Strategies to Mitigate Methane Emissions in Lowland Rice Fields in South Brazil

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Minimum tillage, reducing irrigation water application, and crop diversification are identified as efficient strategies to mitigate CH_4 emissions in rice fields while also increasing yield. Even though land area under rice cultivation increased 30% from 1990 to 2005 and the IPCC predicted an associated 30% increases in CH_4 emissions, introduction of minimum tillage resulted in a 4% decrease in total CH_4 emissions and a 48% decrease in emissions per unit of grain production. This is an example of how evaluation and establishment of local indexes of GHG emissions enables consideration of the impact of adopting new technologies that generalized indexes miss.

The global index proposed by IPCC for CH_4 emission predicted a 30% increase in Rio Grande do Sul State in southern Brazil (**Figure 1A**). This prediction was primarily attributed to the increase in cultivated area under flooded rice that occurred between 1990 and 2005 (Bayer et al., 2012). There is a significant chance this index has misled policy-makers and environmental monitors into maintaining a negative perception of rice production. Technologies have been developed and adopted, both in Brazil and worldwide, to increase rice yields while reducing the environmental footprint of its production. In southern Brazil, groups contributing to this science include IRGA (Rice Research Institute), EMBRAPA (Brazilian Agricultural Research Corporation) and Federal Universities (UFPel, UFSM and UFRGS). Some of these technologies and their environmental impacts are discussed below.

Minimum Tillage

Minimum tillage is an example of a new technology that is helping farmers plant their crops within periods that are better timed to minimize GHG emissions (SOSBAI, 2012). For example, systems including conventional tillage will plow the soil just before rice is sown. Thus rice straw and winter crop residues are incorporated into soil, acting as a source of labile C for CH_4 production. Conversely with minimum tillage, soil is disturbed in the fall or winter when rice residues are incorporated into soil under non-flooded conditions. Thus part of the labile C is converted into CO_2, decreasing CH_4 emission potential once the area is flooded in preparation for the next rice crop (**Figure 2**).

Minimum tillage also maintains more weeds and winter crop residues on the soil surface contributing to a lower emission of CH_4 than is observed under conventional tillage (**Figure 3**) (Costa, 2005; Zschornack, 2011; Moterle, 2011; and Buss, 2012). Conventional tillage incorporates C residues within the 0 to 20 cm depth, where soil reduction status is much higher than on the surface layer, resulting in a higher production of CH_4 by methanogenic microorganisms (Costa, 2005; Zschornack et al., 2011; Zschornack, 2011). Data collected over seven years and three sites in southern Brazil shows that soil CH_4 emissions were 33% lower under minimum tillage than conventional tillage.

Common abbreviations and notes: C = carbon; CH_4 = methane; CO_2 = carbon dioxide; N_2O = nitrous oxide; GHG = greenhouse gas; IPCC = Intergovernmental Panel on Climate Change; Gg = gigagram.

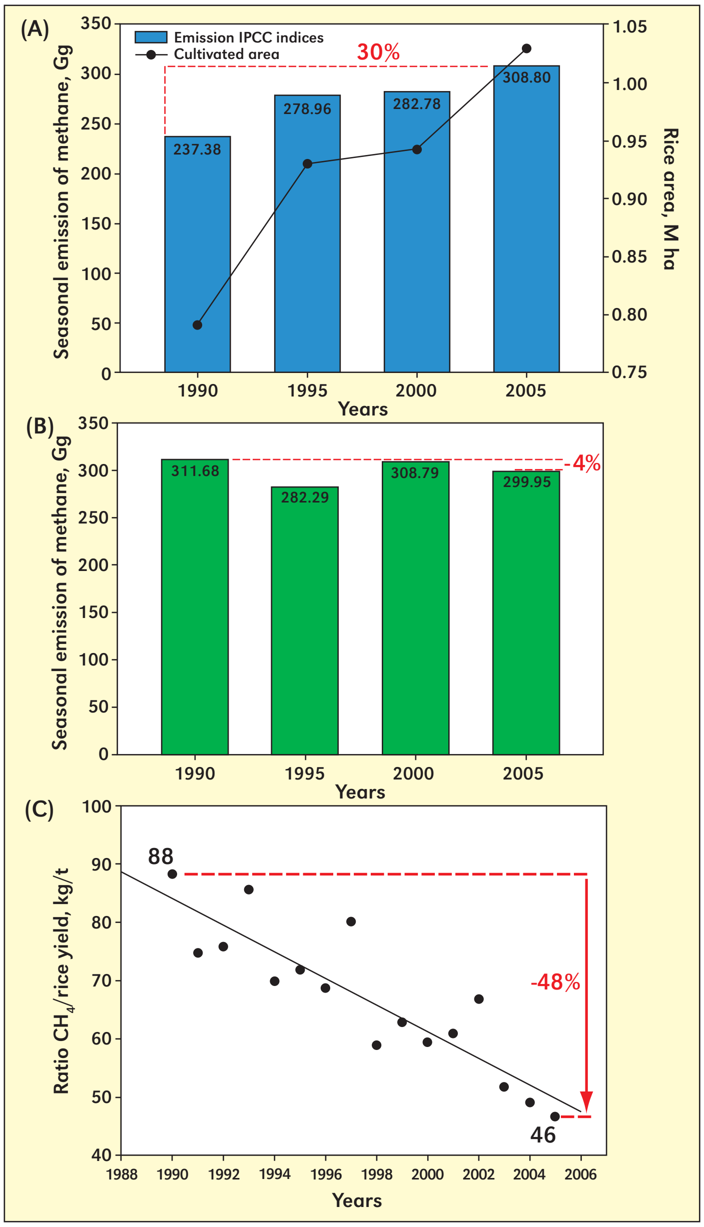

Figure 1. Changes in lowland rice area and seasonal CH_4 emission in Rio Grande do Sul State in southern Brazil based on the IPCC indexes (A), regional data for seasonal CH_4 emission considering evolution of minimum tillage adoption (B), and CH_4 emission per unit of rice production (C). Source: Bayer et al. (2012).

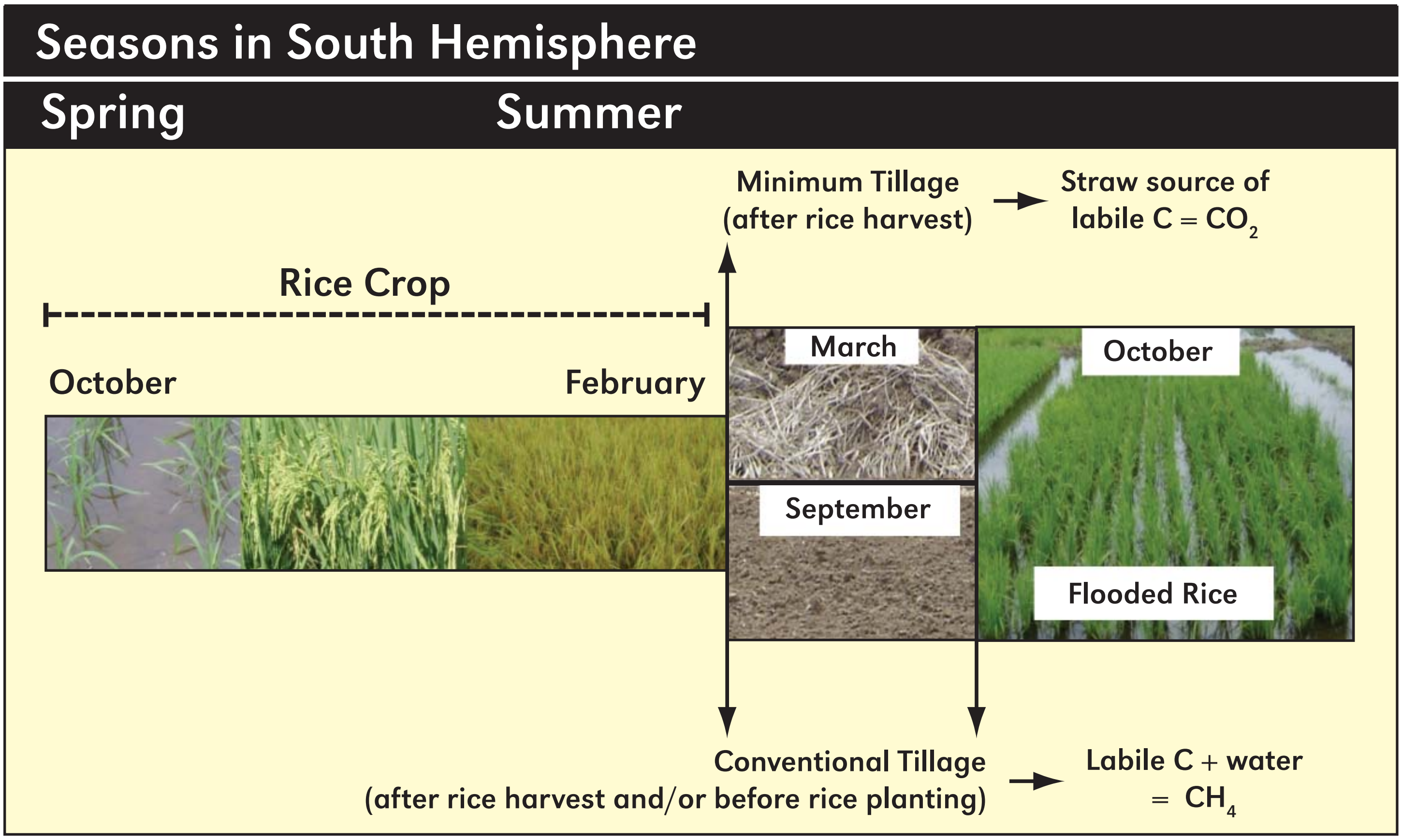

Figure 2. Conventional tillage and minimum tillage technologies adopted by southern Brazilian farmers.

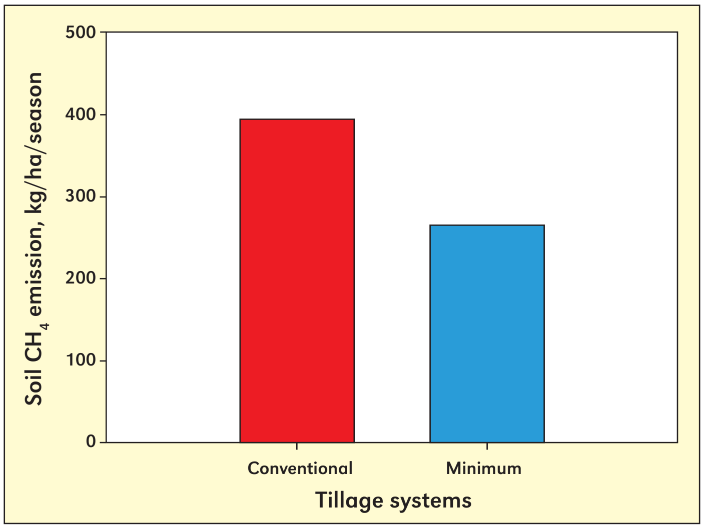

Figure 3. Seasonal methane (CH_4) emissions in flooded rice fields under conventional and minimum tillage systems in southern Brazil.

Local GHG emission data also shows that despite the 30% increase in cultivated rice area from 1990 to 2005, the estimated soil CH_4 emissions decreased by 4% (**Figure 1B**). Stable soil CH_4 emissions despite an increase in cultivated area, was the consequence of widespread adoption of minimum tillage by farmers. In 1990, about 80% of the total rice area in southern Brazil was cultivated under conventional tillage and only 20% was under minimum tillage. From 1990 to 2005, there was a continuous substitution of conventional tillage by minimum tillage, and in 2005, almost 80% of the total cultivated area was under minimum tillage. The impact of minimum tillage adoption on CH_4 emissions may not have been taken into consideration when IPCC indexes were applied.

Also, results were expressed only as per unit area, and not as per unit of food production. An increase in rice yield from 4.5 to 6.0 t/ha has occurred from 1990 to 2005 as a consequence of the introduction of new cultivars and the adoption of better soil and crop management practices. Considering this increase in yield, CH_4 emission has fallen from 88 to 46 kg of CH_4 per t of rice grain production (**Figure 1C**).

Reducing Irrigation Water Application

Areas under rice cultivation in the state of Rio Grande do Sul are traditionally irrigated by maintaining a water level during most of the life cycle of the rice plants (about 90 days). The practice consumes a large volume of water ranging from 8,000 to 10,000/m^3/ha (SOSBAI, 2012). Reducing irrigation water application to rice from continuous to intermittent use (i.e., suspending application of irrigation water at certain crop stages) has led to a 43% (9 to 77% range) reduction in soil CH_4 emission (**Figure 4**). These results are in agreement with similar studies around the world. Reducing irrigation water application also decreases the chances of iron (Fe) toxicity to rice plants.

Crop Diversification

Rice farmers in southern Brazil have recently started adopting crop diversification in paddy fields. In particular, soybean has been introduced within the rotation and this has had a positive impact on GHG emission from these poorly-drained soils. For example, partial global warming potential

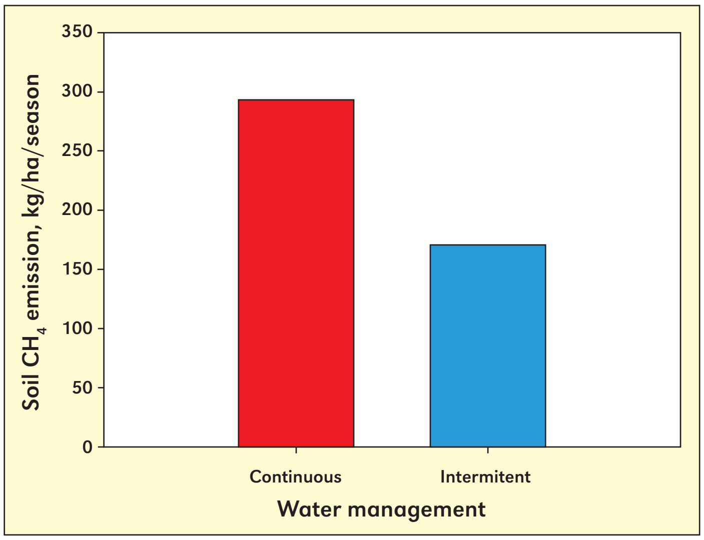

Figure 4. Potential of water saving regimes (intermittent) to mitigate soil CH_4 emissions in southern Brazilian lowland rice fields. Source: Zschornack (2011), Wesz (2012), Buss (2012), Moterle (2011), Camargo (data not published).

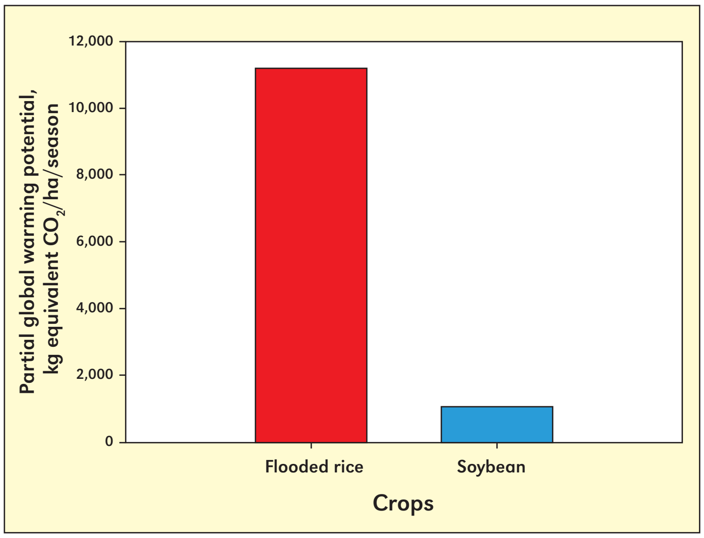

Figure 5. Partial global warming potential (CH_4+N_2O in CO_2 equivalent) in lowland fields cultivated with soybean and rice under traditional irrigation methods in southern Brazil. Source: Camargo (unpublished data).

(i.e., CH_4+N_2O in equivalent CO_2) was found to be 10-fold lower under soybean than under rice (**Figure 5**).

Summary

Development of environmental-friendly agricultural production systems with a low C footprint is a crucial strategy that will drive international agricultural markets in the near future. Thus, regional GHG research is crucial to identify or develop low C emission production systems. In flooded rice production systems, some technologies such as minimum tillage, reduction in irrigation water application, and crop diversification have been found to have the potential to mitigate CH_4 emissions in southern Brazil. BC

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