Role of Biochar and Agriculture in Reducing Carbon Emissions

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INTRODUCTION

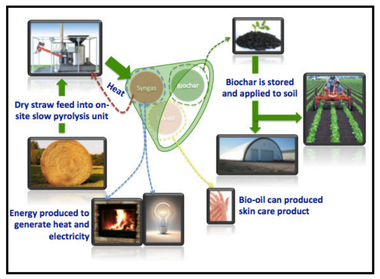
In 2015, Canada's agricultural industry was responsible for emitting 48 megatonnes (Mt) of carbon dioxide equivalent (CO_2 eq) to the atmosphere, making up 8% of total emissions in Canada [1].

A growing body of evidence suggests potential for greenhouse gas (GHG) emissions offsets and long-term carbon sequestration in agricultural soils through the use of biochar [2, 3, 4, 5]. Biochar is a solid that can be considered a "permanent" form of carbon storage [6], most often produced using slow pyrolysis, where biomass is heated with little or no oxygen present. Crop residues are an ideal feedstock for this process, and the resulting biochar can be re-applied to crop land as a soil enhancer [2, 5].

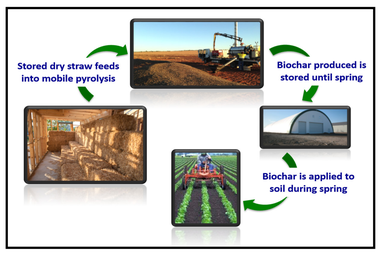
METHODS

Using historical data [1, 7, 8], trends for agricultural production and emissions were projected to 2060. An alternative scenario was then established where crop residues were diverted for biochar at an uptake rate of 25%, starting in 2017. Life cycle emissions of the pyrolysis process were evaluated [3,4], and net CO_2 offsets were determined. Lastly, cost benefit was calculated assuming an agriculture specific carbon tax starting in 2025, growing linearly to meet projected pricing [9] by 2060.

Onsite Production



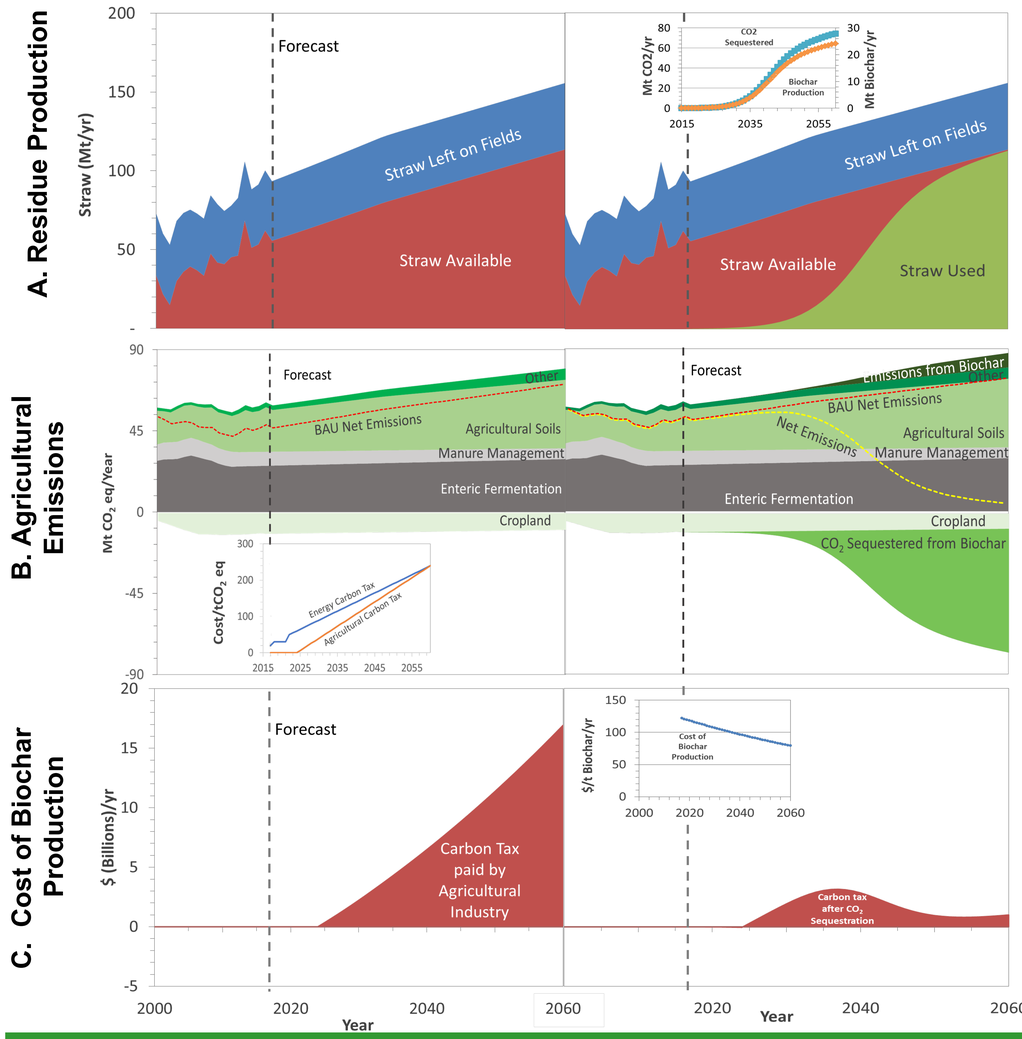
Mobile Production



	Onsite Production	Mobile Production
Cost per tonne ($/t)	122	166
Waste Heat Used	Yes	No
LCA Emissions (t CO_2/t BC) [4]	0.07	0.0701

RESULTS

1. Business as usual Scenario 2. Alternative Scenario: Biochar production

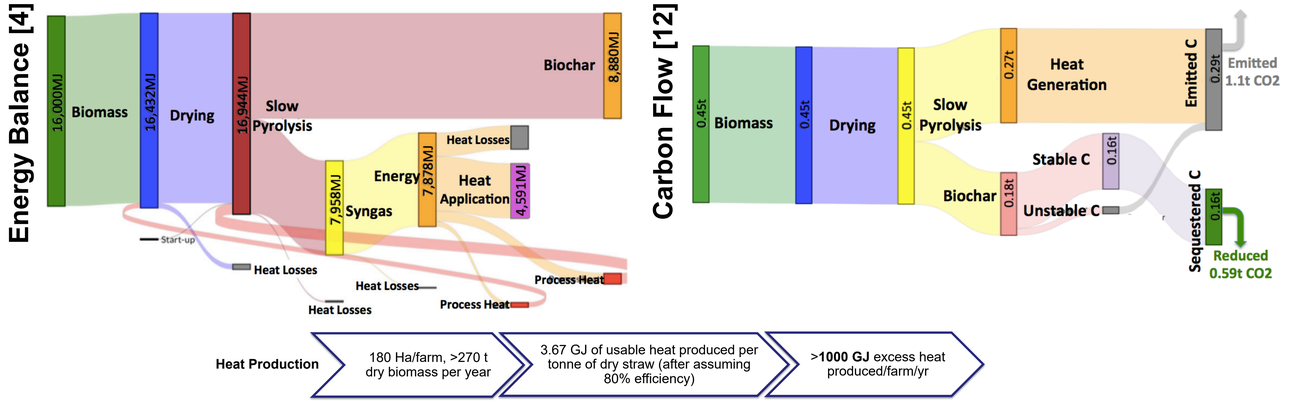


- 25% adoption rate for biochar production assumed
- Biochar production calculated for a slow pyrolysis unit operating at 450°C with a residence time of 10 min, giving a yield of 28.5%
- In 2060, 24 Mt of biochar can be produced which would sequester about 80 Mt of CO_2

- By 2060, agricultural emissions could be as high as 70Mt CO_2 eq.
- While carbon tax is not currently applied to agriculture, we predicted it will be implemented on the industry by 2025
- By utilizing biochar, agricultural emissions could decrease to only 4Mt CO_2 eq. emitted per year by 2060.

- The agricultural industry would owe $17 billion in carbon tax for the year 2060 based on current emission trends
- Alternative maximum cost peaks at $ 5 billion
- Carbon credits offset carbon tax on agricultural emissions
- Cost of production assumed to decrease by 1% /year from $122/tonne biochar (see inset figure)

FLOW DIAGRAMS



DISCUSSION

Currently, Canadian emissions estimates do not account for the bio-carbon flows central to the agricultural industry, yet Figure B.2 gives a clear visual of their significance, and the difference accounting for these flows would make. If Biochar production from crop residues were implemented on a Canada-wide scale, an estimated 74.8 Mt of CO_2 would be sequestered in the year 2060, almost negating all agricultural emissions for that same year.

These results agree with previous studies on biochar systems emissions, where results consistently indicated a net negative offset [3, 4]. It should also be noted that conservative estimates were made for available straw due to limited information on soil requirements assuming application of biochar to cropland.

Figure C.2 illustrates the clear economic incentive for adoption of biochar production and application, regardless of agriculture specific carbon tax implementation. While the agricultural sector does not currently pay a carbon tax, should one be implemented, the motivation for adoption increases substantially.

CONCLUSIONS

1. If the agricultural industry were to adopt a biochar model as presented here, industry-wide CO_2 emissions could be significantly reduced or eliminated. Given the right variables, the industry could become carbon negative.
2. Biochar production provides cost benefits both prior and post a hypothetical implementation of carbon tax on agriculture. Post implementation, the incentive for adoption is further increased.

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REFERENCES

[1] Environment and Climate Change Canada (2017) National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada.
[2] Cha, JS, Park, SH, Jung, S-C, Ryu, C, Jeon, J-K, Shin, M-C, & Park, Y-K (2016). Production and utilization of biochar: A review. Journal of Industrial and Engineering Chemistry, 1-15.
[3] Homagain, K., Shahi, C., Luckai, N., & Sharma, M. (2015). Life cycle environmental impact assessment of biochar-based bioenergy production and utilization in Northwestern Ontario, Canada. Journal of Forestry Research, 26(4), 799-809. Available at: https://link.springer.com/article/10.1007/s11676-015-0132-y
[4] Roberts, K., Gloy, B., Joseph, S., Scott, N., Lehmann, J. (2010). Life cycle assessment of biochar systems: Estimating the energetic, economic, and climate change potential. Environmental Science and Technology, 44(2), 827-833. DOI: 10.1021/es902266r
[5] Ahmed, M. B., Zhou, J. L., Ngo, H. H., & Guo, W. (2016). Insight into biochar properties and its cost analysis. Biomass and Bioenergy, 76-86
[6] Kuzyakov, Y., Bogomolova, I., & Glaser, B. (2014). Biochar stability in soil: Decomposition during eight years and transformation as assessed by compound-specific 14C analysis. Soil Biology and Biochemistry, 229-236.
[7] www5.statcan.gc.ca. (2017). CANSIM - 001-0010 - Estimated areas, yield, production and average farm price of principal field crops, in metric units. [online] Available at: http://www5.statcan.gc.ca/cansim/a26?lang=eng&id=10010 [Accessed 31 August. 2017]
[8] Li, X., Mupondwa, E., Panigrahi, S., Tabil, L., Sokhansanj, S., & Stumborg, M. (2012). A review of agricultural crop residue supply in Canada for cellulosic ethanol production. Renewable and Sustainable Energy Reviews, 16(5), 2954–2965. https://doi.org/10.1016/j.rser.2012.02.013
[9] Layzell, D. (2017). SCIE 529. Lecture 6.
[10] whatIf? Technologies Inc., 2014. Canadian Energy Systems Simulator (CanESS) - version 6, reference scenario. www.caness.ca
[11] Layzell, D. (2017). SCIE 529. S curve SpreadSheet
[12] Ronsse, F. Van Hecke, S. Dickinson, D. Prins, Wolter. (2013) Production and characterization of slow pyrolysis http://onlinelibrary.wiley.com/doi/10.1111/gcbb.12018/full

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