for SOM reproduction, predictions were made concerning humus reproduction.

Effect of biochars on crop yields and N uptake

Andreas Meyer-Aurich, Anja Sanger, Zhencai Sun (Leibniz Institute for Agricultural Engineering Potsdam-Bornim)

In the field experiment, located in Berge near by Potsdam, with applied full recommended fertilizer additions of different biochars from wood, straw, and digestate did not show significantly effect on the straw and grains yield of four cultivated crop, i.e., winter wheat in 2012-2013, winter rye in 2013-2014, oil radish in 2014-2015, and maize in 2015.

Another trail in this field was focusing on the interaction between biochar and nitrogen at different supply levels (0, 75, 150, and 195 N kg ha⁻¹), which cover deficient to over-sufficient dose. Biochar made from wood chips was employed here. A significant interaction effect of biochar and N fertilizer was observed on N uptake of oil radish. Briefly, addition of biochar showed a positive effect on N uptake of oil radish while no given fertilizer, but the presence of biochar significantly decreased N uptake at the over-sufficient fertilizer level.

Regarding the mechanisms on the observed biochar-N fertilizer interaction, firstly, in the laboratory, we conducted a experiment to investigate the adsorption of reactive nitrogen (ammonium and nitrate) on biochar. The same biochar and fertilizer used in the field experiment was employed, and the ratio of biochar to fertilizer rate was corresponding to 9 Mg ha⁻¹ and 380 Kg N ha⁻¹. No significant adsorption of either ammonium or nitrate on biochar was measured. Furthermore, there was no significant change in the concentration of ammonium or nitrogen in the leachate. On the other hand, we also measured the microbiological characteristics, i.e., microbial biomass, basal soil respiration, metabolic quotient (qCO_2), and abundance of major microbial group. All these parameters did not significantly differ between the treatment with biochar and the treatment without biochar under identical N fertilizer level. While at the over-sufficient fertilizer supply rate, we observed cumulative N₂O-N missions in the biochar-mediated treatment was lower compared to that of the treatment without biochar, which may to certain content contribute to the N loss. In the case of no fertilizer, higher cumulative CO₂-C emissions and higher ammonium concentration were measured, which could to certain extent explain the observed higher N uptake.

Short-term incubation studies on degradation of biochar in soil

Giacomo Lanza, Jürgen Kern (Leibniz Institute for Agricultural Engineering Potsdam-Bornim)

Within the 10-day incubation lab experiments different degradation dynamics have been identified between two soil char-substrates mixtures amended with nitrogen and glucose:

- All treatments with char decreased soil respiration compared to unmodified maize straw indicating an increased stability of organic substrates in the soil.
- Respiration in soil-HTC char mixtures was higher than in soil-pyrolysis char mixtures.
- HTC char showed a two-step decay kinetic, which could not be explained with a simple double-pool model. This phenomenon in the context of biochar application to soil substrates has been published the first time by Lanza et al. (2015).

Within a few days of investigation, qualitative and semi-quantitative information can already be achieved. Although the exact time scales of long-term physical phenomena cannot be obtained by this way, short-term studies are helpful to compare different treatments and to gain insight into features of the initial decay dynamics. In the case of slowly-decaying substrates like biochar, these studies can facilitate early decisions on appropriate feedstocks, production parameters or post-treatments of chars, which are provided for soil amendment.

Welfare analysis

Claudia Kemfert, Isabel Teichmann (German Institute for Economic Research)

Abstracting from any cost considerations, biochar allows for an annual technical GHG mitigation potential in Germany in the range of 2.1-3.2 million tons (Mt) of carbon dioxide equivalents (CO₂e) in 2015, 2.8-10.2 Mt CO₂e by 2030 and 2.9-10.6 Mt CO₂e by 2050. In 2030 and 2050, this corresponds to approximately 0.4-1.5% and 0.3-1.1% of the respective GHG reduction targets. Thereby, forestry residues are associated with the greatest GHG mitigation potentials of biochar, followed by cereal straw, green waste from extensive grassland, solid cattle manure, and some other solid biomass residues. In terms of the net GHG emissions that can be avoided per dry ton of feedstock, biochar from biomass with a low water content (e.g., cereal straw) appears superior to biochar from wet feedstocks (e.g., solid cattle manure). Some feedstocks with very high water contents – liquid cattle and swine manure, sugar-beet leaf and potato haulm, sewage sludge, and digestates are even associated with a negative GHG mitigation balance due to the high amount of energy required to dry the feedstocks and are, thus, considered unsuitable for slow-pyrolysis-biochar carbon sequestration. In many cases, a negative GHG mitigation balance is also obtained for industrial wood waste and short-rotation coppice, the feedstocks that are assumed to be directly combusted in the baseline scenario. Besides the type and available amount of biomass and the choice of the baseline scenario, the net avoided GHG emissions are strongly influenced by the type of fossil fuel considered and by whether process heat is recovered during pyrolysis. In contrast, the size of the pyrolysis plants and, thus, the transport distances for biomass and biochar play only a minor role.

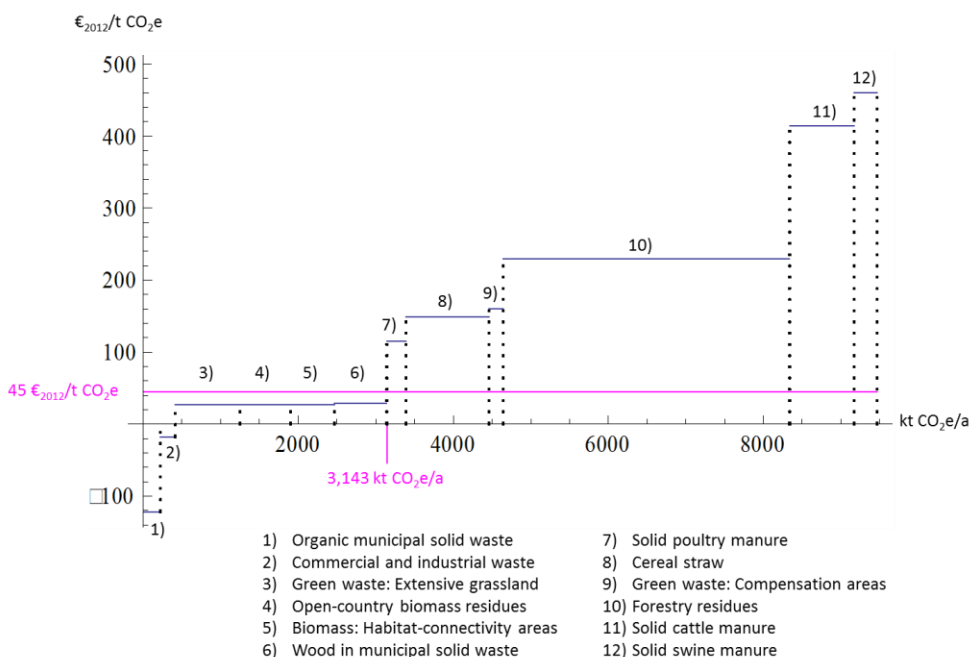


Fig 2. The greatest greenhouse gas mitigation potential under cost aspects in 2030.

The mitigation potential is reduced if costs are taken into account. Only about 3.1 Mt CO₂e could be maximally abated in 2030 at costs below €₂₀₁₂45 per ton of CO₂ (Figure 2) – the then assumed maximum price for GHG emission certificates – and nearly 3.8 Mt CO₂e in 2050 at costs below €₂₀₁₂75 per ton of CO₂. This translates into about 0.5% and 0.4%, respectively, of the 2030 and 2050 GHG reduction targets and about a third of the maximum technical GHG mitigation potential of 10.2 Mt CO₂e in 2030 and of 10.6 Mt CO₂e in 2050. The feedstocks associated with these economic GHG mitigation potentials mainly refer to green waste from extensive grassland, open-country biomass residues, biomass from habitat-connectivity areas, and wood in municipal solid waste. In 2030, they also include organic municipal solid waste as well as commercial and industrial waste, and, in 2050, cereal straw and green waste from compensation areas.

While the amount of biochar carbon sequestered in soil is an important factor for the technical GHG mitigation potentials of biochar, the study has revealed that the contribution of the pyrolysis by-products offsetting GHG emissions from fossil fuels might often be equally or even more important than that of biochar soil incorporation. This indicates that other conclusions about the technical and economic GHG mitigation potentials of biochar might be obtained when focusing on the use of biochar for energetic purposes or on the extraction of pyrolysis oils and gases (rather than biochar) for energy generation. These alternative uses and the general trade-offs between the choice of feedstock, conversion process, highest heating temperature, biochar (carbon) yield, and biochar carbon stability call for more research on the optimal feedstock-specific GHG mitigation strategies with biochar.

Biochar network

Coordination and dissemination; Life cycle assessment and farm economic evaluation of biochar

Dr. Andreas Meyer-Aurich
Dr. Anja Sanger
Dr. Zhencai Sun
(Leibniz-Institut for Agricultural Engineering Potsdam-Bornim)

Research station Berge

Dr. Andreas Muskulus
(Institute of Agricultural and Urban Ecological Projects)

Gas flux measurements at the research station Berge

Dr. Jurgen Kern
Dr. Christiane Dicke
Giacomo Lanza – PhD Student
(Leibniz-Institut for Agricultural Engineering Potsdam-Bornim)

Effects of biochar on the Soil-Plant-System

Prof. Dr. Frank Ellmer
Dr. Katharina Reibe
Heiko Vogel
(Humboldt-Universitat zu Berlin)

Effects of biochar on the dynamics of soil aggregation

Prof. Dr. Martin Kaupenjohann
Frederick Buks – PhD Student
(Technische Universitat Berlin)

Impact of biochar on soil biota and microbial activities

Dr. Peter Lentzsch
Dr. Monika Joschko
Dr. Stephan Wirth
Philip Rebensburg – PhD Student
(The Leibniz Centre for Agricultural Landscape Research)

Field experiment with biochar in Selangor, Malaysia

Prof. Dr. Azni Idris
Assoc. Prof. Dr. Rosenani Abu Bakar
Assoc. Prof. Dr. Tinia Idaty Mohd. Ghazi
Che Fauziah Ishak
Khairuddin Abdul Rahim
Sherwin Lee Chan Kit – PhD student
(University of Putra Malaysia)

Welfare analysis

Prof. Dr. Claudia Kemfert
Dr. Isabel Teichmann
(German Institute for Economic Research)

Char materials (Pyro- and HTC char)

Dr. Jan Mumme
Dr. Mamadou Diakite
(Leibniz-Institut for Agricultural Engineering Potsdam-Bornim)

Impact of biochar application on soil nematodes

Stefanie Menzel – PhD Student
(Humboldt-Universitat zu Berlin)



Contributions (2015-2016)

Publications

Lanza, G., Wirth, S., Geßler, A. and Kern, J., 2015. Short-term response of soil respiration to addition of chars: Impact of fermentation post-processing and mineral nitrogen. *Pedosphere*, 25(5): 761-769.

Teichmann, I., 2015. An economic assessment of soil carbon sequestration with biochar in Germany. DIW Discussion Paper 1476.

Lanza, G., Rebenburg, P., Kern, J., Lentsch, P. and Wirth, S., 2016. Impact of chars and readily available carbon on soil microbial respiration and microbial community composition in a dynamic incubation experiment. *Soil and Tillage Research*, in press.

Dilfuza, E., Wirth, S., Behrendt, U., Abd-Allah, E.F. and Berg, G., 2016. Biochar treatment resulted in a combined effect on soybean growth promotion and a shift in plant growth promoting rhizobacteria. *Front Microbiology*, 7, Article 209.

Presentation

Lanza, G., June, 11, 2015. FeldTag LaTerra, Welzow: "Wirkung unterschiedlich gedüngter Kohlen auf den Pflanzenenertrag in einem Feldversuch".

Lanza, G., May, 28-29, 2015. Biochar – Contribution to Sustainable Agriculture, Potsdam: "Short-term response of soil respiration to addition of chars: effect of readily available nitrogen and carbon".

Lanza, G., April, 15-17, 2015. Nanjing, China: "Short-term response of microbial communities to addition of chars: effect of readily available carbon".

Rebenburg, P., May, 28-29, 2015. Biochar – Contribution to Sustainable Agriculture, Potsdam: "Impact of biochar on the population structure of soil biota".

Lee, S., May, 28-29, 2015. Biochar – Contribution to Sustainable Agriculture, Potsdam: "Impact of empty fruit bunch biochar on nitrogen leaching and N¹⁵-labelled fertilizer recovery in maize on an oxisol".

Teichmann, I., May, 28-29, 2015. Biochar – Contribution to Sustainable Agriculture, Potsdam: "An economic assessment of soil carbon sequestration with biochar in Germany".

Sänger, A., May, 28-29, 2015. Biochar – Contribution to Sustainable Agriculture, Potsdam: "Effects of biochars, digestate and mineral N fertilizer on soil C and N and crop yields on a sandy soil".

Participation in conferences

Meyer-Aurich, A., Sängler, A., Lee, S., Rebenburg, P., Lanza, G., Sun, Z.C., Büks, F., Reibe, K., Wirth, S., Kaupenjohann, M., Abu Bakar, R., Idaty Mohd Ghazi, T., Teichmann, I., Mumme, J., May, 28-29, 2015. International Biochar Symposium: Biochar-Contribution to Sustainable Agriculture, Potsdam, Germany

Lanza, G., September, 21-24, 2015. 5th International Symposium on Organic Matter, Göttingen: *Short-term response of soil respiration and microbial communities after addition of chars – effect of nitrogen and readily available carbon*. (Poster)

Büks, F., 2015. Tagung der Deutschen Bodenkundlichen Gesellschaft (DBG): *Effects of motion and feeding of the nematode Acrobeloides buetschlii on aggregate stability in a sandy agricultural soil*. (Poster)

Teichmann, I., June, 17-18, 2015. Congress "Ecoinnovations from Biomass", Papenburg: *3N Kompetenzzentrum Niedersachsen Netzwerk Nachwachsende Rohstoffe e.V.*

Lanza, G., 27.04-02.05, 2014. European Geosciences Union General Assembly, Vienna, Austria: *Short-term incubation studies on degradation of biochar in soil*. (Poster)

Theses

Medick, J., 2014. *Hydrothermal carbonization of green wastes: A techno-economic assessment of sustainable organic waste management in the metropolitan region of Berlin*. Master thesis. Humboldt University Berlin.

Teichmann, I., 2016. *Three topics in agriculture: Private quality standards, marketing channels, and biochar*. Doctoral thesis. Humboldt University Berlin.

Policy reports

Haubold-Rosar, M., Heinkle, T., Rademacher, A., Kern, J., Dicke, C., Funke, A., Germer, S., Karagöz, Y., Lanza, G., Libra, J., Meyer-Aurich, A., Mumme, J., Theobald, A., Reinhold, J., Neubauer, Y., Medick, J., Teichmann, I., 2016. *Chancen und Risiken des Einsatzes von Biokohle und anderer "veränderter" Biomasse als Bodenhilfsstoffe oder für die C-Sequestrierung in Böden*. Texte 04/2016. Dessau-Roßlau: Umweltbundesamt.