Brief for GSDR

2016 Update

Towards a greener rice production system in developed and developing nations (with the example of Lao PDR, Japan and Australia)

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Introduction: The LCA tool and implications for sustainable agriculture

In recent years, agricultural production has been broadly impacted by debates on environmental sustainability. Life Cycle Assessment (LCA) is a tool for integral assessment of the environmental impact of products, processes and services (Thomassen et al., 2008), applied both as a research tool and to achieve accountability in the market place. However, despite a growing need for sustainable production and climate change mitigation, comparison between nations to identify emission hotspots is limited. The main sources of greenhouse gas (GHG) emissions from agriculture are from grazing livestock such as cattle, agricultural soils, and rice production (US EPA, 2013), and rice cultivation is one of the largest sources of anthropogenic greenhouse gas emissions per hectare (ha), notably methane (CH_4). This brief compares the emission hotspots associated with rice production in three nations: Lao People's Democratic Republic (Lao PDR), Japan and Australia.

Methodology

Farmer interviews were conducted in 6 farms in Laos across two villages, and three farms in Japan. Australian production was assessed using data from the New South Wales (NSW) Department of Primary Industries (DPI) gross margin data (DPI, 2012 & 2013). Intergovernmental Panel on Climate Change (IPCC) emission factors of 160, 150 and 225 were used for Laos, Japan and Australia, respectively (IPCC, 2007). An emission factor is a representative value that relates the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant (EPA, 2015). Rice yields for Laos were 3.4 tonnes per ha (t ha-1) for wet season, and 3.9 t ha-1 for dry season rice in Dunien village, and 2.3 t ha-1 for wet season in Nakau village. The average yields for Japan and Australia were 4.8 and 10 t ha-1, respectively. All data were entered into SimaPro software, which was designed to collect, analyse and monitor the sustainability performance data, and the climate change impact was assessed.

Results and Discussion

1. *Laos (emissions profile: Figure 1&2)*

Comparing the two villages in Laos, Dunien village had a slightly more GHG-efficient production system (per kg of rice), which resulted from the yield increase due to higher manure application. The GHG emissions from manure were higher in Dunien village at higher application rates. However, this was substantially offset in terms of total emissions intensity by the corresponding increase in yield. Rice growers in Dunien village used approximately four times more organic manures than Nakau village, which increased rice yield by 63%.

In this study, Laos had the lowest average yield and GHG emission efficiency among the three countries. However, focusing on increased manure (which is a pure organic fertiliser) application, the resulting yield increase will proportionally increase their system efficiency. This could easily be promoted in developing countries, and farmers would be able to aim for yield increase for better income and lifestyle. Facing the rising demand for food in South-East Asia, increasing the yield and creating sustainable food production systems are both extremely important for conserving Earth's resources (EPA, 2013).

2. *Japan (emissions profile: Figure 3)*

In Japan all the surveyed farmers used various types of fertilisers and chemicals in small quantities at various times in the production cycle (as this is a common practice in Japan), and each of these products emitted GHG in small amounts at a time. Soybean meal, however, provided a relatively large GHG emission considering the quantity which was applied, compared with other fertilisers. Profit is maximised by applying nutrients (fertilisers) in small quantities but often as such an approach tends to be efficient in terms of maximizing the potential of the land, which also reduces the impact on the environment. Moreover, in Japan, the effect of diesel combustion on farm activities (mainly from rice cultivation) on GHG emissions was most substantial among the three countries. Japanese famers tend to cultivate at least once a year (which involves tillage), compared with Australia, where zero tillage is practiced. No tillage management has been promoted as a practice capable of offsetting GHG emissions because of its ability to reduce diesel use as well as sequester carbon in soils, particularly effective in the long term (Six et al., 2004). According to Xue et al. (2013), the no-tillage system has reduced emissions for the whole cropping system, compared with conventional tillage, for instance that in China. Furthermore, cultivation is associated with other environmental concerns such as groundwater contamination (Oren et al., 2004), impacts on soil structure and eutrophication of surface water (Brock et al., 2012) (Brock et al., 2014).

One management practice through which Japanese rice growers were very effective at mitigating GHG production was their treatments of stubble. In both Laos and Australia, stubble burning was performed: 100% in Laos and a major proportion (~80%) in Australia. Both N2O and CH4 are produced from this practice, and the mitigation of these two gases, both with a high Global Warming Potential (GWP): 298-310 for N2O and 21-25 for CH4 (IPCC, 2007), is critical. Even though N2O was produced in the process of decomposing stubble in Japan, the carbon dioxide equivalent (CO2-e) value was substantially lower than from stubble burning. Another main source of N2O production was the production and application of fertiliser. According to Towprayoon et al. (2005), N2O emission offsets the reduction of CH4 emission (for example, in the case of mid-season drainage in Japan) when nitrogen fertiliser is applied at a high rate.

In all emission profiles, the most dominant emission was the methane, which accounted for 70-90% of total emissions in Australia and Japan, and more than 90% in Laos. This is primarily due to the anaerobic breakdown of organic matter in wetland rice soils, exclusively by methane-generating-bacteria (Neue, 1993). In Japan, midseason drainage is practiced and there are alternative wetting and drying cycles. This reduces the methane emission by over 40%, and there are also other associated benefits such as water conservation and increased yields. This may have contributed to the emission factor for methane (15 g/m2) in Japan, which was lower than the other two countries, also possibly along with the shorter growing season (Wassamann et al., 2009). There are also alternative ways of mitigating methane emission from rice plants, for example, introducing the no-till system (Six et al., 2004), adding soil amendments such as nitrification inhibitors (Wassamann et al., 1993) or encapsulated calcium carbide (ECC) (Bronson & Mosier, 1991), adding Iron(III) (Lovley et al., 2004), increasing the use of urea and ammonium phosphate (Dong et al., 2011), and finally, introducing modern technologies such as cultivar selection and selective breeding (Gogoi et al., 2008).

3. Australia (emissions profile: Figure 4)

Australia had the lowest amount of methane emissions per kg rice due to the high grain yield, brought about by the heavy use of urea. Urea fertilizers contains an excellent source of nitrogen for crop production, however this nitrogen can be easily lost to the atmosphere. In Australia, despite there was a substantial increase in GHG production from urea production and use, the higher yield still resulted in the lowest emission intensity. However, there are sustainability issues for high urea usage, as urea application to agricultural fields can contribute to acid rain, ground water contamination and ozone depletion. One third to half of the applied urea-N can be lost into the soil and atmosphere (Prasad, 1998). In future LCA studies for rice, there is opportunity to include different impact categories other than greenhouse gas production. In particular, whilst some of the side effects of different fertiliser choice and management, such as eutrophication, are mentioned, they are not quantified in this single-issue LCA.

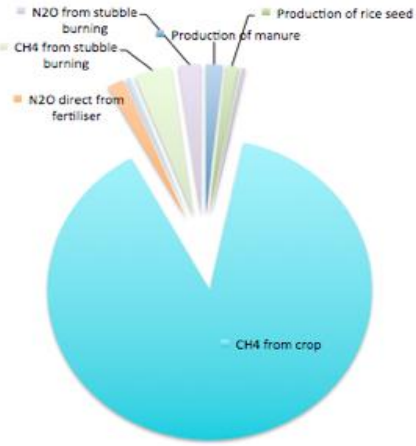

Figure 1. Major components of the emissions profile for rice production in Laos (Dunien village, wet season, for rice productions total: 1342.8kg CO2-e/kg rice)

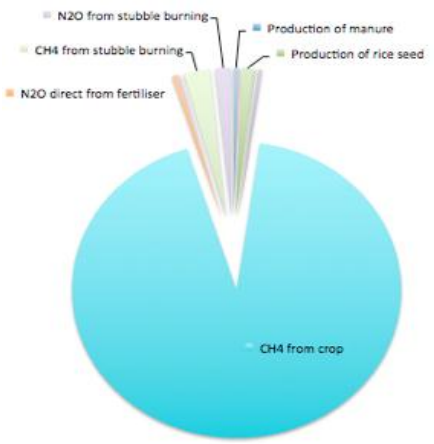

Figure 2. Major components of the emissions profile for rice production in Laos (Nakau village, wet season, total: 1917 kg CO2-e/kg rice)

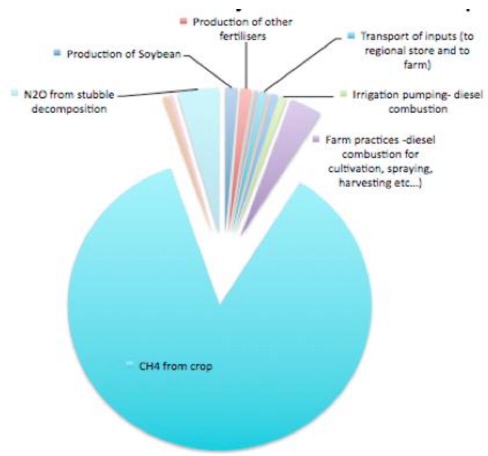

Figure 3. Major components of the emissions profile for rice production in Japan (total: 917.9 kg CO2-eq/kg rice)

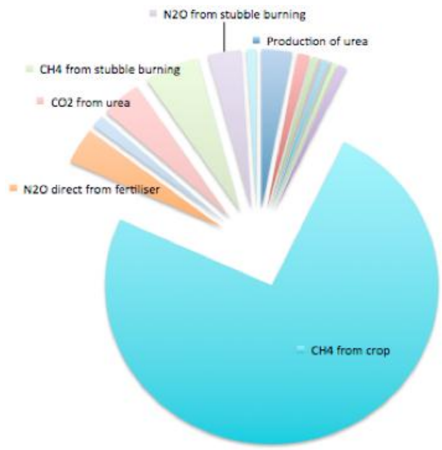

Figure 4. Major components of the emissions profile for rice production in Australia (total: 760.6kg CO2/kg rice)

Recommendations

1. Traditional practices could be sustainable

Considering future environmental sustainability and global food security, it is important to re-visit the traditional methods widely used in many developing nations. For example, the application of manure as a (pure organic) fertilizer source may provide insights to creating 'closed-loops' which are missing in many current agricultural systems in developed nations. There is potential that the current 'developed' methods benefit from the traditional methods and become overall 'greener'.

2. Reconsidering mass production…

Previous studies as well as this study have shown that CH_4 arising from anaerobic respiration of rice crops in flooded fields is the dominant emission source in rice production. Japan's stubble treatment and mid-season drainage are effective in mitigating CH_4 emissions (as well as N_2O in the stubble treatment), which should be promoted. Furthermore, there are also other aspects of the production system that could be modified for more sustainable rice production. Australia has the lowest amount of methane emissions per kg rice (in this study); however, the environmental sustainability of continuous heavy usage of urea is highly doubtful. Japan provided an overall 'more sustainable' example for fertilizer use, by applying them in small amounts at different times according to the growth of their rice crops, which provided them decent yield whilst maintaining environmental sustainability.

3. Need for more application of the LCA analysis

Life Cycle Assessments can be used to assess environmental impacts such as eco-toxicity, energy use, or climate change. Applying this technique more on various products also apart from agricultural crops will help identifying 'unsustainable' hotspots and creating greener life-cycles for multiple products. Therefore, it may be useful for companies/organizations to promote training on the software, so it can be more easily used across various sectors. Furthermore, this paper revealed that, additional analysis, for example one which calculates the CO_2-e values per unit area or per economic value of production, is likely to provide a different result and perspective between the different nations. There is more training needed within and beyond the LCA analysis.

References

-Brock P, Madden P, Schwenke G and Herridge D (2012) Greenhouse gas emissions profile for 1 tonne of wheat produced in Central Zone (East) New South Wales: a Life Cycle Assessment approach. Crop and Pasture Science 63(4) 319-329.
[http://www.publish.csiro.au/paper/CP11191.htm]

-Brock P, Muir, S and Simmons A (in press, 2014) LCA as a tool for targeted GHG mitigation in Australian cropping systems. *Proceedings of the 9th International Conference LCA of Food 8-10 October, 2014, San Francisco, USA.*

-Bronson, K., & Mosier, A. (1991). "Effect of encapsulated calcium carbide on dinitrogen, nitrous oxide, methane, and carbon dioxide emissions from flooded rice", *Biology and Fertility of Soils*, Vol. 11**,** pp. 116-120.

-Dong, H., Yao, Z., Zheng, X., Mei, B., Xie, B., Wang, R., Deng, J., Cui, F., & Zhu, J. (2011). "Effect of ammonium-based, non-sulfate fertilizers on CH< sub> 4</sub> emissions from a paddy field with a typical Chinese water management regime", *Atmospheric Environment*, Vol. 45**,** pp. 1095-1101.

-Department of Primary Industries (2012, 2013). "Summer Crop Gross Margin Budgets: Rice (aerial sown)",
http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/175886/Rice-Medium-Grain-aerial-sown-Murrumbidgee.pdf, viewed 4th March 2014.

-Gogoi, N., Baruah, K., & Gupta, P. K. (2008). "Selection of rice genotypes for lower methane emission", *Agronomy for sustainable development*, Vol. 28**,** pp. 181-186.

-Intergovernmental Panel on Climate Change (2007). "Direct Global Warming Potentials",
http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html, viewed 10th June 2014.

-Lovley, D. R., Holmes, D. E. & Nevin, K. P. (2004) "Dissimilatory fe (iii) and mn (iv) reduction", *Advances in microbial physiology,* Vol. 49**,** pp. 219-286.

-Neue, H.-U. (1993). "Methane emission from rice fields", *Bioscience***,** pp. 466-474.

-Oren, O., Yechieli, Y., Böhlke, J. K., & Dody, A. (2004). "Contamination of groundwater under cultivated fields in an arid environment, central Arava Valley, Israel", *Journal of hydrology,* Vol. 290, No. 3, pp. 312-328.
-Prasad, R. (1998). “Fertiliser urea, food security, health and the environment”, Current Science, Vol. 75, No. 7, pp. 677.
-Six, J., Ogle, S. M., Conant, R. T., Mosier, A. R., & Paustian, K. (2004). "The potential to mitigate global warming with no-tillage management is only realized when practised in the long term.", *Global change biology,* Vol. 10, No.2, pp.155-160.
-Thomassen M.A., van Calker K.J., Smits M.C.J., Iepema G.L., de Boer I.J.M. (2008). “Life cycle assessment of conventional and organic milk production in the Netherlands”, *Agricultural Systems*, Vol. 96, No.1–3, pp. 95–107.
-Towprayoon, S., K. Smakgahn, & S. Poonkaew (2005). "Mitigation of methane and nitrous oxide emissions from drained irrigated rice fields", *Chemosphere,* Vol. 59, No. 11, pp. 1547-1556.
-United States Environmental Protection Agency (2013). “Sources of Greenhouse Gas Emissions” http://www.epa.gov/climatechange/ghgemissions/sources.html, viewed 2nd June 2014.
-United States Environmental Protection Agency (2015). “Air Quality Emission Factor” http://www3.epa.gov/airquality/aqmportal/management/emissions_inventory/emission_factor.htm, viewed 21nd Dec 2015.
-Wassmann, R., Hosen, Y., & Sumfleth, K. (2009). “Reducing methane emissions from irrigated rice”. International Food Policy Research Institute (IFPRI).
-Wassmann, R., Papen, H., & Rennenberg, H. (1993). “Methane emission from rice paddies and possible mitigation strategies”, *Chemosphere*, Vol. 26**,** pp. 201-217.
-Xue, J. F., Liu, S. L., Chen, Z. D., Chen, F., Lal, R., Tang, H. M., & Zhang, H. L. (2013). “Assessment of carbon sustainability under different tillage systems in a double rice cropping system in Southern China”. *The International Journal of Life Cycle Assessment*, pp. 1-12.