UTILIZATION OF RICE STRAW BIOCHAR AND UREA TO MITIGATE GREENHOUSE GASES EMISSION IN SUSTAINABLE RICE PRODUCTION

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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The agricultural sector generally emits three main greenhouse gases (GHGs) to the atmosphere, namely, nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2). For sustainable rice production and soil health, the application of mineral fertilizers along with organic fertilizers under mitigation option for climate change is of concern. Hence, the present study was undertaken to determine how the effect of rice straw biochar (BC) and urea management can mitigate GHG emission to ensure sustainable rice production. Three pot experiments were conducted in a randomized complete block design with four replications. The first pot experiment consisted of treatments with rice straw BC (9 t/ha) and different rates of urea (30, 60, 90, 120 and 150 kg N/ha) and a control of 150 kg N/ha to determine the effect on GHG emission and soil fertility in rice production. The increased % of grain yield over control (20.7, 21.2 and 21.1%) were found in treatments BC+ 60, 90 and 120 kg N/ha respectively. The lowest combined global warming potential (GWP) by CH_4 and N_2O (46788 kg CO_2-eq/ha) was recorded in treatment, BC + 30 kg N/ha and followed by BC + 60 kg N/ha which had 50751kg CO_2-eq/ha. Improved soil properties and higher nutrient (P, K and Mg) uptake were also observed in all BC treatments (except BC+ 30 kg N/ha) although there was no consistency among the BC treatments. The application of rice straw BC (9 t/ha) through 60 kg N/ha is proposed for increasing yield, improving soil properties and reduced GHG emission in relative to control. The second pot experiment was conducted to determine the persistent effect of rice straw BC (9 t/ha) on GHG and soil fertility by the same treatments as the first, but without additional nutrient. Although control itself had lower yield (34.7%) than optimum from the first experiment, increased grain yield over control (%) at 4.2, 5.1, 14.5 and 19.7% in treatments BC+60, 90, 120, 150 kg N/ha respectively were recorded. The lower GWP by CH_4 (219.6-244.4 kg CO_2-eq/ha) was estimated in all BC treatments relative to control (361.5 kg CO_2-eq/ha) due to reduced methane gas emission regardless of rate of urea. Soil parameters, CEC and residual nutrients such as, P, K, Cu, Fe and Mn were consistently higher in all BC soil relative to control. In terms of food security in the residual BC soil, some extent of supplemental fertilizer should be considered although residual rice straw BC (9 t/ha) had positively persistent effect over control. The third pot experiment was carried out to determine the most feasible rate of rice straw BC by applying with optimum rate of urea. Treatments comprised of different rates of rice straw BC (9, 8, 7, 6, and 5 t/ha) + 60 kg N/ha, control (150 kg N/ha) and 60 kg N/ha. Increased % of grain yield over control (14-16%) were found in rice straw BC (9, 8, 7 and 6 t/ha + 60 kg N/ha) regardless of rates of BC. Lower combined GWP (by CH_4 and N_2O) (44438-45640 kg CO_2-eq/ha) were amounted in all BC treatments irrespective of rates of BC. Improved soil properties except P and Ca were observed in all BC soil. Besides, major nutrients, N, P, and K uptake were higher in all BC plants. The mechanism of effect of BC on reduced N_2O emission was due to significantly reduced nitrite concentration in BC (6 t/ha) + 60 kg N/ha over control (150 kg N/ha) in which NO_2^- (conc) was highly correlated with the absorbance of bacteria, *Nitrosomonas europaea.* Thus, the present study proposes that rice straw BC (6 t/ha) + 60 kg N/ha should be recommended for sustainable rice productivity. Although this research was limited to pot and there was no nutrient leaching losses, the synergetic effect of rice straw biochar and reduced rate of urea was worth mentioning for acidic paddy soil. Field experiment of this organic soil amendment should be conducted to demonstrate and transfer technology to farmers.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENGGUNAAN BIOCHAR JERAMI DAN UREA UNTUK MENGURANGKAN PELEPASAN GAS RUMAH HIJAU DALAM PENGELUARAN BERAS YANG BERKEKALAN

Oleh

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Sektor pertanian umumnya mengeluarkan tiga gas rumah hijau yang utama (GHGs) ke atmosfera, iaitu nitrous oksida (N_2O), metana (CH_4) dan karbon dioksida (CO_2). Bagi mengekalkan kesuburan tanah dan pengeluaran padi yang berterusan, penggunaan baja mineral dengan baja organik dipilih untuk dikurangkan kerana perubahan iklim yang membimbangkan. Oleh itu, kajian ini dijalankan untuk mengkaji kesan biochar daripada jerami (BC) dan strategi pengurusan baja nitrogen terhadap pembebasan GHG bagi mengekalkan pengeluaran padi yang berterusan. Tiga eksperimen telah dijalankan dalam susunan rekabentuk RCBD dengan empat replikasi. Eksperimen yang pertama terdiri daripada rawatan dengan BC jerami padi (9 t/ha) dengan kadar baja N yang berlainan (30, 60, 90, 120 dan 150 kg N/ha) dan kawalan 150 kg N/ha untuk menunjukkan kesan pembebasan GHG dan kesuburan tanah dalam pengeluaran padi. Peratus peningkatan hasil biji padi berbanding kawalan (20.7, 21.2 dan 21.1%) telah didapati dalam rawatan BC + 60, 90 dan 120 kg N/ha masing-masing. Gabungan pemanasan global yang terendah (GWP) oleh CH_4 dan N_2O (46788 kg CO_2-eq/ha) direkodkan pada T_2 (BC + 30 kg N/ha) dan diikuti oleh T_3 (BC + 60 kg N/ha) 50751kg CO_2-eq/ha. Ciri-ciri tanah yang lebih baik dan pengambilan nutrien yang lebih tinggi (P, K dan Mg) juga diperhatikan dalam semua rawatan BC (kecuali T_2, BC + 30 kg N/ha) walaupun tidak ada konsistensi di antara rawatan BC. Penggunaan BC jerami padi pada 9 t/ha dan 60 kg N/ha adalah dicadangkan untuk meningkatkan hasil, menambah baikkan sifat tanah dan mengurangkan pembebasan GHG secara relatif berbanding kawalan. Eksperimen kedua dijalankan untuk menyiasat kesan yang berterusan ke atas BC jerami padi (9 t/ha) pada GHG dan hasil menggunakan rawatan yang sama dengan yang pertama, tetapi tanpa nutrisi tambahan. Walaupun kawalan itu sendiri mempunyai hasil yang lebih rendah (34.7%) daripada optimum dari eksperimen pertama, peningkatan % hasil bijirin melebihi kawalan pada 4.2, 5.1, 14.5 dan 19.7% dalam rawatan BC + 60, 90, 120, 150 kg N/ha masing-masing telah direkodkan. GWP yang lebih rendah oleh CH_4 (219.6- 244.4 kg CO_2-eq/ha) telah direkodkan dalam semua rawatan BC berbanding dengan kawalan (361.5 kg CO_2-eq/ha) disebabkan pengurangan gas metana tanpa mengira baja N. Parameter tanah, CEC dan sisa nutrien seperti, P, K, Cu, Fe dan Mn lebih tinggi secara konsisten di semua tanah BC

berbanding dengan kawalan tanpa mengira kadar baja nitrogen. Dari segi keselamatan makanan di dalam tanah sisa BC, sebahagian besar tambahan baja N perlu dipertimbangkan walaupun jerami padi BC (9 t/ha) mempunyai kesan positif yang berterusan berbanding kawalan. Eksperimen ketiga dijalankan untuk mengkaji kadar BC jerami padi yang paling sesuai dengan menggunakan kadar baja N yang optimum. Rawatan terdiri daripada kadar BC jerami padi yang berbeza (9, 8, 7, 6, dan 5 t/ha) + 60 kg N/ha, kawalan (150 kg N/ha) dan 60 kg N/ha. Peningkatan % hasil bijirin pada kawalan (14-16%) ditemui dalam BC jerami padi (9, 8, 7 dan 6 t/ha + 60 kg N/ha) tanpa mengira kadar BC. Gabungan GWP yang lebih rendah (oleh CH_4 dan N_2O) (44438-45640 kg CO_2-eq/ha) telah direkodkan dalam semua rawatan BC tanpa mengira kadar BC. Penambahbaikan sifat-sifat tanah kecuali P dan Ca direkodkan di dalam semua tanah BC. Selain itu, pengambilan nutrien utama N, P, dan K adalah lebih tinggi di semua tanaman BC. Mekanisme kesan BC pada pelepasan N_2O yang berkurangan disebabkan oleh berkurangnya kepekatan nitrit di dalam BC (6 t/ha) + 60 kg N/ha berbanding kawalan di mana NO_2^- (conc) sangat berkesinambungan dengan penyerapan bakteria, *Nitrosomonas europaea*. Kajian ini mencadangkan bahawa BC jerami padi (6 t/ha) + 60 kg N/ha harus disarankan untuk produktiviti padi yang berkekalan. Walaupun penyelidikan ini hanya terhad dalam baldi dan didapati tiada kehilangan pelepasan nutrien, namun kesan daripada sinergi biochar jerami padi dan pengurangan unsur N adalah bernilai untuk digunakan pada tanah padi yang berasid. Eksperimen lapangan bagi bahan tambah tanah organik ini perlu dijalankan bagi tujuan demonstrasi dan pemindahan teknologi kepada petani.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

C	Carbon
C:N	Carbon nitrogen ration
CEC	Cation exchange capacity
CH_4	Methane
CO_2	Carbon Dioxide
DSR	Direct seeded rice
GHG	Greenhouse gas
GWP	Global warming potential
kg N/ha	Kilogram nitrogen per hectare
Mg/ha	Mega gram/hectare
N	Nitrogen
N_2O	Nitrous Oxide
NH_3	Ammonia
NH_4	Ammonium
NH_4Cl	Ammonium chloride
NO_3	Nitrate
NPK	Nitrogen, phosphorus and potassium
O_2	Oxygen
OD	Optical density
PVC	Polyvinylchloride
RPM	Revolutions per minute
Si	Silicon
SPAD	Silicon photon activated diode
SRI	System of rice intensification
t/ha	Tonnage per hectare
ton/yr	Tonnage per year
v/v	Volume per volume
w/w	Weight per weight

CHAPTER 1

INTRODUCTION

The increasing greenhouse gases (GHGs) in the atmosphere lead to higher global warming potential (GWP) due to their heat absorbing capacity (Kaiser, 1989). Karl et al. (1990) estimated an increase in global temperature from 2.8 to 5.2˚C for the next hundred years due to the release of greenhouse gases from human activities. Agriculture is one of the most vulnerable sectors affected by climate change such as fluctuation of temperature and rainfall (Reilly, 1995). Besides, the economies and livelihood of the developing countries mainly depend on agriculture and consequently they suffer seriously from climate change due to global warming (Moorhead, 2009). As such, mitigation options for climate change are important for crop productivity and farmers' livelihood (Reilly and Schimmelpfennig, 1999).

More than 60% of global populations are provided by rice (Gathorne-Hardy, 2013) and 90% of world rice is grown and consumed in Asian countries (Hayashi 2013c). So its cultivation is the most important agricultural consideration worldwide. Moreover, in the year 2025, 70% or more rice needs to be produce in comparison to year 2001 to feed the growing population (Dubey, 2001). Therefore, wide use of mineral fertilizer will increase and worsen greenhouse gases emission problem (Dubey, 2005).

Around 90% of global rice is grown under flooded conditions (Wassmann et al., 2009). Flooded rice fields are the main source of methane (CH_4) from bacterial activities in anaerobic condition and it accounts for 20% of global warming potential (Sass et al., 2017). Babu1 et al. (2005) estimated for the year 2020, global CH_4 emission from paddies may range from 29 to 61 ton/yr because global rice production must almost double for high demand which will lead to increase in CH_4 fluxes by up to 50%. Carbon dioxide (CO_2) is emitted from the respiration of rice plant and also from soil microorganism (Komiya et al., 2015). Besides, Nitrogen is needed as the major nutrient to increase the yields of cultivated crops and plant can uptake it in various forms but release N_2O form from the soils (Gathorne-Hardy, 2013). Nitrification which take place in aerobic microbial oxidation of ammonium to nitrate and denitrification which is anaerobic microbial reduction of nitrate to nitrogen gas (N_2) are the major sources of N_2O emission (De Klein et al., 2006). Hence, rice agricultural sector emit three main greenhouse gases (GHGs), Nitrous Oxide (N_2O), Methane (CH_4) and Carbon dioxide (CO_2) and their global warming potential are 300 and 23 times higher than that of CO_2 respectively (Agriculture and forestry greenhouse gas stake holder group, 2011). Therefore, we need to stop adding greenhouse gases to the atmosphere to escape the worst concomitant of climate change.

For sustainable agriculture, mineral fertilizer application should be addressed not only for the food but also mitigation option for climate change (Brentrup and Palliere, 2008). Nguyen (2004) also indicated that sustainable rice productivity for food security will require the improvement of the production systems which are adaptable to global climate change as well as possible ways to mitigate global warming. Therefore, to reduce GHG emissions and to achieve sustainable yield, optimized N use efficiency (NUE) than to simply reduce N fertilizer rate (Groenigen et al., 2011) and soil carbon sequestration are essential (Smith et al., 2007). The important long-term contributions for mitigating GHG emission through carbon sequestration can be achieved by the improved crop productivity and nitrogen balance (Marland et al., 2003). Reicosky et al. (2000) also mentioned that increased food production efficiency with minimum impact on environmental quality and greenhouse gases will be achieved by the intercontinental understanding of the decisive managements such as water and carbon arrangement, soil and variety assortment, fertilizer type and amount. Furthermore, Dumanski et al. (2010) stated that improved fertilizer and soil nitrogen management can mitigate greenhouse gases emission.

In the agricultural world, the huge amount of biomass that cannot be used is burnt in the field which causes air pollution and loss of carbon from fertile soil. It should be converted into black carbon (biochar) that will lead to improved air quality and enchanced soil productivity. Biochar is an organic matter that is processed in depressed oxygen and it contains high amount of carbon than biomass itself (Wang et al., 2012b). In Malaysia, total rice cultivation area is 685454 ha with grain yield of 2, 599 382 tonnes produced straw yield of 3,177 022 tonnes and most are burned as the current cultural practice to prevent pest and diseases and to prepare the field for next planting which causes environmental pollution and loss of carbon storage (Rosmiza et al., 2017). Besides, rice straws are left in the field that leads to significant methane gas emitted to the atmosphere (Silalertruksa and Gheewala, 2013). In addition, Malaysian farmers use N fertilizer more than the recommended rate of 170 kg N/ha to obtain maximum rice yield (Herman et al., 2015). Therefore rice straw should be used as an alternative nutrient source such as biochar. According to Roberts et al. (2010) and Fong (2012) attentive biochar feedstock selection is needed for greater economic and environmental stability from the benefits of its implementation. Besides, rice straw contains a huge amount of nitrogen, potassium and silicon (Alhassan, 2014). After pyrolysis of rice material at high temperature (600˚C), the combination of inorganic and organic substances formed Si-C bonds can prevent degradation of carbon (Parr, 2006; Guo and Chen, 2014; Jindo et al., 2014). Hance, in order to manage Malaysia's sustainable rice productivity, we should focus on improved optimum fertilizer used efficiency by using rice residue.

Rice farmer has less real adoptions of GHG mitigating measures due to limitation of income and time. Besides, our rice farmers should upgrade and well equip themselves with the scientific principles of rice paddy ecosystems with integrated nutrient management system. In addition, we have to change the ecosystem of carbon and nutrient nitrogen pathway for the global climate change but we should also well-known their synergistic effect of continuous changes. Therefore recently taking into considerations of the potentialities of organic residue and their interactive effects with mineral fertilizers for increased crop productivity, improved soil health and environmental protection are essential. So this study aimed to determine the effect of rice straw biochar and urea management on greenhouse gas emission for sustainable rice production. It is hypothesized that the integrated usage of rice straw biochar and urea fertilizer managements influenced on rice yield, GHG emission and nutrient availability. The specific objectives were:

i. To determine the optimum rate of urea in conjunction with rice straw biochar (9 t/ha) that can reduce GHG emission in rice productivity

ii. To determine the residual effect of both rice straw biochar (9 t/ha) and different rates of urea amendments on greenhouse gas emissions and rice yields

iii. To determine the most feasible rate of biochar with optimum rate of urea management for sustainable rice production

REFERENCES

Abou, E. M. M., and Hoda, M. A. (2005). Relationships, growth, yield of broccoli with increasing N, P or K ratio in a mixture of NPK fertilizers. *Annual Agricultural Science Moshtohor*, 43 (2): 791-803.

Abukari, A. (2014). Effect of rice husk biochar on maize productivity in the Guinea Savannah Zone of Ghana (Master Thesis, Department of Agroforestry, Kwame Nkrumah University of Science and Technology).

Accardi-dey A., Gschwend P. M. (2002). Assessing the aspects of phosphate adsorption by charcoal. *Soil Science Society of America Proceeding, 24,* 340-346.

Adhya, T. K.,. Linquist, B., Searchinger, T., Wassmann, R. and Yan, X. (2014). Wetting and Drying: Reducing Greenhouse Gas Emissions and Saving Water from Rice Production. Working Paper, Installment 8 of Creatinga Sustainable Food Future. Washington, DC: World Resources Institute. Available online at http://www.worldresourcesreport.org.

Aggarwal, P. K. (2003). Impact of climate change on Indian agriculture. *Journal of Plant Biology-new Delhi*, *30*(2), 189-198.

Agriculture and forestry greenhouse gas stake holder group. (2011). Report by the Agriculture and forestry greenhouse gas stake holder group. In: Dairy Sector: How to reduce costs and cut Greenhouse Gas (GHG) Emissions. Available at: https://www.lmcni.com/site/wp-content/uploads/2015/04/efficient-farming-cuts-greenhouse-gases1.pdf. (accessed 19 January 2016).

Akhtar, S. S. (2015). Biochar Ameliorate Drought and Salt Stress in Plants. (Abstract of Doctoral dissertation, Department of Plant and Environmental Sciences, Faculty of Science, University of Copenhagen).

Alhassan, A. Y. (2014). Manual of soil fertility improvement technologies in lowland rice ecologies of Ghana. https://www.ji rcas.go.jp/ja/file/17598/dow nload?toke n=0IhUWt0_ cited in 24/8/2017.

Ali, K., Munsif, F., Zubair, M., Hussain, Z., Shahid, M., Din, I. U. and Khan, N. (2011). Management of organic and inorganic nitrogen for different maize varieties. *Sarhad Journal of Agriculture*, 27(4): 525-529.

Ali, M. A., Lee, C. H., Kim, P. J. (2008). Effect of silicate fertilizer on reducing methane emission during rice cultivation. *Biology and Fertility of Soils, 44*:597–604.

Al-Kaisi, M. M., Kruse, M. L. and Sawyer, J. E. (2008). Effect of nitrogen fertilizer application on growing season soil carbon dioxide emission in a corn-soybean rotation. *Journal of Environmental Quality*, 37: 325-332.

Anderson, J. P. E., Domsch, K. H. (1978). A physiological method for the quantitative measurement of microbial biomass in soils. *Soil Biology and Biochemistry,* 10:215–221

Asai, H., Samson, B. K., Haefele, S. M., Songyikhangs, K., Homma, K., Kiyono, Y., Inoue, Y., Shiraiwa, T., Horie, T. (2009). Biochar amendment techniques for upland rice production in Northern Laos. 1. Soil physical properties, leaf SPAD and grain yield. *Field Crops Research*, *111*, 81–84.

Atkinson, C. J., Fitzgerald, J. D., Hipps, N. A. (2010). Potential mechanisms for achieving agricultural benefits from biochar application to temperate soils: a review. *Plant and Soil,* 337: 1–18.

Aulakh, M. S., Wassmann, R., Bueno, C. and Rennenberg, H. (2001a). Impact of root exudates of different cultivars and plant development stages of rice (*Oryza sativa* L.) on methane production in a paddy soil. *Plant Soil,* 230, 77–86. (doi:10.1023/A:1004817212321)

Aulakh, M. S., Wassmann, R., Bueno, C., Kreuzwieser, J., Rennenberg, H. (2001b). Characterization of root exudates at different growth stages of ten rice (Oryza sativa L.) cultivars. *Plant Biology, 3*:139–148.

Babu1, Y. J., Li1, C., Frolking, S., Nayak, D. R., Datta, A. and Adhya. T. K. (2005). Modelling of methane emissions from rice-based production systems in India with the denitrification and decomposition model. *In* Field validation and sensitivity analysis. *Current science*. Vol. 89, No. 11

Baggs, E. M., Rees, R. M., Smith, K. A., and Vinten, A. J. A. (2000). Nitrous oxide emission from soils after incorporating crop residues. *Soil use and management*, *16*(2), 82-87.

Bagreev, A., Bandosza, T. J., Locke, D. C. (2001). Pore structure and surface chemistry of adsorbents obtained by pyrolysis of sewage sludge-derived fertilizer. *Carbon, 39*, 1971–1979.

Baligar, V. C. and O. L Bennett. (1986). Outlook on fertilizer use efficiency in the tropics. *Fertilizer Research,* 10:83-96.

Ball, P. N., MacKenzie, M. D., DeLuca, T. H., and Montana, W. E. (2010). Wildfire and charcoal enhance nitrification and ammonium-oxidizing bacterial abundance in dry montane forest soils. *Journal of Environmental Quality*, *39*(4), 1243-1253.

Barnard, R., Le Roux X., Hungate B. A., Cleland E. E., Blankinship J. C., Barthes L. and Leadley P. W. (2006). Several Components of Global Change Alter Nitrifying and Denitrifying Activities in an Annual Grassland. *Functional Ecology,* 20 (4): 557–564

Baumert, K. A., Herzog, T., Pershing, J. (2005). Navigating the Numbers. Greenhouse Gas Data and International Climate Policy. Washington D.C., World Resources Institute. http://pdf.wri.org/navigating_numbers.

Bauza, J., Morell, J. M., and Corredor, J. E. (2002). Biogeochemistry of nitrous oxide production in the red mangrove (*Rhizophora mangle*) forest soils. *Estuarine Coastal and Shelf Science, 55,* 697-704.

Bhatia, A., Aggarwal, P. K., Jain, N. and Pathak, H. (2012). Greenhouse gas emission from rice and wheat-growing areas in India: Spatial analysis and upscaling. *Greenhouse Gases: Science and Technology,* 2: 115-125.

Bhattarai, B., Neupane, J., Dhakal, S. P., Nepal, J., Gnyawali, B., Timalsina, R., and Poudel, A. (2015). Effect of Biochar from Different Origin onPhysio-Chemical Properties of Soil and Yield of Garden Pea (Pisum sativum L.) at Paklihawa, Rupandehi, Nepal. *World Journal of Agricultural Research*, *3*(4), 129-138.

Bi, Q. F., Chen, Q. H., Yang, X. R., Li, H., Zheng, B. X., Zhou, W. W., Liu, X. X., Dai, P. B., Li, K. J. and Lin, X. Y. (2017). Effects of combined application of nitrogen fertilizer and biochar on the nitrification and ammonia oxidizers in an intensive vegetable soil. *AMB Express*, *7*(1), 198.

Binod P., Sindhu R., Singhania R. R., Vikram S., Devi L., Nagalakshmi S., Kurien N., Sukumaran R. K., Pandey A. (2010). Bioethanol production from rice straw: an overview. Bioresource Technology, 101:4767–4774.

Bird, M. I., Ascough, P. L., Young, I. M., Wood, C. V., Scott, A. C. (2008). X-ray microtomographic imaging of charcoal. *Journal of Archaeological Science, 35,* 2698–2706

Biswas, H., Mukhopadhyay, S. K., Sen, S. and Jana, T. K. (2007). Spatial and temporal patterns of methane dynamics in the tropical mangrove dominated estuary, NE coast of Bay of Bengal, India, *Journal of Marine System*, 68, 55–64.

Blake, W.P. (1893). Note upon the absorption of sulphur by char-coal. *Science*, 21, 326–327.

Blanco-Canqui, H. and Lal, R. (2004). Mechanisms of carbon sequestration in soil aggregates. *Critical Review in Plant Science,* 23(6), 481–504.

Bodelier, P. L. E. (2003). Interactions between oxygen releasing roots and microbial processes in flooded soils and sediments.*in* H. de Kroon and E. J. W. Visser, editors. Root ecology. *Springer*, Berlin, Germany

Boeckx, P., Van Cleemput, O. and Villaralvo, I. (1997). Methane oxidation in soils with different textures and land use. *Nutrient Cycling in Agroecosystems*. 49: 91-95.

Brady, N. C., Weil, R. R. (2008). The Nature and Properties of Soils, 14th edition Pearson Prentice Hall.

Brantley, K. E., Savin, M. C., Brye, K. R. and Longer, D. E. (2015). Pine woodchip biochar impact on soil nutrient concentrations and corn yield in a silt loam in the mid-Southern US. *Agriculture*, *5*(1), 30-47.

Brentrup, F. and Pallière, C. (2008). Energy efficiency and greenhouse gas emissions in European nitrogen fertilizer production and use. In: the International Fertiliser Society [www.fertiliser-society.org] from its Proceedings 639 (2008). Available at http://www.fertilizerseurope.com/ fileadmin/user upload/publications/ agriculture_public ations/Energy_Efficiency__V9.pdf. (accessed September 17, 2017)

Brentrup, F., Küsters, J., Lammel, J. and Kuhlmann, H. (2000). Methods to estimate on-field nitrogen emissions from crop production as an input to LCA studies in the agricultural sector. *The international journal of life cycle assessment*, *5*(6), 349-357.

Brown, J. R., Blankinship J. C., Niboyet A., van Groenigen K. J., Dijkstra P., Le Roux X., Leadley P. W. and Hungate B. A. (2012). Effects of Multiple Global Change Treatments on Soil N2O Fluxes. *Biogeochemistry* 109 (1–3): 85–100.

Bruinsma, J. (Ed.). (2003). World agriculture: towards 2015/2030. FAO perspective. Earthscan, London and FAO, Rome.

Brunn W. E., Ambus P, Egsgaard H, Nielsen H. H. (2012). Effects of slow and fast pyrolysis biochar on soil C and N turnover. *Soil Biology and Biochemistry* 46:73-79.

Bruun, E. W., Mu¨ller-Sto¨ver, D., Ambus, P., Hauggaard-Nielsenet, H. (2011). Application of biochar to soil and N2O emissions: potential effects of blending fast-pyrolysis biochar with anaerobically digested slurry. *European Journal of Soil Science,* 62:581–589

Burger, M., and Jackson, L. E. (2003). Microbial immobilization of ammonium and nitrate in relation to ammonification and nitrification rates in organic and conventional cropping systems. *Soil Biology and Biochemistry*, *35*(1), 29-36.

Butphu, S., Toomsan, B., Cadisch, G., Rasche, F., and Kaewpradit, W. (2014). Impact of biochar application on upland rice production, N use efficiency and greenhouse gas emissions in a rotation system with sugarcane. Available at: https://fsc.uni-hohenheim.de/fileadm in/einrichtungen/fsc/FSC_Brief_No.27.pdf. Cited in 27, January, 2016

Cai, Z. C. (1999). Effect of water regime on CO_2, CH_4 and N_2O emissions and overall potential for Greenhouse effect caused by emitted gases. Acta Pedolofica Sinica (in Chinese), 36(4) : 484-491.

Cai, Z. C. and Mosier, A. R. (2000). Effect of NH4Cl addition on methane oxidation by paddy soils. *Soil Biology and Biochemistry*. 32:1537-1545.

Cai, Z. C., Tsuruta, H. and Minami, K. (2000). Methane emissions from rice fields in China: measurements and influencing factors. *Journal of Geophysical Research, 105,* 17 231–17 242. (doi:10.1029/2000JD900014)

Cai, Z., Xing, G., Yan, X., Xu, H., Tsuruta, H., Yagi, K. and Minami, K. (1997). Methane and nitrous oxide emissions from rice paddy fields as affected by nitrogen fertilisers and water management. *Plant and soil*, *196*(1), 7-14.

California Climate and Agricultue Network. (2011). The Climate Benefits of Organic Agriculture Available at: http://calclimateag.org/wp-content/uploads/2011/04/Organic-Climate-Benefits-fact-sheet.pdf (accessed 23 January 2016)

Campbell, N., Reece, J. (2008). Biology 8th Edition. Pearson International Edition The World Bank. 2012. Climate Change, Africa. http://climatech ange.worldbank.org/content/africa [12-01-04]

Canfield, D. E., Glazer, A. N. and Falkowski, P. G. (2010). The Evolution and Future of Earth's Nitrogen Cycle. *Science, 330*: 192-196.

Carter, S., Shackley, S., Sohi, S., Suy, T. B. and Haefele, S. (2013). The impact of biochar application on soil properties and plant growth of pot grown lettuce (*Lactuca sativa*) and cabbage (*Brassica chinensis*). *Agronomy*, *3*(2), 404-418.

Carvalho, M. D. M., Madari, B., Bastiaans, L., Van Oort, P., Heinemann, A., da Silva, M. A. S. Maia , A. H. N. and Meinke, H. (2014a). Growth of aerobic rice in the presence of biochar as soil amendment: short-term effects in a clayey Rhodic Ferralsol in the Brazilian savanna (Cerrado). *Embrapa Meio Ambiente-Artigo em periódico indexado (ALICE)*.

Carvalho, M. T., Madari, B. E., Bastiaans, L., van Oort, P. A. J., Heinemann, A. B., da Silva, M. A. S., Maia, A. D. H. N. and Meinke, H. (2014b). Biochar improves fertility of a clay soil in the Brazilian Savannah: short term effects and impact on rice yield. *Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS)*, *114*(2), 101-107.

Case, S. (2013). Biochar amendment and greenhouse gas emissions from agricultural soils, PhD Thesis, School of Geosciences, University of Edinburgh, United Kingdom.

Cavigelli M. A., Robertson G. P. (2001). Role of denitrifier diversity in rates of nitrous oxide consumption in a terrestrial ecosystem. *Soil Biology and Biochemistry,* 33:297–310

Cavigelli, M. A., and Robertson, G. P. (2000). The functional significance of denitrifier community composition in a terrestrial ecosystem. *Ecology*, *81*(5), 1402-1414.

Cha, J. S., Park, S. H., Jung, S. C., Ryu, C., Jeon, J. K., Shin, M. C., and Park, Y. K. (2016). Production and utilization of biochar: a review. *Journal of Industrial and Engineering Chemistry*, *40*, 1-15.

Chan K. Y., Zwieten V. L., Meszaros I., Dowine A., Joseph S. (2008a). Using poultry litter biochars as soil amendments. *Australian Journal of Soil Research, 46,* 437-444.

Chan, K. Y., and Xu, Z. (2009). Biochar: Nutrient Properties and Their Enhancement. In: Lehmann, J., and Joseph, S. (Eds), Biochar for Environmental Management, Science and Technology. Earthscan, London, pp, 67-81.

Chan, K. Y., Van Zwieten, L., Meszaros, I., Downie, A. and Joseph, S. (2007). Agronomic Values of Green Waste Biochar as a Soil Amendment. Australian Journal of Soil Research, 45, 629-634. http://dx.doi.org/10.1071/SR07109

Chan, K. Y., Van Zwieten, L., Meszaros, I., Downie, A., and Joseph, S. (2008b). Agronomic values of greenwaste biochar as a soil amendment. *Soil Research*, *45*(8), 629-634.

Chang, C., Janzen, H. H., Cho, C. M., Nakonechny, E. M., (1998). Nitrous oxide emission through plants. *Soil Science Society of America Journal,* 62, 35-38.

Chaudhry, U. K., Shahzad, S., Naqqash, M. N., Saboor, A., Yaqoob, S., Salim, M., and Khalid, M. (2016). Integration of biochar and chemical fertilizer to enhance quality of soil and wheat crop (Triticum aestivum L.). *PeerJ PrePrints*, *2016*(01).

Chen K. Y., Van Z. L., Meszaros I., Downie A., Joseph S. (2007). Agronomic values of green waste biochar as a soil amendment. *Australian Journal of Soil Research,* 45:629-634.

Chen, C. R., Phillips, I. R., Condron, L. M., Goloran, J., Xu, Z. H., Chan, K. Y., (2013). Impacts of greenwaste biochar on ammonia volatilisation from bauxite processing residue sand. *Plant Soil* 367, 301–312.

Chen, G., Chen, B, Yu, D., Ye, Y., Nora F. Y. Tam, Chen, S. (2016). Soil greenhouse gases emissions reduce the benefit of mangrove plant to mitigating atmospheric warming effect Biogeosciences Discussions, doi:10.5194/bg-2015-662, 2016 https://www.biogeosciences-discuss.net/bg-2015-662/bg-2015-662.pdf

Cheng, C. H., Lehmann, J., and Engelhard, M. (2008). Natural Oxidation of Black Carbon in Soils: Changes in Molecular Form and Surface Charge along a Cli-Mosequence. *Geochimica Et Cosmochimica Acta, 72*:1598–1610. 169

Cheng, C. H., Lehmann, J., Thies, E., Burton, S. D. and Engelhard, M. H. (2006). Oxidation of Black Carbon by Biotic and Abiotic Processes. Organic Geochemistry, 37:1477–1488.

Chidthaisong, A., Watanabe, I. (1997). Methane formation and emission from flooded rice soil incorporated with 13C-labeled rice straw. *Soil Biology and Biochemistry* 29, 1173-1181.

Christensen, T. R., Ekberg, A., Ström, L., Mastepanov, M., Panikov, N., Öquist, M., Svensson, B. H., Nykänen, H., Martikainen, P. J. and Oskarsson, H. (2003). Factors controlling large scale variations in methane emissions from wetlands. *Geophysical Research Letters*, *30*(7).

Climate Tech Wiki, 2006. http://www.climatetechwiki.org/technology/rice-mid-season-drainage

Clough, T. J. and Condron, L. M. (2010). Biochar and the nitrogen cycle: introduction. *Journal of environmental quality*, *39*(4), 1218-1223.

Clough, T., Bertram, J., Ray, J., Condron, L., O'Callaghan, M., Sherlock, R., Wells, N. (2010). Unweathered wood biochar impact on nitrous oxide emissions from a bovine-urine-amended pasture soil. *Soil Science Society of American Journal,* 74:852–860

Clough, T., Condron, L., Kammann, C. and Müller, C. (2013). A review of biochar and soil nitrogen dynamics. *Agronomy,* *3*:275–293. doi:10.3390/agronomy3020275

Conen, F., Dobbie, K. E., Smith, K. A. (2000). Predicting N2O emissions from agricultural land through related soil parameters. *Global Change Biology. 6,* 417–426.

Cordovil C. M. d. S. (Ed). (2014). Proceedings from 18th Nitrogen Workshop: *The contribution of crop residues to Nitrous Oxide Emissions from Arable Crops*. 30th June – 3rd July 2014. Lisboa, Portugal. Pp 485-486.

Corredor, J. E., Morell, J. M. and Bauz, J. (1999). Atmospheric nitrous oxide fluxes from mangrove soils. *Marine Pollution Bulletin, 3*, 473–478.

Cross, A., Sohi, S. P. (2011). The priming potential of biochar products in relation to labile carbon contents and soil organic matter status. *Soil Biology and Biochemistry,* 43, 2127–2134.

D. Giltrap, Saggar, and Wilde, H. (2008). Using the NZ-DNDC model to estimate agricultural N2O emissions in the Manawatu-Wanganui region, *Plant and Soil*, vol. 309, pp. 191-209,

Davidson, E. A., Keller, M., Erickson, H. E., Verchot, L. V. and Veldkamp, E. (2000). Testing a Conceptual Model of Soil Emissions of Nitrous and Nitric Oxides: Using two functions based on soil nitrogen availability and soil water content, the hole-in-the-pipe model characterizes a large fraction of the observed variation of nitric oxide and nitrous oxide emissions from soils. *Bioscience*, *50*(8), 667-680.

Davy, E. W. (1856). XXII. On some experiments made with a view to determine the comparative value of peat and peat-charcoal for agricultural purposes. *Philosophical Magazine Series, 4*, *11*(71), 172-178.

De Klein, C. A. M., Ledgard, S. F and Clark, H. (2002). Evaluation of two potential on-farm measures for reducing greenhouse gas emissions from an average dairy farm on the West Coast of the South Island of New Zealand, Proceedings of the New Zealand Grassland Association 64: 159–165

De Klein, C., Novoa, R. S. A., Ogle, S., Smith, K. A., Rochette, P., Wirth, McConkey, B. G., Mosier, A., Rypdal, K., Walsh, M. and Williams, S. A. (2006). N2O

Emissions from Managed Soils, and CO2 Emissions from Lime and Urea Application. Volume 4: Agriculture, Forestry and Other Land Use, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Intergovernmental Panel on Climate Change. *Institute for Global Environmental Strategies: Hayama, Japan.*

Deenik, J. L., McClellan, T., Uehara, G., Antal, M. J. and Campbell, S. (2010). Charcoal volatile matter content influences plant growth and soil nitrogen transformations. *Soil Science Society of American Journal, 74*:1259–1270. doi:1 0.2136/sss aj2009.0115

DeLuca, T. H., Gundale, M. J., MacKenzie, M. D. and Jones, D. L. (2015). Biochar effects on soil nutrient transformations. *Biochar for environmental management: Science, technology and implementation*, 421-454.

Dempster, D. N., Gleeson, D. B., Solaiman, Z. M., Jones, D. L. and Murphy, D. V. (2012). Decreased soil microbial biomass and nitrogen mineralisation with Eucalyptus biochar addition to a coarse textured soil. *Plant Soil, 354*:311–324. doi:10.1007/s11104-011-1067-5

Department of Agriculture, (2013). Australian agriculture:reducing emissions and adapting to a changing climate. Key findings of the Climate Change Research Program. CC BY 3.0 Available at:http://www.agricultu re.gov.au/Style%20Library/I mages/DAFF/__data/ass ets/pdffile/ 0006/23 59815/red ucing-emis sons-adapting-changing-climate.pdf.(accessed 26 March 2017)

Dhakal, P., Matocha, C. J., Huggins, F. E., Vandiviere, M. M. (2014). Nitrite reactivity with magnetite. *Environmental Science and Technology, 47*, 6206–6213.

Dharmakeerthi, R. S., Chandrasiri, J. A. S. and Edirimanne, V. U. (2012). Effect of rubber wood biochar on nutrition and growth of nursery plants of Hevea brasiliensis established in an Ultisol. SpringerPlus, 1:1-12 http://www.springerplus.com/content/1/1/84

Ding, Y., Liu, Y., Liu, S., Li, Z., Tan, X., Huang, X., Zeng, G., Zhou, L. and Zheng, B. (2016). Biochar to improve soil fertility. A review. *Agronomy for sustainable development*, *36*(2), 36.

Ding, Y., Liu, Y., Wu, W., Shi, D., Yang, M. 2010. Evaluation of biochar effects on nitrogen retention and leaching in multi-layered soil columns. *Water Air and Soil Pollution.* 213, 47-55.

Dinnes D. L., Karlen, D. L., Jaynes, D. B., Kaspar, T. C., Hatfield, J. L., Colvin, T. S., Cambardella, C. A. (2002). Nitrogen management strategies to reduce nitrate leaching in tile-drained Midwestern soils. *Agronomy. Journal. 94*: 153–171.

Dobermann, A. and Fairhurst, T. H. (2002). Rice straw management. Better crops. Intern 16 (Sp. Supp. May), 7-9.

Domene, X., Hanley, K., Enders, A., Lehmann, J. (2015). Short-term mesofauna responses to soil additions of corn stover biochar and the role of microbial biomass. *Applied Soil Ecology, 89*:10–17. doi:10. 1016/j.apsoil.2014.12.005

Dong, D., Feng, Q., McGrouther, K., Yang, M., Wang, H. and Wu, W. (2015). Effects of biochar amendment on rice growth and nitrogen retention in a waterlogged paddy field. *Journal of soils and sediments*, *15*(1), 153-162.

Dong, D., Yang, M., Wang, C., Wang, H., Li, Y., Luo, J., and Wu, W. (2013). Responses of methane emissions and rice yield to applications of biochar and straw in a paddy field. *Journal of soils and sediments*, *13*(8), 1450-1460.

Downie, A., Crosky, A., Munroe, P. (2009). Physical properties of biochar. In: Biochar for Environmental Management (eds Lehmann J, Joseph S), pp 13–29. Earthscan, London.

Dubey, S. K. (2005). Microbial ecology of methane emission in rice agroecosystem: a review. *Applied ecology and environmental research*, *3*(2), 1-27.

Dubey, S.K. (2001): Methane emission and rice agriculture. *Current Science*, 81, 345-346.

Duku, M. H., Gu, S. and Hagan, E. B. (2011). *Renewable and Sustainable Energy Reviews*. 15 3539.

Dumanski, J., Desjardins, R. L., Lal, R., De Freitas, P. L., Gerber, P., Steinfeld, H., Verchot, L., Schuman, G. E., Derner, J. D. and Rosegrant, M. (2010). Strategies and economies for greenhouse gas mitigation in agriculture. In *Applied agrometeorology* (pp. 983-988). Springer Berlin Heidelberg.

Dzomeku, I. K., Illiasu, O., Birteeb, P. T., Obanyi, S., and Wood, T. (2016). Role of Residual Organic Materials on Productivity of Zea mays L. for Sustainable Soil Fertility Restoration in the Guinea Savannah Zone, Ghana. *Current Agriculture Research Journal*, *4*(2), 131-142.

Ekblad, A., Högberg, P. (2000). Analysis of δ13C of CO2 distinguishes between microbial respiration of added C4-sucrose and other soil respiration in a C3-ecosystem. *Plant Soil,* 219:197–209

Environmental Management. (Eds J Lehmann and S Joseph) pp. 207-226. (Earthscan: EPA, (2010). Methane and nitrous oxide emissions from natural sources. Report EPA430-R-10-001 Office of Atmospheric Programs (6207J) Washington, DC., nepis.epa.gov. Accessed at December 08, 2015.

Fageria N. K., Baligar V. C. (2005). Enhancing nitrogen use efficiency in crop plants. Advances in agronomy. 88: 97–185.

Fageria, N. K. and V. C. Baligar. (2001). Lowland rice response to nitrogen fertilization Communications in Soil Science and Plant Analysis 32: 1405–1429.

Fageria, N. K., Baligar, V. C., Jones, C. A. (1997). Growth and Mineral Nutrition of Field Crops; 2nd Ed; Marcel Dekker: New York Weerakoon W.M.W., Ingram K.T., Moss D.N. 2005.

Fang, Y., Singh, B. P. and Singh, B. (2014). Temperature sensitivity of biochar and native carbon mineralisation in biochar-amended soils. *Agriculture, Ecosystems and Environment, 191,* 158–167.

FAO, (2014). FAOSTAT Food and Agriculture Organization of the United Nations,Rome, http://faostat3.fao.org/home/E (last access April 18, 2016).

FAO. (2002). Rice in producing countries. In Nguyen, V. N., Tran, D. V. (Eds.). FAO rice information. (pp. 126–128) Rome, Italy: FAO

Faraji, F., Esfahani, M., Kavousi, M., Nahvi, M. and Forghani, A. (2013). Effect of nitrogen fertilizer levels on Fe and protein content, grain breakage and grain yield of rice (Oryza sativa L. cv. Khazar). *Biharean Biologist*, *7*(1), 25-28.

Farmers advice service newsletter, FAS Technical Article February 2014 Final

Feiziene, D., Feiza, V., Vaideliene, A., Povilaitis, V., and Antanaitis, S. (2010). Soil surface carbon dioxide exchange rate as affected by soil texture, different long-term tillage application and weather. *Agriculture*, *97*(3), 25-42.

Feng, Y., Xu, Y., Yu, Y., Xie, Z. and Lin, X. (2012). Mechanisms of biochar decreasing methane emission from Chinese paddy soils. *Soil Biology and Biochemistry,* 46, 80–88

Filiberto, D. M., J. L. Gaunt. (2013). Practicality of additions to enhance soil and Crop productivity. *Agriculture (2013), 3,* 715-725; doi:10.3390/ agriculture 3040715, www.mdpi.com/ journal/ agriculture

Firouzi, S. (2015). Grain, milling, and head rice yields as affected by nitrogen rate and bio-fertilizer application. *Acta agriculturae Slovenica*, *105*(2), 241-248.

Fong, E. (2012). Application of Low-Temperature Produced Biochar on Plant Growth in Californian Alfisol Soil. Low Temp. Biochar Effect on Alfisol Soil , *Spring* 2011.

Food and Agriculture Organization (FAO). (2012). Scarcity and degradation of land and water: grow-ing threat to food security. http://www.fao.org/news /story/en/item/95153/icode/ [12-01-04]

Franzluebbers, A. J., Hons, F. M., Zuberer, D. A. (1995). Tillage-induced seasonal changes in soil physical properties affecting soil CO2 evolution under intensive cropping. *Soil and Tillage Research. 34,* 41–60.

Furuya, J. and Koyama, O. (2005). Impacts of climatic change on world agricultural product markets: Estimation of macro yield functions. *JARQ*, 39(2): 121–134.

Gaskin, J. W., Speir, R. A., Harris, K., Das, K. C., Lee, R. D., Morris, L. A., Fisher, D. S. (2010). Effect of peanut hull and pine chip biochar on soil nutrients, corn nutrient status, and yield. *Agronomy Journal, 102:*623–633.

Gathorne-Hardy, A. (2013). Greenhouse gas emissions from rice. *Harriss–White B (Ed.)*.

Gebrekidan, H. and Seyoum M. (2006). Effects of mineral N and P fertilizers on yield and yield components of flooded lowland rice on vertisols of Fogera Plain, Ethiopia. *Journal of Agriculture and Rural Development in the Tropics 107 (2):*161-176.

Gebremariam, G., and Baraki, F. (2016). Response of rice yield and yield parameters to timings of nitrogen application in Northern Ethiopia.

Gebremedhin, G. H., Bereket, H., Daniel, B. and Tesfaye, B. (2015). Effect of biochar on yield and yield components of wheat and post-harvest soil properties in Tigray, Ethiopia. *Journal of Fertilizers & Pesticides*, *6*(2).

Ghoneim, A. M., and Ebid, A. I. (2013). Impact of rice-straw biochar on some selected soil properties and rice (Oryza sativa L.) grain yield. *International Journal of Agronomy and Agricultural Research*, *3*, 14-22.

Giacomini, S. J., Jantalia, C. P., Aita, C., Urquiaga, S. S., and Alves, B. J. R. (2006). Nitrous oxide emissions following pig slurry application in soil under no-tillage system. *Pesquisa Agropecuaria Brasileira*, *41*(11), 1653-1661.

Gilbert, B. and P. Frenzel. (1998). Rice roots and CH4 oxidation: the activity of bacteria, their distribution and the microenvironment. *Soil Biology and Biochemistry* 30:1903-1916.

Glaser, B., Haumaier, L., Guggenberger, G. and Zech, W. (2001) 'The Terra Preta phenomenon: A model for sustainable agriculture in the humic tropics', *Naturwissenschaften,* vol 88, pp37–41

Glaser, B., Lehmann, J. and Zech, W. (2002). Ameliorating Physical and Chemical Properties of Highly Weathered Soils in the Tropics with Charcoal - A Review, *Biology and Fertility of Soils, 35:* 219-230.

Greenhouse Gas Working Group. (2010). Agriculture's role in greenhouse gas emissions and capture. Greenhouse Gas Working Group Rep. The American Society of Agronomy, The Crop Science Society of America, and The Soil Science Society of America, Madison, WI.

Groenigen, J. W., Oenema, O., Groenigen, K. J., Velthof, G. and Kessel, C. (2011). Best Nitrogen Management Practices to Decrease Greenhouse Gas Emissions. *Better Crops*, 95: 16-17

Grossman, J., O'Neill, B. E., McPhillips, L., Tsai, S. M., Liang, B., Neves, E., Lehmann, J., Thies, J. E. (2010). Amazonian anthrosols support similar microbial communities that differ distinctly from those extant in adjacent, unmodified soils of the same mineralogy. *Microbial Ecology,* 60:192-205.

Guerena, D. (2012). Agronomic Potential Of Biochar In Contrasting Maize-Based Temperate And Tropical Agro-Ecological Zones. MSc Thesis, Cornell University, Ithaca, New York.

Güereña, D., Lehmann, J., Hanley, K., Enders, A., Hyland, C., and Riha, S. (2013). Nitrogen dynamics following field application of biochar in a temperate North American maize-based production system. *Plant and soil*, *365*(1-2), 239-254.

Gundale, M. J., DeLuca, T. H. (2006). Temperature and source material influence ecological attributes of ponderosa pine and Douglas-fir charcoal. *Forest Ecology and Management*, 231, 86–93.

Guo, J. and Chen, B. (2014). Insights on the molecular mechanism for the recalcitrance of biochar: interactive effects of carbon and silicon components. *Environmental Science and Technology*, 48, 9103–9101.

Gupta, P. K., Sahai, S., Singh, N., Dixit, C. K., Singh, D. P., Sharma, C., Tiwari, M. K., Gupta, R. K. and Garg, S. C. (2004). Residue burning in rice–wheat cropping system: causes and implications. *Current Science,* 87 1713-1717.

Hadi A, Inubushi K, Purnomo E, Razie F, Yamakawa K, Tsurata H. (2000). Effect of land-use changes on nitrous oxide (N_2O) emission from tropical peat lands. *Chemosphere-Global Changes Science 2:* 347-358.

Hadi, A., Inubushi, K., and Yagi, K. (2010). Effect of water management on greenhouse gas emissions and microbial properties of paddy soils in Japan and Indonesia. *Paddy and Water Environment*, *8*(4), 319-324.

Hai-Ming, T. A. N. G., Xiao-Ping, X. I. A. O., Wen-Guang, T. A. N. G., and Guang-Li, Y. A. N. G. (2011). Effects of straw recycling of winter covering crop on methane and nitrous oxide emissions in paddy field. *Acta Agronomica Sinica*, *37*(9), 1666-1675.

Hak, R., Rinderle-Zimmer, U., Lichtenthaler, H. K., Natr, L. (1993). Chlorophyll a fluorescence signatures of nitrogen deficient barley leaves. *Photosynthetica 28:* 151–159

Hakoomat, A. L. I., Hasnain, Z., Shahzad, A. N., Sarwar, N., Qureshi, M. K., Khaliq, S., and Qayyum, M. F. (2014). Nitrogen and Zinc Interaction Improves Yield and Quality of Submerged Basmati Rice. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *42*(2), 372.

Han, X., C. F. Liang, T. Q. Li., K. Wang, H. G. Huang, X. Yang. (2013). Simultaneous removal of cadmium and sulfamethoxazole from aqueous solution by rice straw biochar. Journal of Zhejiang University-SCIENCE B (Biomedicine and Biotechnology) ISSN 1673-1581 (Print); ISSN 1862-1783 (Online) www.zju.edu.cn/jzus; www.springerlink.com

Han, X., Sun, X., Wang, C., Wu, M., Dong, D., Zhong, T., Thies, J. E. and Wu, W. (2016). Mitigating methane emission from paddy soil with rice-straw biochar amendment under projected climate change. *Scientific reports*, *6*, 24731.

Hansen, J., M. Sato, P. Kharecha, D. Beerling, R. Berner, V. Masson-Delmotte, M. Pagani, M. Raymo, D. Royer, and J. Zachos. (2008). Target atmospheric CO2: Where should humanity aim? *Open Atmospheric Science Journal* 2:217-231.

Haque, M. A. and Haque, M. M. (2016). Growth, yield and nitrogen use efficiency of new rice variety under variable nitrogen rates. *American Journal of Plant Sciences*, *7*(03), 612.

Hardy, A. G. Greenhouse gas emissions from rice. (2013). Retrieved 30 June, 2014 from http://www.southasia.ox.ac.uk/sites/si as/files/documents/GHG%20emissions%20from%20rice%20-%20%20working%20paper.pdf

Hariz, A. M., Azlina, W. W., Fazly, M. M., Norziana, Z. Z., Ridzuan, M. M., Tosiah, S., and Ain, A. N. (2015). Local practices for production of rice husk biochar and coconut shell biochar: Production methods, product characteristics, nutrient and field water holding capacity. *Journal of Tropical Agriculture and Food Science* , *43*(1), 91-101.

Hauser, E. and Tang, J. (2013). Controls on Greenhouse Gas Fluxes from Soils: Effects of Nitrogen Fertilizers Available at: http://www.mbl.edu/ses/files/2012/12/Hauser-Emma.pdf (accessed 19 January 2016).

Hayashi, K (edt) (2013a). Proceedings from Biochar for future food security: learning from experiences and identifying research priorities. Bogor, West Java, Indonesia pp 25-31.

Hayashi, K (edt) (2013b). Proceedings from Biochar for future food security: learning from experiences and identifying research priorities. Bogor, West Java, Indonesia pp 32-36.

Hayashi, K., (2013c). The role of biochar and prospects for its use in rice production in Southeast Asia; Proceedings of Biochar for future food security: learning from experiences and identifying research priorities. Feb. 4-5, 2013, Bogor, West Java, Indonesia pp 1-4.

He, L., Zhao, X., Wang, S., and Xing, G. (2016). The effects of rice-straw biochar addition on nitrification activity and nitrous oxide emissions in two Oxisols. *Soil and Tillage Research*, *164*, 52-62.

Herman, T., Murchie, E. H. and Warsi, A. A. (2015). Rice Production and Climate Change: A Case Study of Malaysian Rice. *Pertanika Journal of Tropical Agricultural Science*, 38(3).

Hirzel, J., Pedreros, A. and Cordero, K. (2011). Effect of nitrogen rates and split nitrogen fertilization on grain yield and its components in flooded rice. *Chilean Journal of Agricultural Research*, *71*(3), 437.

Hoben, J. P., Gehl R. J., Millar N., Grace P. R. and Robertson G. P. (2011). Nonlinear nitrous oxide (N_2O) response to nitrogen fertilizer in on-farm corn crops of the US Midwest. *Global Change Biology, 17*: 1140-1152.

Hütsch, B. W. (1996). Methane oxidation in soils of two long-term fertilization experiments in Germany. *Soil Biology and Biochemistry,* 28, 773–782.

Hyland, C. (2010). Nitrogen leaching in soil amended with biochars produced at low and high temperatures from various feedstocks. In *Proceedings of 19th World Congress of Soil Science, Soil Solutions for a Changing World* (pp. 1-6). International Union of Soil Sciences (IUSS): Wien, Austria.

International Food Policy Research Institute (IFPRI). (2011). https://www.ifpri.org/file/13161/download. (Accessed at 7.4.2017).

International Rice Research Institute (IRRI). (2002). Website at http://www.irri.org.

International Rice Research Institute (IRRI). (2005). Rice. International Rice Research Institute. Las Banas, Phillipines.

Iowa Climate Change Advisory Council. (2008). Agricultural practices, Producing and Reducing Greenhouse Gas Emissions, Final Report, Iowa chapter, Iowa Department of Natural Resources, pp 1-4.

Ippolito, J. A., Laird, D. A., and Busscher, W. J. (2012). Environmental benefits of biochar. *Journal of environmental quality*, *41*(4), 967-972.

Islam, M. S., Peng, S., Visperas, R. M., Ereful, N., Bhuiya, M. S. U. and Julfiquar, A. W. (2007) Lodging-Related Morphological Traits of Hybrid Rice in a Tropical Irrigated Ecosystem. *Field Crops Research*, 101, 240-248. http://dx.doi.org/10.1016/j.fcr.2006.12.002

Jama, B., Palm, C. A., Buresh, R. J., Niang, A., Gachengo, C., Nziguheba, G. and Amadalo, B. (2000). Tithonia diversifolia as a green manure for soil fertility improvement in western Kenya: A review. *Agroforestry Systems*, 49:201-221.

Jansen, R., Van Bekkum, H., 1994. Amination and ammoxidation of activated carbons. *Carbon* 32, 1507–1516

Jarecki, M. K., Parkin, T. B., Chan, A. S., Hatfield, J. L. and Jones, R. (2008). Greenhouse gas emissions from two soils receiving nitrogen fertilizer and swine manure slurry. *Journal of environmental quality*, *37*(4), 1432-1438.

Jeffery, S., Verheijen, F. G., van der Velde, M., and Bastos, A. C. (2011). A quantitative review of the effects of biochar application to soils on crop productivity using meta-analysis. *Agriculture, ecosystems and environment*, *144*(1), 175-187.

Jenkinson, D. S., Adams, D. E. and Wild, A. (1991). Model estimate of CO2 from soil in respons to global warming. *Nature, 351*, 304-306.

Jia, J., Li, B., Chen, Z., Xie, Z., and Xiong, Z. (2012). Effects of biochar application on vegetable production and emissions of N2O and CH4. *Soil science and plant nutrition*, *58*(4), 503-509.

Jia, Z., and Cai, Z. (2003). Effects of rice plants on methane emission from paddy fields. *Ying yong sheng tai xue bao= The journal of applied ecology*, (Abstract) *14*(11), 2049-2053 .

Jindo, K., Mizumoto, H., Sawada, Y., Monedero, M. A. S. and Sonoki, T. (2014). Physical and chemical characterization of biochars derived from different agricultural residues. *Biogeosciences, 11,* 6613–6621.

Jones, D. L., Murphy, D. V., Khalid, M., Ahmad, W., Edward-Jones, G., Deluca, T. H. (2011). Short-term biochar induced increase in soil CO2 release is both biotically and abiotically mediated. *Soil Biology and Biochemistry. 43,* 1723–1731.

Jones, D., Rousk, J., Edwards-Jones, G., DeLuca, T., Murphy, D. (2012). Biochar-mediated changes in soil quality and plant growth in a three year field trial. *Soil Biology and Biochemistry, 45,* 113–124.

Joseph, S., Graber, E.R., Chia, C., Munroe, P., Donne, S., Thomas, T., Nielsen, S., Marjo, C., Rutlidge, H., Pan, G.X. and Li, L. (2013). Shifting paradigms: development of high-efficiency biochar fertilizers based on nano-structures and soluble components. *Carbon Management*, *4*(3), 323-343.

Jung, W. K. (2012). Rice Yield Response to Biochar Application Under Different Water Managements Practices. *Korean Journal of Soil Science and Fertilizer*, *45*(1), 16-19.

Kaiser, H. M. (1989). Climate change and agriculture. *Space*, 4, 11-0.

Kamara, A., Kamara, H. S. and Kamara, M. S. (2015). Effect of rice straw biochar on soil quality and the early growth and biomass yield of two rice varieties. *Agricultural Sciences*, *6*(8), 798.

Kamara, A., Mansaray, M. M., Kamara, A. and Sawyerr, P. A. (2014). Effects of biochar derived from maize stover and rice straw on the early growth of their seedlings. *American Journal of Agriculture and Forestry*, *2*(5), 232-236.

Kang, G. D., Cai, Z. C. and Feng, X. Z. (2002). Importance of water regime during the non-rice growing period in winter in regional variation of CH4 emissions from rice fields during following rice growing period in China. *Nutrient Cycling in Agroecosystem, 64,* 95–100. (doi:10.1023/A:1021154932643)

Karer, J., Wimmer, B., Zehetner, F., Kloss, S., and Soja, G. (2013). Biochar application to temperate soils: effects on nutrient uptake and crop yield under field conditions. *Agricultural and food science*, *22*(4), 390-403.

Karhu, K., Mattila, T., Bergstrom, I. and Regina, K. (2011). Biochar addition to agricultural soil increased CH4 uptake and water holding capacity-Results from a short-term pilot field study. *Agriculture, Ecosystem and Environment*, 140, 309–313

Karl, T. R., Diaz, H. and Bamett, T. 1990. Climate variations of the past century and the greenhouse effect (a report based on the Fkst Climate Trends Workshop). Rockville, MD: National Climate Program Office/NOAA, 1990.

Ke, Y. J., Hu, X. Y., Yi, Q. and Yu, Z. (2014). Impacts of rice straw biochar on organic carbon and CO2 release in arable soil. *35*(1), 93-99. (in Chinese with English abstract) Available at https://www.ncbi.nlm.nih. gov/pub med/24720191 (Cited on 26.2.17)

Khan, S., Chao, C., Waqas, M., Arp, H. P. H. and Zhu, Y. (2013). Sewage sludge biochar influence upon rice (*Oryza sativa* L) yield, metal bioaccumulation and greenhouse gas emissions from acidic paddy soil. *Environmental Science and Technology,* 47, 8624–8632

Kim, H. Y., Lieffering, M., Kobayashi, K., Okada, M., Mitchell, M. W., and Gumpertz, M. (2003). Effects of free-air CO 2 enrichment and nitrogen supply on the yield of temperate paddy rice crops. *Field Crops Research*, *83*(3), 261-270.

Kindred, D., Berry, P., Burch, O. and Bradley, R. S. (2008). Effects of nitrogen fertiliser use on green house gas emissions and land use change, Effects of Climate Change on Plants: Implications for Agriculture. *Aspects of Applied Biology* 88, 1-4.

Knoblauch, C., Maarifat, A. A., Pfeiffer, E. M. and Haefele, S. M. (2011). Degradability of black carbon and its impact on trace gas fluxes and carbon turnover in paddy soils. *Soil Biology and Biochemistry*, *43*(9), 1768-1778.

Knoblauch, C., Marifaat, A. A., Haefele, M. S. (2008). Biochar in rice-based system: impact on carbon mineralization and trace gas emissions. http://www.biocharinternational. org/2008/conference/posters.

Komiya, S., Noborio, K., Katano, K., Pakoktom, T., Siangliw, M. and Toojinda, T. (2015). Contribution of ebullition to methane and carbon dioxide emission from water between plant rows in a tropical rice paddy field. *International scholarly research notices, 2015*.

Kondo, S., T. Ishikawa, and I. Abe. (2001). Science of adsorption. (In Japanese.) 2nd ed.Maruzen, Tokyo.

Kowalchuk, G. A, Stephen, J. R. (2001) Ammonia-oxidizing bacteria: a model for molecular microbial ecology. *Annual Review of Microbiology* 55(1):485–529

Koyama, S., Katagiri, T., Minamikawa, K., Kato, M., and Hayashi, H. (2016). Effects of Rice Husk Charcoal Application on Rice Yield, Methane Emission, and Soil Carbon Sequestration in Andosol Paddy Soil. *Japan Agricultural Research Quarterly: JARQ*, *50*(4), 319-327.

Kumar, S, Masto R. E., Ram, L. C., Sarkar, P., George, J., Selvi, V. A. (2013). Biochar preparation from parthenium hysterophorus and its potential use in soil application. *Ecological Engineering* 55: 67-72.

Kuzyakov, Y., Subbotina, I., Chen, H., Bogomolova, I., Xu, X. (2009) Black carbon decomposition and incorporation into microbial biomass estimated by 14C labeling. *Soil Biology and Biochemistry*, 41:210–219. doi:10. 1016/j.soilbio.2008.10.016

Kyaw, K. Z., (2016). Testing the effects of biochars on crop yields and soil properties in a rice-based cropping system of Myanmar: Field experiment and modeling. (Doctoral Theses, Faculty of Sustainability of Leuphana University of Lüneburg). DOI: urn:nbn:de:gbv:luen4-opus-143988

Laboratory of Daniel J. Arp, Oregon State University, Corvallis OR 97331, USA. (2017). Nitrification network; To advance facilitate and promote the study and understanding of nitrification, http://nitrificationnetwork.org/Nerecipe.php (Accessed 31 December 2017).

Lair, G. J., Gerzabek, M. H., Haberhauer, G., Jakusch, M., Kirchmann, H. (2006): Response of the sorption behavior of Cu, Cd, and Zn to different soil management. *Journal of Plant Nutrition and Soil Science,* 169, 60–68.

Laird, D. A., Fleming, F, Davis, D. D., Horton, R., Wang, B. Q., Karlen, D. L. (2010a). Impact of biochar amendments on the quality of a typical midwestern agricultural soil. *Geoderma*. 158:443-449.

Laird, D., Fleming, P., Wang, B., Horton, R., Karlen, D. (2010b). Biochar impact on nutrient leaching from a midwestern agricultural soil. Geoderma, 158: 436–442.

Lal, R. (2006). Enhancing crop yields in the developing countries through restoration of soil organic carbon pool in agricultural lands. *Land Degradation and Development*. 17:197–209.

Latham, J., Cumani, R., Rosati, I., Bloise, M., (2014). Global Land Cover SHARE(GLC-SHARE) database. Beta-Release Version 1.0. http://www.glcn.or g/downs/prj/glcshare/GLC SHARE beta v1.0 2014.pdf (last access April 18, 2016).

Laufer, J. and Tomlinson, T. (2013). International biochar initiative research summary-Biochar field studies-May 2013 page 1-10, info@biochar-international.org

Lawlor, D. W. (2002). Carbon and nitrogen Assimilation in Relation to Yield: Mechanisms Are the Key to Understanding Production Systems. *Journal of Experimental Botany*, 53, 773-787. http://dx.doi.org/10.1093/jexbot/53.370.773

Le Mer, J. and Roger, P. (2001). Production, oxidation, emission and consumption of methane by soils: A review. *European Journal of Soil Biology,* 37: 25{50.)

Lee, J., Hopmans, J. W., van Kessel, C., King, A. P., Evatt, K. J., Louie, D., Rolston, D. E. and Six, J. (2009). Tillage and seasonal emissions of CO 2, N 2 O and NO across a seed bed and at the field scale in a Mediterranean climate. *Agriculture, Ecosystems and Environment*, *129* (4), 378-390.

Lee, T. S., Haque, M. A., and Najim, M. M. M. (2005). Scheduling the cropping calendar in wet-seeded rice schemes in Malaysia. *Agricultural water management*, *71*(1), 71-84.

Lehman J, Gaunt K, Rondon M. (2006). Biochar sequestration in terrestrial ecosystems, A review. *Mitigat. Adapt. Strate. Global Change 11,* 403-427.

Lehmann J, Kern D. C., Glaser B., Woods W. I. (2003). Biochar and carbon sequestration. In: Amazonian Dark Earths: Origin, Properties, Management. Kluwer Academic Publishers, Netherlands, 523.

Lehmann, J. (2007). A handful of carbon. *Nature*, *447*(7141), 143-144.

Lehmann, J., Joseph, S. (2009). Biochar for environmental management: an introduction. In: Lehmann, J., Joseph, S. (Eds.), Biochar for Environmental Management: Science and Technology. Earthscan, London, UK, pp. 1–12.

Lehmann, J., Kern,D., German, L., McCann, J., Martins,G. and Moreira, A. (2003). 'Soil fertility and production potential', in J. Lehmann, D. C. Kern, B. Glaser and W. I. Woods (eds.) *Amazonian Dark Earths:Origin, Properties,Management*, Kluwer Academic Publishers, The Netherlands, pp105–124

Lehmann, J., Rillig, M. C., Thies, J., Masiello, C. A., Hockaday, W. C., Crowley, D. (2011). Biochar effects on soil biota—a review. *Soil Biology Biochemistry,* 43:1812–1836. doi:10.1016/j.soilbio.2011.04.022

Leu, A. (2015). IFOAM Organics International, Response to 'Does certified organic farming reduce greenhouse gas emissions from agricultural production?'Available at: http://www.ifoam.bio/sites /default/files/response_to_mail_online_final.pdf (Assessed 23 January 2016)

Li, C. H., Tang, L. S., Jia, Z. J. and Li, Y. (2015). Profile Changes in the Soil Microbial Community When Desert Becomes Oasis. *PloS one,* 10, e0139626

Li, C., Salas, W., DeAngelo, B. and Rose, S. (2006). Assessing alternatives for mitigating net greenhouse gas emissions and increasing yields from rice production in China over the next twenty years. *Journal of Environmental Quality*, *35*(4), 1554-1565.

Li, F., Cao, X., Zhao, L., Yang, F., Wang, J., and Wang, S. (2013). Short-term effects of raw rice straw and its derived biochar on greenhouse gas emission in five typical soils in China. *Soil science and plant nutrition*, *59*(5), 800-811.

Li, H.-L., Zhang, W.-F., Zhang, F.-S. (2010). Chemical fertilizer use and efficiency change of main grain crops in China. *Acta Metallurgica Sinica,* 16 (5), 1136–1143.

Li, L., Fu, X., Xie, Q., Qiu, L., Lu, Z. and Pan, G. (2017). Effect of biochar compound fertilizers on crop yield and fertilizer N use efficiency. In *EGU General Assembly Conference Abstracts* (Vol. 19, p. 4262).

Li, Y., Chen X., Shamsi I. H., Fang P., Lin Y. (2012). Effects of Irrigation Patterns and Nitrogen Fertilization on Rice Yield and Microbial Community Structure in Paddy Soil. Pedospher, 22 (5): 661–672, doi: 10.1016/S1002-0160(12)60051-4

Liang, B., Lehmann, J., Sohi, S. P., Thies, J. E., O'Neill, B., Trujillo, L., Gaunt, J., Solomon, D., Grossman, J., Neves, E. G., Luizão, F. J. (2010). Black carbon affects the cycling of non-black carbon in soil. *Organic Geochemistry, 41:* 206–213. doi:10.1016/j.orggeochem.2009.09.007

Liang, B., Lehmann, J., Solomon, D., Kinyangi, J., Grossman, J., O'Neill, B., Skjemstad, J. O., Thies, J., Luizão, F. J., Petersen, J. (2006). Black carbon increases cation exchange capacity in soils. *Soil Science Society of American Journal, 70:*1719–1730

Linquist, B. A., Borbe, M. A. A., Pittelkow, C. M., Kessel, C. and Groenigen, K. J. (2012). Fertilizer management practices and greenhouse gas emissions from rice systems: A quantitative review and analysis. *Field Crops Research,* 135: 10–21.

Liu, C., Shi, B., Zhou, J., Tang, C. (2011). Quantification and characterization of microporosity by image processing, geometric measurement and statistical methods: application on SEM images of clay material. *Applied Clay Science,* 54:97–106

Liu, J., Shen, J., Li, Y., Su, Y., Ge, T., Jones, D. L., Wu, J. (2014). Effects of biochar amendment on the net greenhose gas emission and greenhouse gas intensity in a Chinese double rice cropping system. *European Journal of Soil Biology, 65*:30–39

Liu, N., Charrua, A. B., Weng, C. H., Yuan, X. and Ding, F. (2015). *Bioresource Technology.* 198 55.

Liu, S., Zhang, Y., Lin, F., Zhang, L. and Zou. J. (2014). Methane and nitrous oxide emissions from direct-seeded and seedling-transplanted rice paddies in southeast China, DOI 10.1007/s11104-013-1878-7, *Plant Soil, 374*:285–297

Liu, Y., Yang, M., Wu, Y., Wang, H., Chen, Y. and Wu, W. (2011). Reducing CH 4 and CO 2 emissions from waterlogged paddy soil with biochar. *Journal of Soils and Sediments*, *11*(6), 930-939.

Lu, K., Yang, X., Shen, J., Robinson, B., Huang, H., Liu, D., Bolan, N., Pei, J. and Wang, H. (2014). Effect of bamboo and rice straw biochars on the bioavailability of Cd, Cu, Pb and Zn to Sedum plumbizincicola. *Agriculture, Ecosystems and Environment*, *191*, 124-132.

Lu, Y., and Xu, H. (2014). Effects of Soil Temperature, Flooding, and Organic Matter Addition on N2O Emissions from a Soil of Hongze Lake Wetland, China. *The Scientific World Journal*, *2014*.

Luo, L. G, Kondo, M. and Itoh, S. (2010). NO and CH_4 emission from Japan rice fields under different long-term fertilization patterns and its environmental impact. *Journal of Applied Ecology, 21* (12): 3200–3206. (in Chinese with English abstract)

Luo, L., Kondo, M., and Itoh, S. (2002). The impact of long-term consecutive different N source management practices on greenhouse gases emission from paddy field. available online at www.coalin fo.net.cn/coalbed /meeting/2203/pa pers/agricul ture/018.pd. Accessed at 15 December 2016.

Luo, Y., Durenkamp, M., De Nobili, M., Lin, Q., Brookes, P. C. (2011). Short term soil priming effects and the mineralisation of biochar following its incorporation to soils of different pH. *Soil Biology and Biochemistry, 43*:2304–2314

Luo, Z. K., Wang, E. L., Sun, O.J. (2010). Can no-tillage stimulate carbon sequestration in agricultural soils? A meta-analysis of paired experiments. *Agriculture Ecosystems and Environment 139* (1-2), 224-231.

Ly, P., Vu, Q. D., Jensen, L. S., Pandey, A. and de Neergaard, A. (2015). Effects of rice straw, biochar and mineral fertiliser on methane (CH4) and nitrous oxide (N2O) emissions from rice (Oryza sativa L.) grown in a rain-fed lowland rice soil of Cambodia: a pot experiment. *Paddy and water environment*, *13* (4), 465-475.

Ma Yi-hu., Gu, D. J., Liu, L. J., Wang, Z. Q., Zhang, H., and Yang, J. C. (2014). Changes in grain yield of rice and emission of greenhouse gases from paddy fields after application of organic fertilizers made from maize straw. *Rice Science*, *21*(4), 224-232.

Ma, L., G. L. Velthof, C. Kroeze, X. Ju, C. Hu, O. Oenema, and F. Zhang. (2014). Mitigation of nitrous oxide emissions from food production in China. Review. System dynamics and sustainability. (Editors) C. Kroeze, W. Vries and S. Seitzinger. Current Opinion in Environmental Sustainability 2014, 9–10:82–89 http ://dx. doi.org/ 10.1016/j.cos u st.2014.09.006. Available online at www.sciencedirect.com.

Ma, L., Shan, J., Yan, X. Y. (2015). Nitrite behavior accounts for the nitrous oxide peaks following fertilization in a fluvo-aquic soil. *Biology and Fertility of Soils, 51*, 563–572.

Ma, Y., Wang, J., Zhou, W., Yan, X., Xiong, Z. (2012). Greenhouse gas emissions during the seedling stage of rice agriculture as affected by cultivar type and crop density. *Biology and Fertility of Soils,* 48, 589–595.

Major, J. A., Rondon, M., Molina, D., Riha, S. J., Lehmann, J. (2011). Nutrient leaching in a Columbian savanna oxisol amended with biochar. *Journal of Environmental Quality, 41*, 1076–1086.

Major, J., Lehmann, J., Rondon, M. and Goodale, C. (2010a). Fate of soil applied black carbon: downward migration, leaching and soil respiration. *Global Change Biology, 16*, 1366–1379.

Major, J., Rondon, M., Molina, D., Riha, S. J., Lehmann, J. (2010b). Maize yield and nutrition during 4 years after biochar application to a Colombian oxisol. *Plant Soil,* 333:117-128.

Major, J., Steiner, C., Downie, A., Lehmann, J. (2009). Biochar effects on nutrient leaching. Chapter 15. In: Lehmann J, Joseph S (eds) Biochar for environmental management: science and technology. Earthscan, London, p 271

Majumdar, D. (2003). Methane and nitrous oxide emission from irrigated rice fields: Proposed mitigation strategies. *Current Science*, 1317-1326.

Makino, A. (2011). Photosynthesis, grain yield, and nitrogen utilization in rice and wheat. *Plant Physiology,* 155(1), 125–129.

Maljanen, M., Komulainen, V. M., Hytönen, J., Martikainen, P. J., Laine, J. (2004). Carbon dioxide, nitrous oxide and methane dynamics in boreal organic agricultural soils with different soil characteristics. *Soil Biology and Biochemistry. 36*,1801–1808.

Mancinelli, R.L. (1995). The regulation of methane oxidation in soil. *Annual Review of Microbiology,* 49: 581-605.

Marland, G., West, T. O., Schlamadinger, B. and Canella, L. (2003). Managing soil organic carbon in agriculture: the net effect on greenhouse gas emissions. *Tellus B*, *55*(2), 613-621.

Marris, E. (2006). Putting the carbon back: black is the newgreen. *Nature, 442*, 624–626.

Maru, A., Haruna, O. A. and Charles Primus, W. (2015). Coapplication of Chicken Litter Biochar and Urea Only to Improve Nutrients Use Efficiency and Yield of Oryza sativa L. Cultivation on a Tropical Acid Soil. *The Scientific World Journal*, *2015.*

Masiello, C. A. (2004). New direction in black carbon organic geochemistry. *Chemistry,* 92: 201-213.

Masutomi, Y., Takahashi, K., Harasawa, H., and Matsuoka, Y. (2009). Impact assessment of climate change on rice production in Asia in comprehensive consideration of process/parameter uncertainty in general circulation models. *Agriculture, Ecosystems and Environment*, *131*(3), 281-291.

McCarl, B. A., Adams, R. M. and Hurd, B. H. (2001). Global climate change and its impact on agriculture. *Texas A&M University, Texas, USA*.

Mikutta, R., Kleber, M., Kaiser, K. and John, R. (2005). Review: Organic matter removal from soils using hydrogen peroxide, sodium hypochloride, and disodium perodisulfate. *Soil Science Society of American Journal, 69,* 120-135.

Millar, N., Doll, J. E. and Robertson, G. P. (2014). Management of nitrogen fertilizer to reduce nitrous oxide (N_2O) emissions from field crops. Bulletin of Michigan State University Extension, Michigan State University

Miranda, N. D. O., Pimenta, A. S., Silva, G. G. C. D., Oliveira, E., Mota, M. and Carvalho, M. A. B. D. (2017). Biochar as soil conditioner in the succession of upland rice and cowpea fertilized with nitrogen. *Revista Caatinga*, *30*(2), 313-323.

Mohamed, Z., Terano, R., Shamsudin, M. N. and Abd Latif, I. (2016). Paddy Farmers' Sustainability Practices in Granary Areas in Malaysia. *Resources*, 5 (2), 17.

Möller, K. and Stinner, W. (2009). Effects of different manuring systems with and without biogas digestion on soil mineral nitrogen content and on gaseous nitrogen losses (ammonia, nitrous oxides). *European Journal of Agronomy*,*30* (1), 1-16.

Moorhead, A. (2009). Climate, agriculture and food security: A strategy for change. Alliance of the CGIAR Centers.

Morison, J., Vanguelova, E., Broadmeadow, S., Perks, M., Yamulki, S. and Randle, T. (2010). Understanding the GHG implications of forestry on peat soils in Scotland. *The Research Agency of the Forestry Commission. Scotland*.

Mukherjee, A., Lal, R. and Zimmerman, A. R. (2014a). Effects of biochar and other amendments on the physical properties and greenhouse gas emissions of an artificially degraded soil. *Science of the Total Environment*, *487*, 26-36.

Mukherjee, A., Lal, R. and Zimmerman, A. R. (2014b). Impacts of biochar and other amendments on soil-carbon and nitrogen stability: A laboratory column study. *Soil Science Society of America Journal*, *78*(4), 1258-1266.

Mukherjee, A., Zimmerman, A. R. and Harris, W. G. (2011). Surface chemistry variations among a series of laboratory-produced biochars. *Geoderma,* 163:247–255. doi:10.1016/j.geoderma.2011.04.021

Mukome, F. N. D., Six, J. and Parikh, S. J. (2013). The effects of walnut shell and wood feedstock biochar amendments on greeehouse gas emissions from a fertile soil. Geoderma, 200–201:90–98. doi:10.1016/j.geoderma.2013.02.004

Muller, A., Jawtusch, J. and Gattinger, A. (2011). Mitigating greenhouse gases in agriculture–a challenge and opportunity for agricultural policies. *Diakonisches*

Werk der Evangelischen Kirche in Deutschland e. V., Stuttgart. Abrufbar unter http://orgprints. org/19989.

Mutezo, W. T. (2013). Early crop growth and yield responses of maize (*Zea mays*) to biochar applied on soil. Natural resourses, agricultural development and food security. International research network. International working paper series. Paper no 13/03. http://economia.unipv.it/naf/

Najim, M. M. M., Lee, T. S., Haque, M. A. and Esham, M. (2007). Sustainability of rice production: A Malaysian perspective. *Journal of Agricultural Sciences*, 3(1).

Nartey, O. D., and Zhao, B. (2014). Biochar preparation, characterization, and adsorptive capacity and its effect on bioavailability of contaminants: an overview. *Advances in Materials Science and Engineering*, *2014*.

Nayak, D., Cheng, K., Wang, W., Koslowski, F., Yan, X., Guo, M., Newbold, J., Moran, D., Cardenas, L., Pan, G., Smith, P. (2013). Technical options to reduce greenhouse gas emissions from croplands and grasslands in China. UK-China Sustainable Agriculture Innovation Network-SAIN www.sainoline.org, Policy brief, 9: 1-9

Nayak, D., Saetnan, E., Cheng, K., Wang, W., Koslowski, F., Cheng, Y. F., Zhu, W.Y., Wang, J.K., Liu, J.X., Moran, D. and Yan, X. (2015). Management opportunities to mitigate greenhouse gas emissions from Chinese agriculture. *Agriculture, Ecosystems and Environment*, *209*, 108-124.

Nelissen, V., Rütting, T., Huygens, D., Staelens, J., Ruysschaert, G., Boeckx, P. (2012) Maize biochars accelerate short-term soil nitrogen dynamics in a loamy sand soil. *Soil Biology and Biochemistry* 55:20–27. https://doi.org/10.1016/j.soilbio.2012.05.019

Nguyen, N. V. (2002). Global climate changes and rice food security. *Ed, Vol FAO, Rome, Italy*, 24-30.

Nguyen, V. N. (2004). Global climate changes and rice food security, Overview, Part I, p 24-30.

Nori, H., Abdul, Halim, R. and Ramlan, M. F. (2008). Effects of nitrogen fertilization management practice on the yield and straw nutritional quality of commercial rice varieties. *Malaysian Journal of Mathematical Sciences*, *2*(2), 61–71.

Novak, J. M., Busscher, W. J., Laird, D. L., Ahmedna, M., Watts, D. W., Niandou, M. A. S. (2009a). Impact of biochar amendment on fertility of a southeastern coastal plain soil. *Soil Science, 174*, 105–112.

Novak, J. M., Lima, I., Xing, B., Gaskin, J. W., Steiner, C., Das, K. C., Ahmedna, M., Rehrah, D., Watts, D. W., Busscher, W. J. and Schomberg, H. (2009b). Characterization of designer biochar produced at different temperatures and their effects on a loamy sand. *Annals of Environmental Science*, *3*(2), pp.195-206.

O'Neill, B., Grossman, J., Tsai, M. T., Gomes, J. E., Lehmann, J., Peterson, J., Neves, E., Thies, J. E. (2009). Bacterial community composition in Brazilian Anthrosols and adjacent soils characterized using culturing and molecular identification. *Microbial Ecology,* 58: 23–35.

Oertel, C., Matschullat, J., Zurba, K., Zimmermann, F. and Erasmi, S. (2016). Greenhouse gas emissions from soils. A review. *Chemie der Erde-Geochemistry*, *76*(3), 327-352.

Oguntunde, P. G., Abiodun, B. J., Ajayi, A. E., van de Giesen, N. (2008). Effects of charcoal Production on soil physical properties in Ghana. *Journal of Plant Nutrient and Soil Science 171,* 591–596.

Oguntunde, P. G., Fosu, M., Ajayi, Major, J., Lehmann, J., Rondon, M., Goodale, C. (2010a). Fate of soil-applied black carbon: downward migration, leaching and soil respiration. *Global Change Biology, 16,* 1366–1379.

Okuda, A., Takahashi, E. (1962). Studies of the physiological role of silicon in crop plants (Part 6). Effect of silicon on iron uptake by rice plant and oxidation power of root. *J Sei Soil Manure* Jpn 33:59–64 (in Japanese)

Palm, C. A., Myers, R. J. K., and Nandwa, S. M. (1997). Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment. p. 193–217. *In* R.J. Buresh, P.A. Sanchez, and F. Calhoun (ed.) Replenishing soil fertility in Africa. SSSA Spec. Publ. 51. SSSA and ASA, Madison, WI.

Pan G. X., Zhou P., Li Z. P., Smith P., Li L. Q., Qiu D. S., Zhang X. H., Xu X. B., Shen S. Y., Chen, X. M. (2009). Combined inorganic/organic fertilization enhances N efficiency and increases rice productivity through organic carbon accumulation in a rice paddy from the Tai Lake region, China. *Agriculture, Ecosystem and Environment, 131,* 274-280.

Pandey, A., Mai, V. T., Vu, D. Q., Bui, T. P. L., Mai, T. L. A., Jensen, L. S., de Neergaard, A. (2014). Organic matter and water management strategies to reduce methane and nitrous oxide emissions from rice paddies in Vietnam. *Agriculture, Ecosystem and Environment,196*:137–146

Panettieri, M., Knicker, H., Murillo, J. M., Madejón, E., Hatcher, P. G. (2014). Soil organic matter degradation in an agricultural chronosequence under different tillage regimes evaluated by organic matter pools, enzymatic activities and CPMAS 13C NMR. *Soil Biology and Biochemistry, 78,* 170–181.

Parmar, A., Nema, P. K., and Agarwal, T. (2014). Biochar production from agro-food industry residues: a sustainable approach for soil and environmental management. *Current Science*, *107*(10), 1673-82.

Parr, J. F. (2006): Effect of fire on phytolith coloration, *Geoarcheology*, 21, 171–185.

Pathak, H. (2015). Greenhouse Gas Emission from Indian Agriculture: Trends, Drivers and Mitigation Strategies. In *Proceedings of the Indian National Science Academy,81 (5),* 1133-1149.

Paustian, K., Antle, M. J., Sheehan, J. and Paul, E. A. (2006). Agriculture's Role in Greenhouse Gas Mitigation Prepared report for the Pew Center on Global Climate Change, Agriculture and Forest Lands: U.S. Carbon Policy Strategies, p iv.

Peng, S., Huang, J., Sheehy, J. E., Laza, R. C., Visperas, R. M., Zhong, X., Centeno, G. S., Khush, G. S. and Cassman, K. G. (2004). Rice yields decline with higher night temperature from global warming. *Proceedings of the National academy of Sciences of the United States of America*, *101*(27), 9971-9975.

Peng, X, Ye, L. L., Wang, C. H., Zhou, H., Sun, B. (2011). Temperature and duration dependent rice straw derived biochar: Characteristics and its effect on soil properties of an ultisol in southern China. *Soil Tillage Research* 112:159-166.

Petter, F. A., Madari, B. E., Silva, M. A. S. D., Carneiro, M. A. C., Carvalho, M. T. D. M., Júnior, M., Hur, B. and Pacheco, L. P. (2012). Soil fertility and upland rice yield after biochar application in the Cerrado. *Pesquisa Agropecuária Brasileira*, *47*(5), 699-706.

Phy, C., Dejbhimon, K., Tulaphitak, D., Lawongsa, P., Keophila, M., Thammasom, N., and Saenjan, P. (2014). Biochar Amendment to Different Paddy Soils on CH4 Production, Labile Organic Carbon, pH and Electrical Conductivity Dynamics: Incubation Experiment. *International Journal of Environmental and Rural Development 5-(1): 58-64.*

Pietikäinen, J.,Kiikkilä, O., Fritze, H. (2000). Charcoal as a habitat for microbes and its effect on the microbial community of the underlying humus. Oikos 89:231–242. doi:10.1034/j.1600-0706.2000.890203.x

Poffenbarger, H. J., Needelman, B. A. and Megonigal, P. J. (2011). Salinity influence on methane emissions from tidal marshes, Wetlands, 31, 831–842.

Poorter, H., Nagel, O. (2000). The role of biomass allocation in the growth response of plants to different levels of light, CO2, nutrients and water: a quantitative review. Australian Journal of Plant Physiology, 27, 595–607.

Powlson, D. S., Stirling, C. M., Jat, M. L., Gerard, B. G., Palm, C. A., Sanchez, P. A., Cassman, K. G. (2014). Limited potential of no-till agriculture for climate change mitigation. *Nature Climate Change, 4,* 678–683.

Prakongkep, N., Gilkes, R. J., Wiriyakitnateekul, W., Duangchan, A. and Darunsontaya, T. (2013). The effects of pyrolysis conditions on the chemical and physical properties of rice husk biochar. *International Journal of Material Science*.

Pratiwi, E. P. A., and Shinogi, Y. (2016). Rice husk biochar application to paddy soil and its effects on soil physical properties, plant growth, and methane emission. *Paddy and Water Environment*, *14*(4), 521-532.

Prendergast-Miller, M. T., Duvall, M., and Sohi, S. P. (2014). Biochar–root interactions are mediated by biochar nutrient content and impacts on soil nutrient availability. *European journal of soil science*, *65*(1), 173-185.

Prommer, J., Wanek, W., Hofhansl, F., Trojan, D., Offre, P., Urich, T., Schleper, C., Sassmann, S., Kitzler, B., Soja, G. and Hood-Nowotny, R. C. (2014). Biochar decelerates soil organic nitrogen cycling but stimulates soil nitrification in a temperate arable field trial. *PLoS One*, *9*(1), e86388.

Prosser, J. I. and Nicol, G. W. (2012). Archaeal and bacterial ammonia-oxidizers in soil: the quest for niche specialization and differentiation. *Trends in microbiology*, *20*(11), 523-531.

Qian, L., Chen, L., Joseph, S., Pan, G., Li, L., Zheng, J., Zhang, X., Zheng, J., Yu, X. and Wang, J. (2014). Biochar compound fertilizer as an option to reach high productivity but low carbon intensity in rice agriculture of China. *Carbon Management*, *5*(2), 145-154.

Qin, R., Biochar Type and Factors Affecting N Transformation, Ammonia Volatilization, and Nitrous Oxide Emissions. (2017). Managing global resources for a secure future, 2017 Annual meeting, Oct. 22-25, Tampa, Fl https://scisoc.confex.com/crops/2017am/we bprogram/Paper107342.html.

Qin, Y., Liu, S., Guo, Y., Liu, Q. and Zou, J. (2010). Methane and nitrous oxide emissions from organic and conventional rice cropping systems in Southeast China. Biology and Fertility of Soils 46:825-834.

Qiu, D., Li, L., Jiao, S., Pan, G., Zhang, Y. (2005). Change of soil fertility under long-term different fertilization practices in a paddy soil from the Tai Lake Region. *Soil Fertility, 4,* 28–32.

Quin, P. R., Cowie, A. L., Flavel, R. J., Macdonald, L. M., Morris, S. G., Singh, B-P., Young, I. M. and Van Zwieten, L. (2014). Oil mallee biochar improves soil structural properties – a study with x-ray micro-CT', *Agriculture Ecosystems Environment,* vol 191, pp142–149

Raitzer, D. A., Bosello, F., Tavoni, M., Orecchia, C., Marangoni, G., and Samson, J. N. G. (2015). *SouthEast Asia and the economics of global climate stabilization*. Asian Development Bank.

Reicosky, C. D., Hatfield, J. L. and Sass, R. L. (2000). In CAB International 2000, Climate Change and Global Crop Productivity (eds K.R. Reddey and H.F. Hodges).

Reilly, J. (1995) Climate change and global agriculture: Recent findings and issues. *American Journal of Agricultural Economics,* 77, 727–733.

Reilly, J. and Schimmelpfennig, D. (1999). Agricultural impact assessment, vulnerability, and the scope for adaptation. *Climate Change,* 43, 745–788.

Rice Production, Best Management Practices, (2000). Nutrient Management p 19. Available at: https://www.slideshare.net/SatriaSakata/rice-production-best-management-practices (accessed 1 September 2017)

Richards, M. and Sander, B. O. (2014). Alternate wetting and drying in irrigated rice: Implementation guidance for policymakers and investors, Retrieved 30 June, 2014 from http://cgspace.cgiar.org/bitstream/handle/10568/35402/info-note_CCAFS_AWD_fi nal_A4.pdf?sequence=1

Ritchie, G. A. F., and Nicholas, D. J. D. (1972). Identification of the sources of nitrous oxide produced by oxidative and reductive processes in Nitrosomonas europaea. *Biochemical Journal,* 126: 1181-1191.

Roberts, K., Gloy, B., Joseph, S., Scott, N., and Neslehmann, A. (2010). Life Cycle Assessment of Biochar Systems: Estimating the Energetic, Economic, and Climate Change Potential. *Environmental science and technology,* 44, 2: 827–833.

Rochette, P., Chantigny, M. H., Ziadi, N., Angers, D. A., Bélanger, G., Charbonneau, É., Pellerin, D., Liang, C. and Bertrand, N. (2014). Soil nitrous oxide emissions after deposition of dairy cow excreta in eastern Canada. *Journal of environmental quality*, *43*(3), 829-841.

Rogers, M., Lassiter, E. and Easton, Z.M. (2014). Mitigation of greenhouse gas emissions in agriculture. Communications and Marketing, College of Agriculture and Life Sciences, Virginia Polytechnic Institute and State University, Available at: https://vtech works.li b.vt.edu/handl e/10919/48084. (accessed 20 January 2016)

Rondon, M. A., Lehmann, J., Ramírez, J., Hurtado, M. (2007). Biological nitrogen fixation by common beans (*Phaseolus vulgaris* L.) increases with bio-char additions. *Biology and Fertility of Soils,* 43:699-708.

Rondon, M. A., Molina D, Hurtado, M., Ramirez, J., Lehmann, J., Major, J., Amezquita, E. (2006). Enhancing the productivity of crops and grasses while reducing greenhouse gas emissions through bio-char amendments to unfertile tropical soils. In: Presentation at the 18thWorld Congress of Soil Science, July 9–15, Philadelphia, Pennsylvania, USA. 138–168

Rosmiza, M. Z., Davies, W. P., CR, R. A., Mazdi, M., & Jabil, M. J. (2017). Farmers' knowledge on potential uses of rice straw: an assessment in MADA and Sekinchan, Malaysia. *Geografia-Malaysian Journal of Society and Space*, *10*(5).

Rousk, J., Bååth, E., Brookes, P. C., Lauber, C. L., Lozupone, C., Caporaso, J. G., Knight, R., Fierer, N. (2010). Soil bacterial and fungal communities across a pH gradient in an arable soil. ISME J 4:134–151. doi:10. 1038/ismej.2010.58

S. Nishimura., Yonemura, S., Minamikawa, K. and Yagi, K. (2015). Seasonal and diurnal variations in net carbon dioxide flux throughout the year from soil in paddy field. *Journal of Geophysical Research G: Biogeosciences,* 120, 1, 63–76.

Saarnio, S., Heimonen, K., Kettunen, R. (2013). Biochar addition indirectly affects N2O emissions via soil moisture and plant N uptake. *Soil Biology and Biochemistry*, *58*, 99–106.

Saenjan, P., K. Dejbhimon., D. Tulaphitak., P. Lawongsa., M. Keophila., N. Thammasom. (2014). Biochar amendment to different paddy soils on CH4 production, labile organic carbon, pH and electrical conductivity dynamics: Incubation experiment. IJERD. *International Journal of Environmental and Rural Development* (2014) 5-1

Saha A., Sarkar, R. K. and Yamagishi, Y. (1998). Effect of time of nitrogen application on spikelet differentiation and degeneration of rice. *Botanical Bullitin of Academia Sinica. 39:* 119-123

Saito, M. (1991). Soil management for the conservation of soil nitrogen. Extension Bulletins 341. Food and Fertilizer Technology Center, Taiwan.

Samborsky, S. (2016). *Effect of Biochar on Ammonification and Nitrification in a Coarse Sandy Soil* (Doctoral dissertation, University of Alberta).

Samonte, S. O. P. B., Wilson, L. T., Medley, J. C., Pinson, S. R. M., Mc- Clung, A. M. and Lales, J. S. (2006). Nitrogen utilization efficiency: relationships with grain yield, grain protein, and yield-related traits in rice. Agronomy Journal 98: 168–176.

Sampanpanish, P. (2012). Effect of Organic Fertilizer Use in Rice Paddy to Reduce Greenhouse Gases. P 79-85. In 2012 2nd International Conference on Environmental and Agriculture Engineering IPCBEE .37:, IACSIT Press, Singapore

Sass, R. L., Janssen, L., Yagi, K., van der Gon, H. D., Lantin, R., Mosier, A., Irving, W. N. (2017). Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories; CH_4 emissions from rice Agriculture; Background paper Available at: http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/4_7_CH4_Rice_Agriculture.pdf (accessed 16 September 2017)

Schaufler, G., Kitzler, B., Schindlbacher, A., Skiba, U., Sutton, M. A., Zechmeister-Boltenstern, S. (2010). Greenhouse gas emissions from Europeansoils under different land use: effects of soil moisture and temperature. *European Journal of Soil Science, 61,* 683–696.

Scheer, C., Grace, P. R., Rowlings, D. W., Kimber, S. and Van Zwieten, L. (2011). Effect of biochar amendment on the soil-atmosphere exchange of greenhouse gases from an intensive subtropical pasture in northern New South Wales, Australia. *Plant Soil,* 345, 47–58

Schimel, J. (2000). Global change: rice, microbes and methane. *Nature,* 403, 375–377

Schmidt, H. P. (2012). 55 Uses of Biochar, *Ithaka Journal*, 1:286–289, Delinat (edit.), Institute for Ecology and Climate farming, CH-1974, Arbaz, www.delinat-institut.org, www.ithaka-journal.net.

Schmidt, M. W. I., Noack, A. G. (2000). Black carbon in soils and sediments: analysis, distribution, implications, and current challenges. *Global Biogeochemical Cycles,* 14, 777–793.

Schulz, H. and Glaser, B. (2011). Biochar - benefits for soil and plants as compared with conventional soil amendments. *Journal of Plant Nutrition and Soil Science* in press.

Schulz, H. and Glaser, B. (2012). Effects of biochar compared to organic and inorganic fertilizers on soil quality and plant growth in a greenhouse experiment. *Journal of Plant Nutrition and Soil Science*, *175*(3), 410-422.

Seehausen, M. L., Gale, N. V., Dranga, S., Hudson, V., Liu, N., Michener, J. and Thomas, S. C. (2017). Is There a Positive Synergistic Effect of Biochar and Compost Soil Amendments on Plant Growth and Physiological Performance?. *Agronomy*, *7*(1): 13.

Serrano-Silva, N., Sarria-Guzmán, Y., Dendooven, L., and Luna-Guido, M. (2014). Methanogenesis and methanotrophy in soil: A review. *Pedosphere*, *24*(3), 291-307.

Shackley. S., S. Carter., T. Knowles., E. Middelink., S. Haefele., S. Haszeldine. (2011). Sustainable gasification–biochar systems? A case-study of rice-husk gasification in Cambodia, Part II: Field trial results, carbon abatement, economic assessment and conclusions. Energy Policy, doi:10.1016/j.enpol.2011.11.023.

Sharma, A. R. and Mittra, B. N. (1991). Effect of different rates of application of organic and nitrogen fertilizers in rice-based cropping system. *Journal of Agricultrual Science (Cambridge.) ,117:* 313-318.

Sheehy, J. E., and Mitchell, P. L. (2011). Rice and global food security: The race between scientific discovery and catastrophe. *ACCESS NOT EXCESS—the search for better nutrition.* (p. 81–90) Cambridgeshire, United Kingdom: Smith-Gordon.

Sheehy, J. E., Mitchell, P. L. and Ferrer, A. B. (2006). Decline in rice grain yields with temperature: models and correlations can give different estimates. *Field Crops Research*, *98*(2), 151-156.

Shen, J., Tang, H., Liu, J., Li, Y., Ge, T. and Wu, J. (2013). A Comparison of Greenhouse Gas Emissions from a Paddy Field Following Incorporation of Rice Straw and Straw-Based Biochar. Functions of Natural Organic Matter in Changing Environment, pp, 1027-1031.

Shen, J., Tang, H., Liu, J., Wang, C., Ge, T., Jones, D.J., Wu, J. (2014). Contrasting effects of straw and straw-derived biochar amendments on greenhouse gas emissions within double rice cropping systems. *Agricultural Ecosysystem and Environment,* 188:264–274

Shibata, M. and Terada, F. (2009). *Factors affecting methane production and mitigation in ruminants,* National Institute of Livestock and Grassland Science, Japan.

Silalertruksa T, Gheewala SH (2013) A comparative LCA of rice straw utilization for fuels and fertilizer in Thailand. *Bioresource Technology* **150**, 412-419.

Simojoki, A. and Jaakkola, A. (2000). Effect of nitrogen fertilization, cropping and irrigation on soil air composition and nitrous oxide emission in a loamy clay. *European Journal of Soil Science*, *51*(3), 413-424.

Singh, J. S., Raghubanshi, A. S., Reddy, V. S., Singh, S. and Kashyap, A. K. (1998) Methane flux from irrigated paddy and dryland rice fields, and from seasonally dry tropical forest and Savanna soils of India. *Soil Biology and Biochemistry*, 30: 135-139.

Singh, Y. and Sidhu, H. S. (2014). Management of cereal crop residues for sustainable rice-wheat production system in the Indo-Gangetic Plains of India. In *Proceedings of the Indian National Science Academy,* 80, (1) 95-114).

Singla, A., Inubushi, K. (2014). Effect of biochar on CH4 and N2O emission from soils vegetated with paddy. *Paddy and Water Environment, 12,* 239–243.

Six, J., Elliott, E. T. and Paustian, K. (1999). Aggregate and soil organic matter dynamics under conventional and no-tillage systems. *Soil Science Society of American Journal, 63,* 1350–1358.

Skiba, U. and K. Smith. (2000). The Control of Nitrous Oxide Emissions from Agricultural and Natural Soils. *Chemosphere-Global Change Science*, 2: 379–386. (abstract in English)

Slavicha, P., Ganib, A., McLeoda, M., Chairunasc. and Efrandid, D. (2011). Rice husk biochar increases nitrogen use efficiency of low land rice in Aceh http://biochar.jp/pdf/2_Slavich_etal.pdf accessed 19.8.2017

Smith, J. L., Collins, H. P. and Bailey, V. L. (2010). The effect of young biochar on soil respiration. *Soil Biology and Biochemistry, 42*, 2345–2347.

Smith, K. A. and Conen, F. (2004). Impacts of land management on fluxes of trace greenhouse gases. *Soil Use and Management.* 20, 255–263. (doi:10.1079/SUM2004238)

Smith, K. A., Thomson, P. E., Clayton, H., McTaggart, I. P., Conen, F. (1998). Effects of temperature, water content and nitrogen fertilisation on emissions of nitrous oxide by soils. *Atmospheric Environment,* 32, 3301–3309.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C., Scholes, B., Sirotenko, O. (2007). Agriculture, Chapter 8. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. . Pp 497-540

Snyder, C. S., Bruulsema, T. W. and Jensen, T. L. (2007). Best management practices to minimize greenhouse gas emissions associated with fertilizer use. *Better Crops*, *91*, 16-18.

Snyder, C. S., E. A. Davidson, P. Smith, R. T. Venterea. (2014). Agriculture: sustainable crop and animal production to help mitigate nitrous oxide emissions. Review. System dynamics and sustainability. (Editors) C. Kroeze, W. Vries and S. Seitzinger Current Opinion in Environmental Sustainability. 9–10:46–54. (http://creative- commons.org/licenses/by-nc-sa/3.0/). Available online at www.sciencedirect.com

Sohi, S. P., Krull, E., Lopez-Capel, E., and Bol, R. (2010). A review of biochar and its use and function in soil. In *Advances in agronomy,* 105, 47-82. Academic Press.

Sohi, S., Loez-Capel, E., Krull, E. and Bol R. (2009). Biochar's Roles In Soil And Climate Change: A Review Of Research Needs. *CSIRO Land and Water Science Report,* 05/09. 64p

Soil conservation council of Canada (2003). Global warming and agriculture. Cow/ calf best management practices. Agriculture and agri food Canada. 3: pp 2.

Sokchea, H.; Borin, K.; Preston, T. (2013). Effect of biochar from rice husks (combusted in a downdraft gasifier or a paddy rice dryer) on production of rice fertilized with biodigester effluent or urea. *Livestock Research for Rural Development*, *25*, Article No. 4. Available online: http://www.lrrd.org/lrrd25/1/ sokc25004.htm (accessed on 23 January 2013).

Song, Y., Zhang, X., Ma, B., Chang, S. X., Gong, J. (2013). Biochar addition affected the dynamics of ammonia oxidizers and nitrification in microcosms of a coastal alkaline soil. *Biology and Fertility of Soils*. 50(2):321–332. https://doi. org/10.1007/s00374-013-0857-8

Sovu, M. T., Savadogo, P., and Odén, P. C. (2012). Facilitation of forest landscape restoration on abandoned swidden fallows in Laos using mixed-species planting and biochar application. *Silva Fennica*, *46*(1), 39-51.

Spokas K. A., Baker J. M., Reicosky D. C. (2010). Ethylene: potential key for biochar amendment impacts. *Plant Soil, 333:*443–452. doi:10.1007/ s11104-010-0359-5

Spokas, K. (2010). Observed ethylene production from biochar additions. http://www.biorenew.iastate.edu/fileadmin/www.biorenew.iastate.edu/biochar2010/Presentations/Spokas.pdf.

Spokas, K. A., Cantrell, K. B., Novak., J. M., Archer, D. W., Ippolito, J. A., Collins, H. P., Boateng, A. A., Lima, I. M., Lamb, M. C., McAloon, A. J., Lentz, R. D. and Nichols, K. A. (2011). Environmental benefits of biochar, Biochar: A Synthesis of Its Agronomic Impact beyond Carbon Sequestration, *Journal of Environmental Quality,* 41, (973-989).

Spokas, K. A., Koskinen, W. C., Baker, J. M., Reicosky, D. C. (2009). Impacts of woodchip biochar additions on greenhouse gas production and sorption/degradation of two herbicides in a Minnesota soil. *Chemosphere 77,* 574-581.

Spokas, K. A., Reicosky, D. C. (2009). Impacts of sixteen different biochars on soil greenhouse gas production. *Annals of Environmental Science,* 3, 4.

Steinbeiss S, Gleixner G, Antonietti M. (2009). Effect of biochar amendment on soil carbon balance and soil microbial activity. *Soil Biology and Biochemistry, 41:* 1301-1310.

Steiner C., Teixeira W. G., Lehmann J., Nehls T., Luis J., De Macedo L. V., Blum W. E. H., Zech W. (2007). Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered central Amazonian upland soil. *Plant Soil, 291:* 275-290

Steiner, C. B, Glaser, B., Teixeira, W. G., Lehmann, J., Blum, W. E. H., Zech, W. (2008). Nitrogen retention and plant uptake on a highly weathered central Amazonian Ferralsol amended with compost and charcoal. *Journal of Plant Nutrition and Soil Science,* 171:893-899.

Steiner, C., Das, K. C., Melear, N., Lakly, D. (2010). Reducing nitrogen loss during poultry litter composting using biochar. *Journal of Environmental Quality*, 39(4):1236–1242. doi:10.2134/jeq2009.0337

Steudler, C. N. P. A., Garcia-Montiel, D. C., Melillo, J. M., Feigl, B. J., Piccolo, M. C. and Cerri, C. C. (2005). Rates and controls of nitrous oxide and nitric oxide emissions following conversion of forest to pasture in Rondônia. *Nutrient Cycling in Agroecosystems*, *71*(1), 1-15.

Sui, Y., Gao, J., Liu, C., Zhang, W., Lan, Y., Li, S., Meng, J., Xu, Z. and Tang, L. (2016). Interactive effects of straw-derived biochar and N fertilization on soil C storage and rice productivity in rice paddies of Northeast China. *Science of The Total Environment*, *544*, 203-210.

Sun, J., Lian, F., Liu, Z., Zhu, L. and Song, Z. (2014). Biochars derived from various crop straws: Characterization and Cd (II) removal potential. *Ecotoxicology and environmental safety*, *106*, 226-231

Syswerda, S. P., Corbin, A. T., Mokma, D. L., Kravchenko, A. N. and Robertson, G. P. (2011). Agricultural management and soil carbon storage in surface vs. deep layers. *Soil Science Society of American Journal,* 75, 92–101

Taghizadeh-Toosi, A., Clough, T. J., Sherlock, R. R., Condron, L. M. (2012). Biochar adsorbed ammonia is bioavailable. *Plant Soil, 350*:57–69

Tan, I. Y., van Es, H. M., Duxbury, J. M., Melkonian, J. J., Schindelbeck, R. R., Geohring, L. D. and Moebius, B. N. (2009). Single-event nitrous oxide losses under maize production as affected by soil type, tillage, rotation, and fertilization. *Soil and Tillage Research*, *102*(1), 19-26.

Tao, F., Hayashi, Y., Zhang, Z., Sakamoto, T. and Yokozawa, M. (2008). Global warming, rice production, and water use in China: Developing a probabilistic assessment. *Agricultural and forest meteorology*, *148*(1), 94-110.

Tayefe, M., Gerayzade, A. and Zade, A. N. (2014). Effect of nitrogen on rice yield, yield components and quality parameters. *African Journal of Biotechnology*, *13*(1), 91.

Taylor C. B. (1951). The nutritional requirements of the predominant bacterial flora of soil. *Journal of Applied Microbiology, 14:*101–111. doi:10.1111/j. 1365-2672.1951.tb01999.x

Thammasom, N., Vityakon, P., Lawongsa, P., and Saenjan, P. (2016). Biochar and rice straw have different effects on soil productivity, greenhouse gas emission and carbon sequestration in Northeast Thailand paddy soil. *Agriculture and Natural Resources*, *50*(3), 192-198.

Thao, P. T. M., Kurisu, K. H. and Hanaki, K. (2011). Greenhouse gas emission mitigation potential of rice husks for An Giang province, Vietnam. *Biomass and bioenergy*, *35*(8), 3656-3666.

The science of biochar, (2018). Available online at https://ww w.wakefieldbio char.com/science-of-biochar/ (accessed 24 November 2018).

Tilak, K. V. B. R., Ranganayaki, N., Pal, K. K., De, R., Saxe-na, A. K., Nautiyal, C. S., Mittal, S., Tripathi, A. K. and Johri, B. N. (2005). Diversity of plant growth and soil health supporting bacteria. *Current Science India,* 89: 136-150.

Towprayoon, S. (2014). *Greenhouse Gas Mitigation Options from Rice Field*, 2004. Retrieved 30 June, from https://unfccc.int/files/meetings /workshops/other_meeti ngs/appl icati on/vnd.ms-powerpoint/towprayoon.ppt

Trotsenko, Y. A. and Khmelenina, V. N. (2002). Biology of extre-mophilic and extremotolerant methanotrophs. *Archives of Microbiology,* 177: 123-131.

Troy, S. M., P. G. Lawlor, C. J. O'Flynn, and Healy, M.G. (2013). Impact of biochar addition to soil on greenhouse gas emissions following pig manure application. *Soil Biology and Biochemistry,* 60:173–181. doi:10.1016/j. soilbio.2013.01.019

Tsedalu, J., Togashi, M. and Urayama, H. (2015). Nitrogen fertilizer application timing on growth and yield of NERICA 4 and Japanese rice variety Toyohatamochi. *International Research Journal of Agricultural Science and Soil Science*, *5*(3), 91-97.

Ulyett, J., Sakrabani, R., Kibblewhite, M. and Hann, M. (2013) 'Impact of biochar addition on water retention, nitrification and carbon dioxide evolution from two sandy loam soils', *European Journal of Soil Science*, vol 65, pp96–104

UNEP (2013). Drawing down N_2O to protect climate and the ozone layer. A UNEP synthesis report. United Nations Environment Programme (UNEP), Nairobi, Kenya.

Unger, R., Killorn, R. (2012). Effect of the application of biochar on selected soil chemical properties, corn grain, and biomass yields in Iowa. *Communication in Soil Science and Plant Analysis*, 42:2441–2451

United Nations Department of Economic and Social Affairs/Population Division World Population Prospects: The 2017 Revision, Key Findings and Advance Tables https://esa.un.org/unpd/wpp/Publications/Files/WPP2017_KeyFindings.pdf. Accessed 18/8/2017.

Vaghefi, N., Shamsudin, M. N., Makmom, A. and Bagheri, M. (2011). The economic impacts of climate change on the rice production in Malaysia. *International Journal of Agricultural Research*, 6 (1), 67-74.

Van Trinh, M., Tesfai, M., Borrell, A., Nagothu, U. S., Bui, T. P. L., and Quynh, V. D. (2017). Effect of organic, inorganic and slow-release urea fertilisers on CH 4 and N 2 O emissions from rice paddy fields. *Paddy and water environment*, *15*(2), 317-330.

Van Zwieten, L., Kimber, S., Morris, S., Chan, K., Downie, A., Rust, J., Joseph, S., Cowie, A. (2010). Effects of biochar from slow pyrolysis of papermill waste on agronomic performance and soil fertility. *Plant Soil, 327*:235–246.

Van Zwieten, L., Singh, B. P., Joseph, S., Kimber, S., Cowie, A., Chan, K. Y. (2009). Biochar and emissions of non-CO2 greenhouse gases from soil. In: Lehmann J, Joseph S (eds) Biochar for environmental management: science and technology. Earthscan, London, pp 227–249

Vinh, N. C., Hien, N. V., Anh, M. T. L., Lehmann, J. and Joseph, S. (2014). Biochar treatment and its effects on rice and vegetable yields in mountainous areas of northern Vietnam. *International Journal of Agricultural and Soil Science*, *2*, 5-13.

Wander, A. E., Madari, B. E., and de Melo Carvalho, M. T. (2012). Economic Viability of Biochar Use in Aerobic Rice Production in the Brazilian Cerrado. Conference on International Research on Food Security, Natural Resource Management and Rural Development organised by: Georg-August Universität Göttingen and University of Kassel-Witzenhausen, September 19-21, 2012

Wang, J. Y., Zhang, M., Xiong, Z. Q., Liu, P. L., Pan, G. X. (2011) Effects of biochar addition on N2O and CO2 emissions from two paddy soils. *Biology and Fertility of Soils, 47*:887–896

Wang, J., Chen, Z., Xiong, Z., Chen, C., Xu, X., Zhou, Q., and Kuzyakov, Y. (2015). Effects of biochar amendment on greenhouse gas emissions, net ecosystem carbon budget and properties of an acidic soil under intensive vegetable production. *Soil use and management*, *31*(3), 375-383.

Wang, J., Pan, X., Liu, Y., Zhang, X., Xiong, Z. (2012a). Effects of biochar amendment in two soils on greenhouse gas emissions and crop production. *Plant and Soil,* 360: 287–298

Wang, S., Zhao, X., Xing, G., and Yang, L. (2012b). Large-scale biochar production from crop residue: A new idea and the biogas-energy pyrolysis system. *BioResources*, *8*(1), 8-11.

Wang, W., Lai, D. Y., Sardans, J., Wang, C., Datta, A., Pan, T., Zeng, C., Bartrons, M. and Penuelas, J. (2015). Rice straw incorporation affects global warming potential differently in early vs. late cropping seasons in Southeastern China. *Field Crops Research*, *181*, 42-51.

Wang, Y., Liu, Y., Liu, R., Zhang, A., Yang, S., Liu, H., Zhou, Y. and Yang, Z. (2017). Biochar amendment reduces paddy soil nitrogen leaching but increases net global warming potential in Ningxia irrigation, China. *Scientific Reports*, *7*(1), 1592.

Wang, Z., Delaune, R.D., Lindau, C.W. and Patrick, W.H. Jr. (1992). Methane production from anaerobic soil amended with rice straw and nitrogen fertilizers. *Fertilizer Research,* 33, 115–121

Wardle D. A., Nilsson M. C., Zackrisson O. (2008). Fire-derived charcoal causes loss of forest humus. Science 320:629–629. doi:10.1126/ science.1154960

Wassmann, R, Jagadish, S. V. K., Peng, S. B., Sumfleth, K., Hosen, Y., and Sander, B. O. (2009) Rice production and global climate change: scope for adaptation and mitigation activities. International Rice Research Institute, Los Banos, Laguna, Philippines.

Wassmann, R., Hosen, Y. and Sumfleth, K. (2009). *Reducing methane emissions from irrigated rice* (No. 16 (3)). International Food Policy Research Institute (IFPRI).

Watanabe, A., Yamada, H. and Kimura, M. (2005). Analysis of temperature effects on seasonal and interannual variation in CH4 emission from rice-planted pots. *Agriculture, ecosystems and environment*, *105*(1-2), 439-443.

Weber, K. and Quicker, P. (2018). Properties of biochar. *Fuel*, *217*, 240-261.

Weerakoon, W. M. W., Ingram, K. T., and Moss, D. N. (2005). Atmospheric CO2 concentration effects on N partitioning and fertilizer N recovery in field grown rice (Oryza sativa L.). *Agriculture, ecosystems and environment*, *108*(4), 342-349.

Welch, J. R., Vincent, J. R., Auffhammer, M., Moya, P. F., Dobermann, A., and Dawe, D. (2010). Rice yields in tropical/subtropical Asia exhibit large but opposing sensitivities to minimum and maximum temperatures. *Proceedings of the National Academy of Sciences*, *107*(33), 14562–14567.

Wendlandt, K. D., Stottmeister, U., Helm, J., Soltmann, B., Jechorek, M. and Beck, M. (2010). The potential of methane-oxidizing bacteria for applications in environmental biotech-nology. *Engineering in Life Sciences,* 10: 87-102.

Whalen, S. C. (2005). Biogeochemistry of methane exchange between naturalwetlands and the atmosphere. *Environmental Engineering Science, 22,* 73–94.

Widowati, Utomo W. H., Soehono L. A., Guritno B. (2011). Effect of biochar on the release and loss of nitrogen from urea fertilization. *Journal of Agriculture and Food Technology, 1:* 127–132.

Widowati, W. U., Guritno, B., and Soehono, L. A. (2012). The effect of biochar on the growth and N fertilizer requirement of maize (Zea mays L.) in green house experiment. *Journal of Agricultural Science*, *4*(5), 255.

Wisnubroto, E. I., Utomo, W. H., and Indrayatie, E. R. (2017). Residual Effect Of Biochar On Growth And Yield Of Red Chili (Capsicum Annum L.). *Journal of Advanced Agricultural Technologies Vol*, *4*(1).

Wong, L. C. (2007, March). Food security and growth: Malaysia's strategic approach and future adjustments. In *Conference Paper presented by Larry CY Wong at the Akademi of Sains Malaysia 2nd Series of ASM Biotechnology and Agriculture Forums: Food Security held at Universiti Malaya, Kuala Lumpur, 16 March 2007.*

Woolf, D., Amonette, J. E., Street-Perrot, F. A., Lehmann, J. and Joseph, S. (2010). Sustainable biochar to mitigate global climate change. *Nature Communications,* 1, 56.

Xiang, J., Liu, D., Ding, W., Yuan, J. and Lin, Y. (2015). Effects of biochar on nitrous oxide and nitric oxide emissions from paddy field during the wheat growth season. *Journal of Cleaner Production*, *104*, 52-58.

Xie, Z., Xu, Y., Liu, G., Liu, Q., Zhu, J., Tu, C., Amonette, J. E., Cadisch, G., Yong, J. W. and Hu, S. (2013). Impact of biochar application on nitrogen nutrition of rice, greenhouse-gas emissions and soil organic carbon dynamics in two paddy soils of China. *Plant and soil*, *370*(1-2), 527-540.

Xiong, Z. Q., Xing, G. X. and Zhu, Z. L. (2007). Nitrous oxide and methane emissions as affected by water, soil and nitrogen. *Pedosphere,* 17, 146–155

Xu, H., Cai, Z. C. and Tsuruta, H. (2003). Soil moisture between rice-growing seasons affects methane emission, production, and oxidation. *Soil Science Society of American Journal, 67,* 1147–1157.

Xu, X., Wu, Z., Dong, Y., Zhou, Z., and Xiong, Z. (2016). Effects of nitrogen and biochar amendment on soil methane concentration profiles and diffusion in a rice-wheat annual rotation system. *Scientific reports*, *6*, 38688.

Yamato, M., Okimori, Y., Wibowo, I. F., Anshori, S. and Ogawa, M. (2006). Effects of the application of charred bark of Acacia mangium on the yield of maize, cowpea and peanut, and soil chemical properties in South Sumatra, Indonesia. *Soil science and plant nutrition*, *52*(4), 489-495.

Yan, X. Y., Shi, S. L., Du, L. J., and Xing, G. (2000). Pathways of N 2 O emission from rice paddy soil. *Soil Biology and Biochemistry*, *32*(3), 437-440.

Yan, X., Hosen, Y. and Yagi, K. (2001). Nitrous oxide and nitric oxide emissions from maize field plots as affected by N fertilizer type and application method. *Biology and fertility of soils*, *34*(5), 297-303.

Yan, X., Ohara, T. and Akimoto, H. (2003). Development of region-specific emission factors and estimation of methane emission from rice field in East, Southeast and South Asian countries. Global Change Biology, 9, 237–254. (doi:10.1046/ j.1365-2486.2003.00564.x)

Yanai, Y., Toyota, K., Okazaki, M. (2007). Effect of charcoal addition on N2O emissions from soil resulting from rewetting air-dried soil in short-term laboratory experiments. *Soil Science and Plant Nutrition, 53,* 181–188.

Yang, R. (2016). Evaluation of Biochar On Reducing Nitrogen Leaching From a Typical Soil in Nova Scotia (Master dissertation).

Yang, S. S., Lai, C. M., Chang, H. L., Chang, E. H. and Wei, C. B. (2009). Estimation of methane and nitrous oxide emissions from paddy fields in Taiwan. *Renewable energy*, *34*(8), 1916-1922.

Yang, Y., Ma, S., Zhao, Y., Jing, M., Xu, Y. and Chen, J. (2015). A field experiment on enhancement of crop yield by rice straw and corn stalk-derived biochar in Northern China. *Sustainability*, *7*(10), 13713-13725.

Yao, Y., Gao, B., Zhang, M., Inyang, M. and Zimmerman, A. R. (2012). Effect of biochar amendment on sorption and leaching of nitrate, ammonium, and phosphate in a sandy soil. *Chemosphere*.

Yoo, G., Kim, Y.J., Lee, Y.O. and Ding, W. (2016). Investigation of greenhouse gas emissions from the soil amended with rice straw biochar. *KSCE Journal of Civil Engineering*, *20*(6), 2197-2207.

Yoseftabar, S. (2013). Effect of Nitrogen Management on Panicle Structure and Yield in Rice (Oryza sativa L.). *International Journal of Agriculture and Crop Science, 5 (11),* 1224-1227.

Yu-xue, L. I. U., Yao-feng, W. A. N. G., Hao-hao, L. Ü., Yi, C. H. E. N., Xu, T. A. N. G., Chun-yan, W. U., Zhe-ke, Z. H. O. N. G. and Sheng-mao, Y. A. N. G. (2013). Effects of biochar application on greenhouse gas emission from paddy soil and its physical and chemical properties. *Yingyong Shengtai Xuebao*, *24*(8). (in Chinese with English abstract)

Zakaria, A. (2006, October). Soil-enhancing technologies for improving crop productivity in Malaysia and considerations for their use. In *International Workshop on Sustained Management of the Soil-Rhizosphere System for Efficient Crop Production and Fertilizer Use* (Vol. 16, p. 20).

Zhang A.F., Y.M. Liu, G.X. Pan, Q. Hussain, L.Q. Li, J.W. Zheng and X.H. Zhang, (2011a). Effect of biochar amendment on maize yield and greenhousegas emissions from a soil organic carbon poor calcareous loamy soil from Central China Plain. *Plant Soil*, doi:10.1007/s11104-011-0957-x

Zhang, A., Bian, R., Hussain, Q., Li, L., Pan, G., Zheng, J., Zhang, X. and Zheng, J. (2013). Change in net global warming potential of a rice–wheat cropping system with biochar soil amendment in a rice paddy from China. *Agriculture, ecosystems and environment*, *173*, 37-45.

Zhang, A., Bian, R., Pan, G., Cui, L., Hussain, Q., Li, L., Zheng, J., Zheng, J., Zhang, X., Han, X. and Yu, X. (2012a). Effects of biochar amendment on soil quality, crop yield and greenhouse gas emission in a Chinese rice paddy: a field study of 2 consecutive rice growing cycles. *Field Crops Research*, *127*, 153-160.

Zhang, A., Cui, L., Pan, G., Li, L., Hussain, Q., Zhang, X., Zheng, J. and Crowley, D. (2010). Effect of biochar amendment on yield and methane and nitrous oxide emissions from a rice paddy from Tai Lake plain, China. *Agriculture, Ecosystems and Environment*, *139*(4), 469-475.

Zhang, A., Liu, Y., Pan, G., Hussain, Q., Li, L., Zheng, J., and Zhang, X. (2012b). Effect of biochar amendment on maize yield and greenhouse gas emissions from a soil organic carbon poor calcareous loamy soil from Central China Plain. *Plant and soil*, *351*(1-2), 263-275.

Zhang, J., Liu, J., Liu, R. (2015). *Bioresource Technology*. 176 288.

Zhang, K., Zheng, H., Chen, F., Li, R., Yang, M., Ouyang, Z. and Xiang, X. (2017). Impact of nitrogen fertilization on soil–Atmosphere greenhouse gas exchanges in eucalypt plantations with different soil characteristics in southern China. *PloS one*, *12*(2), e0172142. doi:10.1371/journal.pone.0172142

Zhang, P., Li, L., Pan, G., Zhang, J. (2003). Influence of long-term fertilizer management on topsoil microbial biomass and genetic diversity of a paddy soil from the Tai Lake region, China. *Acta Ecologica Sinica, 24,* 2818–2824.

Zhang, W., Yu, Y. Q., Huang, Y., Li, T. T. and Wang, P. (2011b). Modeling methane emissions from irrigated rice cultivation in China from 1960 to 2050. *Global Change Biology,* 17: 3511-3523.

Zhang, X., Chang, K., Wang, X., Li, M. and Wang, Y. (2014). Effects of Biochar from Spent Mushroom Substrate on Physic-chemical Properties during Pig Manure Composting. *Frontier of Environmental Science*, *3*(2). .67-74

Zhang, X., Xu, H., and Chen, G. (2002). Important factors controlling rates of N2O emission and CH4 oxidation from forest soil. *Huan jing ke xue= Huanjing kexue*, *23*(5), 8-12.

Zhang, Z., Solaiman, Z. M., Meney, K., Murphy, D. V. and Rengel, Z. (2013). Biochars immobilize soil cadmium, but do not improve growth of emergent wetland species Juncus subsecundus in cadmium-contaminated soil. DOI 10.1007/s11368-012-0571-4, J Soils Sediments (2013) 13:140–151

Zhao, X., Wang, J., Wang, S. and Xing, G. (2014). Successive straw biochar application as a strategy to sequester carbon and improve fertility: A pot experiment with two rice/wheat rotations in paddy soil. *Plant and soil*, *378*(1-2), 279-294.

Zhao, X., Wang, S., Xing, G. (2013). Nitrification, acidification, and nitrogen leaching from subtropical cropland soils as affected by rice straw-based biochar: laboratory incubation and column leaching studies. *Journal of Soils and Sediments, 14*(3):471–482. https://doi.org/10.1007/s11368-013-0803-2

Zheng, W., Sharma, B.K., and Rajagopalan, N. (2010). Using biochar as a soil amendment for sustainable agriculture. Final project report. http://hdl.handle.net/2142/25503.

Zhu Q.H., Peng X.H., Huang T.Q., Xie Z.B., and Holden N.M. (2014). Effect of biochar addition on maize growth and nitrogen use efficiency in acidic red soils. *Pedosphere, 24,* 699- 708, doi:http://dx.doi.org/10.1016/S1002-0160(14)60057-6

Zhu, Q., Peng, X. and Huang, T. (2015). Contrasted effects of biochar on maize growth and N use efficiency depending on soil conditions. *International Agrophysics*, *29*(2), 257-266.

Zhu, X., Silva, L. C. R., Doane, T. A., Horwath, W. R. (2013). Iron: The forgotten driver of nitrous oxide production in agricultural soil. *PLoS One, 8*, e60146.

Zhu, Z. L. and Chen, D. L. (2002). Nitrogen fertilizer use in China contributions to food production, impacts on the environment and best management strategies. *Nutrient Cycling in Agroecosystems*, 63, (2-3), 117–127.

Zimmerman, R. A., Gao, B., Ahn, M. Y. (2011). Positive and negative carbon mineralization priming effects among a variety of biochar-amended soils. *Soil Biology and Biochemistry,* 43, 1169–1179.

Zou, J. W., Huang, Y., Jiang, J. Y., Zheng, X. H., Sass, L. R. (2005). A 3-year field measurement of methane and nitrous oxide emissions from rice paddies in China: effects of water regime, crop residue, and fertilizer application. *Global Biogeochemical Cycle, 19,* doi:10.1029/2004GB002401, GB2021.

Zou, J., Huang, Y. A. O., Qin, Y., Liu, S., Shen, Q., Pan, G., Lu, Y. and Liu, Q. (2009). Changes in fertilizer-induced direct N2O emissions from paddy fields during rice-growing season in China between 1950s and 1990s. *Global Change Biology*, *15*(1), 229-242.

Zwieten, V. L., Singh, B., Joseph, S., Kimber, S., Cowie, A., Chan, Y. K. (2009). Biochar and emissions of non-CO2 greenhouse gases from soil. In: Lehmann, J., Joseph, S. (Eds.), Biochar for Environmental Management Science and Technology. Earthscan Press, UK, pp. 227–249.