McKinsey & Company

Agriculture and climate change report

Technical appendix: Rice

Calculating the baseline of agriculture emissions

The agriculture emissions baseline is calculated based on the Food and Agriculture Organization's Agriculture Emissions Database (Agriculture Total, FAOSTAT, FAO, accessed July 2019, fao.org/faostat), with the following minor adjustments:

— Adapted emissions to reflect AR5 GWP values (*Climate change 2014: Synthesis report*, Intergovernmental Panel on Climate Change, 2015, ar5-syr.ipcc.ch, p. 87)

— Cross-checked with crop and livestock demand estimates contained within FAO's database ("Food and agriculture projections to 2050," Global Perspectives Studies, FAO, 2018, fao.org; see also *The future of food and agriculture: Alternative pathways to 2050*, FAO, 2018, fao.org) and the McKinsey Food Demand Model. This resulted in minor adjustment to emissions expected to be driven by crop agriculture production area (up 9 percent by 2030 and up 13 percent by 2050)

— Given that FAO's estimates for emissions from "energy use in agriculture" were discontinued from 2013 forward, we used 2007–12 compound annual growth rates (CAGRs) by region (Brazil, Europe, China, India, and the rest of Asia) and energy source (electricity, fuel oil, natural gas) to project emissions forward to 2015. Forecasts to 2050 were based on discrete CAGRs (2012–30 and 2030–50) for agricultural acreage projections (*The future of food and agriculture: Alternative pathways to 2050,* FAO, 2018, fao.org)

Key assumptions, by MACC measure

All assumptions made for each part of the marginal abatement cost curve (MACC) are based on published literature.

● 100-year GWP[2] ■ 20-year GWP[2]

Dry direct seeding

374 | **1,122** **Baseline applicable emissions,** MMT CO_2e, 2050 [A]

Source: McKinsey baseline model (via FAOSTAT data): methane emissions from rice cultivation—only relevant to fields considered able to dry in-season (ie, not wet season; approximately 50 percent of hectares)

45 **Incremental lever implementation,** % [B]

Source (current implementation): Hongyan Liu et al., "Progress and constraints of dry direct-seeded rice in China," *Journal of Food Agriculture and Environment*, May 2014, Volume 1212, Number 2, pp. 465–72, researchgate.net

Source (incremental implementation): Jan Hartger Mathijs Harmsen, "Non-CO_2 greenhouse gas mitigation in the 21st century," Utrecht University, 2019, dspace.library.uu.nl

43 **Greenhouse gas reduction factor,**[1] % CO_2e [C]

Source: J.Y. Ko and H.W. Kang, "The effects of cultural practices on methane emission from rice fields," Nutrient Cycling in Agroecosystems, 2000, Volume 58, pp. 311–14

72 | **217** **Emissions reduction potential,** MMT CO_2e [A × B × C][3]

123 | **41** **Lever implementation cost savings,** $/t$CO_2$e

Source: Mihn D Ngo et al., "The current adoption of dry-direct seeding rice (DDSR) in Thailand," CGIAR, June 28, 2019; variable cost index built via World Bank/FAOSTAT data

Improved rice paddy water management

748 | **2,245** **Baseline applicable emissions,** MMT CO_2e, 2050 [A]

Source: McKinsey baseline model (via FAOSTAT data): methane emissions from rice cultivation

30 **Incremental lever implementation,** % [B]

Source (current implementation): Randoph Barker et al., "Increasing water productivity for paddy irrigation in China," *Paddy and Water Environment*, December 2004, Volume 2, Number 4; Jan Hartger Mathijs Harmsen, "Non-CO_2 greenhouse gas mitigation in the 21st century," Utrecht University, 2019, dspace.library.uu.nl; "Adaptation and mitigation initiatives in Philippine rice cultivation," United Nations Development Programme, November 5, 2015, undp.org

Source (incremental implementation): Wina H.J. Crijns-Graus et al., "Marginal greenhouse gas abatement curves for agriculture," *Ecofys*, August 2013; Jan Hartger Mathijs Harmsen, "Non-CO_2 greenhouse gas mitigation in the 21st century," Utrecht University, 2019, dspace.library.uu.nlproduction"; *Carbon Management*, 2017, Volume 8, Number 4, tandfonline.com

44 **Greenhouse gas reduction factor,**[1] % CO_2e [C]

Source: M. Shahe Alam et al., "Economics of alternate wetting and drying method of irrigation: Evidences from farm level study," *The Agriculturists*, December 2009, Volume 7, Numbers 1 and 2, pp. 82–95, Yu Jiang et al., "Water management to mitigate the global warming potential of rice systems: A global meta-analysis," Field Crops Research, March 15, 2019, Volume 234, pp. 47–54

99 | **296** **Emissions reduction potential,** MMT CO_2e [A × B × C][3]

35 | **12** **Lever implementation cost savings,** $/t$CO_2$e

Source: M. Shahe Alam et al., "Economics of alternate wetting and drying method of irrigation: Evidences from farm level study," *The Agriculturists*, December 2009, Volume 7, Numbers 1 and 2, pp. 82–95; variable cost index build via World Bank/FAOSTAT data

Improved rice straw management

748 | **2,245** **Baseline applicable emissions,** MMT CO_2e, 2050 [A]

Source: McKinsey baseline model (via FAOSTAT data): methane emissions from rice cultivation

15 **Incremental lever implementation,** % [B]

Source (current implementation): Tsuneo Kobayashiet al., "Factors affecting farmers' decisions on utilization of rice straw compost in Northeastern Thailand," *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, August 2013, Volume 114, Number 1, pp. 21–27, kobra.uni-kassel.de/handle/123456789/2013030542579

Source (incremental implementation): Wina H.J. Crijns-Graus et al., "Marginal greenhouse gas abatement curves for agriculture," *Ecofys*, August 2013, researchgate.net

44 **Greenhouse gas reduction factor,**[1] % CO_2e [C]

Source: Ryan R. Romasanta et al., "How does burning of rice straw affect CH_4 and N_2O emissions? A comparative experiment of different on-field straw management practices," *Agriculture, Ecosystems & Environment*, February 2017, Volume 239, pp. 143–53

49 | **148** **Emissions reduction potential,** MMT CO_2e [A × B × C][3]

26 | **8** **Lever implementation cost savings,** $/t$CO_2$e

Source: Constancio Asis et al., "Cost-effectiveness analysis of farmers' rice straw management practices considering CH_4 and N_2O emissions," *Journal of Environmental Management*, September 2016, Volume 183

100-year GWP[2] | 20-year GWP[2]

Improved fertilization of rice

748 | 2,245 **Baseline applicable emissions,** MMT CO_2e, 2050 [A]

Source: McKinsey baseline model (via FAOSTAT data): methane emissions from rice cultivation

40 **Greenhouse gas reduction factor,**[1] % CO_2e [C]

Source: Bruce Linquist et al., "Fertilizer management practices and greenhouse gas emissions from rice systems: A quantitative review and analysis," *Science of the Total Environment*, Volume 135, August 30, 2012, pp. 10–21

50 **Incremental lever implementation,** % [B]

Source (current implementation): Market reports; expert estimates

Source (incremental implementation): Jan Hartger Mathijs Harmsen, "Non-CO_2 greenhouse gas mitigation in the 21st century," Utrecht University, 2019, dspace.library.uu.nl; expert estimates

150 | 449 **Emissions reduction potential,** MMT CO_2e [A × B × C][3]

9 | 3 **Lever implementation cost,** $/t$CO_2e$

Source: Hugo A. van der Gon et al., "Sulfate-containing amendments to reduce methane emissions from rice fields: Mechanisms, effectiveness and costs," March 2001, springer.com; variable cost index build via World Bank/FAOSTAT data

[1] Difference due to greenhouse-gas reduction factor, % rounding.
[2] Global warming potential.
[3] A × B × C doesn't always equal the exact final emissions abatement number due to GHG reduction/applicability percentage rounding.