REPORT

WHITE CORN AND POPCORN PRODUCTION SYSTEMS:
AN ESTIMATE OF CARBON AND GHG STOCKS.

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INTRODUCTION

The state of Mato Grosso, the largest producer of meat and soy in Brazil, has displayed a significant increase in maize production in recent years (FAO-Stat; IBGE). This increase is associated with the intensification of land-use in soybean production areas through the practice of corn cultivation in the off-season. As a result, in 2017, the state was responsible for 2.6% of global corn production (30 million tons) and aims to increase its current production by 30% to meet the projected demand for 2025 (IMEA, 2015).

In this context, two varieties of maize stand out: popcorn and white corn. The state of Mato Grosso is the largest producer of both varieties, concentrating most of the production of popcorn in the municipality of Campo Novo dos Parecis. However, the cultivation of these corn varieties is particularly sensitive to the hot and dry climate of Mato Grosso, which necessitates the adoption and maintenance of improved agricultural management and soil conservation practices to maintain productivity levels, such as no-till systems and crop-livestock integration.

These systems are considered sustainable from a productive, environmental and economic point of view, and are among the main Brazilian measures promised as part of the Paris Agreement, supported by the Plano ABC - which aims to reduce greenhouse gas (GHG) emissions and increase agricultural production (UNFCCC, 2015; Brazil, 2015; SEEG, 2019). Previous studies show that no-till practices and crop-livestock integration systems lead to an increase in soil carbon stocks, one of the main indicators of soil conservation, fertility and health. However, it is necessary to evaluate and recommend different cultivation systems and soil management practices for different regions of the country.

OBJECTIVE

To estimate the soil carbon stocks and the GHG emissions balance of popcorn and white maize producing farms in Campo Novo dos Parecis, Mato Grosso, Brazil.

MAIN RESULTS

- No-tillage and livestock crop integration have the potential to keep carbon stocks in the soil at the same levels as in native vegetation. However, for some areas, a more diverse and long-term crop rotation pattern is necessary.
- The production of popcorn and white maize in this region of Mato Grosso state has low GHG emissions impacts, around 1.30 tCO_2e ha^{-1} $year^{-1}$ or 0.25 tCO_2e per ton of grain produced (55% of these emissions come from the use of nitrogen fertilizers), which places the farms evaluated in this study within the most efficient corn production systems globally.
- The scaling of no-tillage and crop-livestock integration systems in Mato Grosso alone could sequester about 300 million tons of carbon (or 1,100 $MtCO_2e$) in the soil - which corresponds to almost 120% of the total emissions reductions promised by Brazil in the Paris Agreement in the year 2030 (925 $MtCO_2e$).
- The results suggest that maintaining or expanding no-tillage and, especially, the integration of crops and livestock in degraded soils in the region is an important strategy to meet future food production and reduce the country's GHG emissions.

PROCEDURES

In total, seven producers of white corn and popcorn were interviewed from Novo Campo dos Parecis, Mato Grosso, to identify the main agricultural management methods used (i.e. use of inputs for the soil, fossil fuels, cultivation systems, cultivation practices and productivity[1]) and select areas representing different situations for soil sampling (Table 1). Figure 1 - Location of Novo Campo dos Parecis, state of Mato Grosso, Brazil.

Table 1. *Historical land use/management practices of the sampled sites in Campo Novo do Parecis, Mato Grosso state, Brazil.*

FARM	LAND USE	YEARS OF IMPLEMENTATION (LAND USE HISTORY)
1	Native vegetation (CE)	Cerrado
	Degraded pasture (PD-1)	30 years (after native Cerrado)
	Integration crop-livestock (ILP-1)	5 years (1980 Cerrado; 80's conventional tillage; 90's-10's no-tillage)
2	No-tillage (PD-2)	30 years (80’s Cerrado; 80’s conventional tillage)
3	Nominal pasture (DP-3)	30 years (after native Cerrado)
	No-tillage (PD-3)	30 years (80’s Cerrado; 80’s conventional tillage)
	Integration crop-livestock (ILP-3)	5 years (80’s Cerrado; 80’s conventional tillage; 90’-10’s no-tillage)

Soil samples for determining density and carbon were collected at five points within each area at depths ranging from 30 to 100 cm in depth. The samples were taken to the laboratory and the carbon stocks were analysed according to the protocol recommended by the IPCC (2006) and EMBRAPA (2013).

The GHG balance of white maize and popcorn production was assessed using a tool based on the GHG Agricultural Protocol (WRI, 2014; 2018), which applies the IPCC directives and guidelines for National Inventories (IPCC, 2006). The scope of the analysis comprises the main sources of GHG emissions and sinks at the property level (“gate inwards”).

[1] The interviews revealed that the production of popcorn and white maize use approximately 100 kg N (mostly urea), 0.5 tons of limestone (assuming an average of 3 years) and 60 litres of diesel oil per hectare per year.

RESULTS AND DISCUSSION
CARBON AND GHG STOCK: WHAT DOES ANALYSIS SHOW?

The data obtained show that the native vegetation (CE) stores about 100 tC ha^{-1} in the first meter of soil, with about 20% (21 tCO_2 ha^{-1}) and 55% (54 tCO_2 ha^{-1}) of this stock being located in the first 10 and 30 cm, respectively. However, the comparison between the different treatments indicated that historical land-use changes influence the original levels (Figure 2).

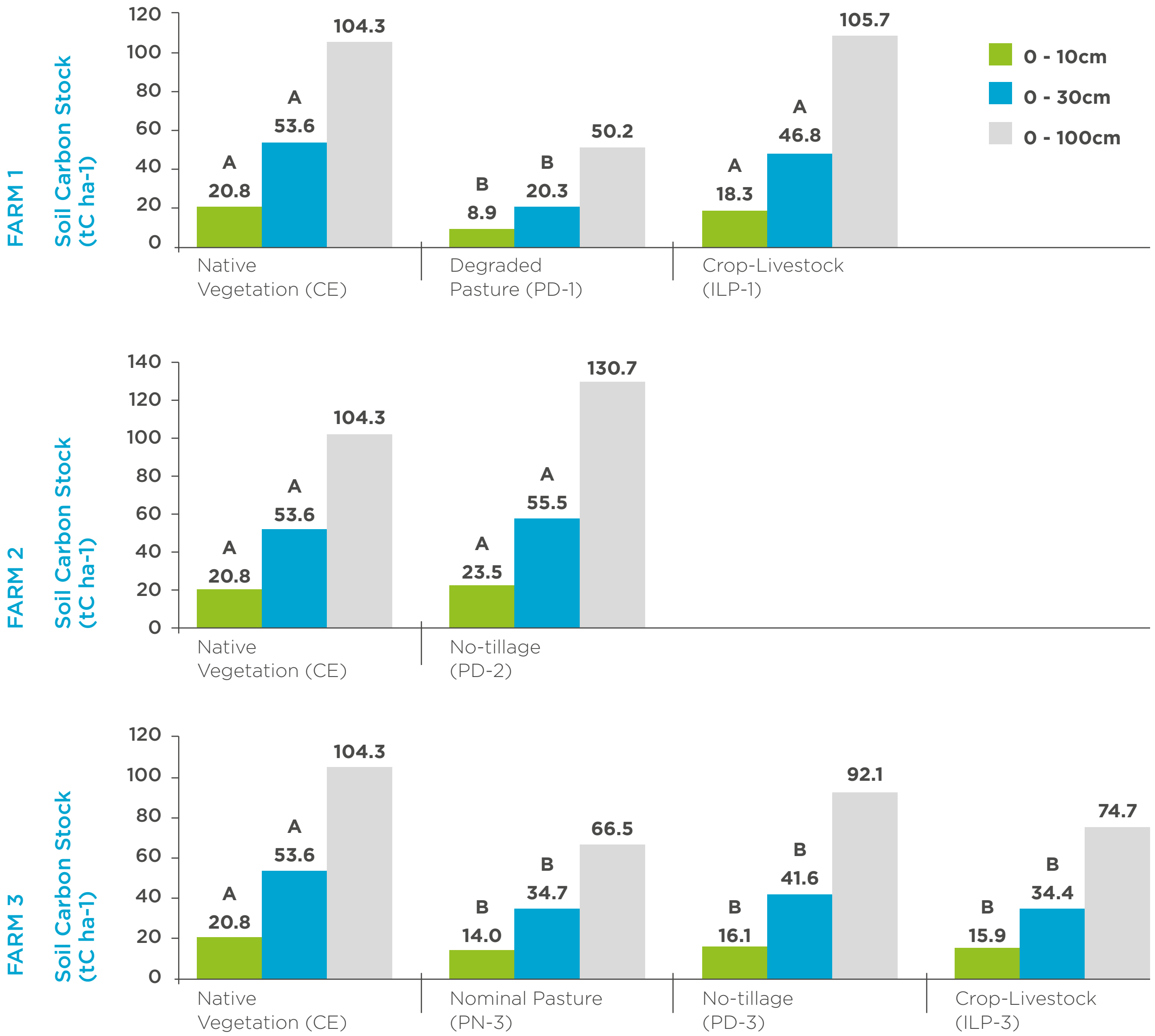

Figure 2. *Carbon stocks in the soil of native vegetation compared to areas of pasture, no-tillage and crop-livestock integration systems at a depth of 100 cm, in Campo Novo dos Parecis, Mato Grosso, Brazil (the clay content in these soils ranged from approximately 20 to 60%). Values followed by the same letter in the same soil layer do not differ, according to the Tukey test ($p \leq 0.05$).*

Conversion of Cerrado to pasture (PD-1 and PN-3) resulted in a significant loss of carbon stocks in the first 10 and 30 cm after 30 years. This trend was more significant in PD-1 pastures, which displayed a total loss of 11 and 30 tC ha^{-1} in the 0-30 cm (or 55% and 38%) soil layer, whereas the PD-3 pasture, lost 6 and 20 tC ha^{-1} (30% in both cases), respectively. The main causes of pasture degradation are overgrazing, a decline in soil fertility, soil erosion, the reduction of root systems and the eradication of grasses, which consequently reduces the supply of organic residues to the soil, which maintains C stocks. For this reason, soil degradation normally leads to a decline in its C stock. This reduction in C stocks is extremely harmful to Cerrado soils, since the soil's organic matter is responsible for 75 to 85% of cation exchange (CTC) of these soils (Silva & Resck, 1997). Similarly, recovery of degraded pastures is capable of increasing C stocks in the soil. In Brazil, about 60 million hectares of pasture, 10 million of which are located in the state of MT, may have undergone some type of degradation and, therefore, are inefficient from an agricultural point of view.

In this context, no-tillage and integrated production systems represent an alternative to minimize the impacts to the soil caused by different forms of land use, since the maintenance of plant residues on the surface, the rotation of crops and minimum ploughing of the soil act to increase carbon stocks (Carvalho et al., 2009).

The results of this study strongly suggest that soybean and maize planting under no-tillage and crop-livestock integration have the capacity to at least maintain the soil carbon stock levels found in native vegetation and outperform those of degraded pastures in the region. (Figure 2). However, in some cases, the quality and quantity of crop residues provided by the strict succession of soybeans/maize may not be sufficient to sustain the soil's carbon stocks at the level of native vegetation, possibly requiring a more diverse and long-term crop rotation pattern in some areas and situations. The implementation of crop-livestock integration systems is often pointed out as an option.

The fact that the crop-livestock integration system (ILP-3) does not yet display differentiated carbon stocks compared to the levels of no-till (PD-3) and natural vegetation, may suggest that 5 years of implementation of ILP-3, after almost 25 years of conventional planting, is not enough time to effect changes in carbon stocks detectable in certain situations. This fact corroborates most studies in the region, which have identified a significant accumulation of carbon in the soil within 8 to 22 years after the implementation of crop-livestock integration systems. In addition, it is important to note that unknown factors linked to the history of land's characteristics and historical uses may also have interfered with the carbon stocks found in this study.

GHG BALANCE

The GHG emissions associated with the production of popcorn and white maize "gate inwards" were estimated at 1.30 and 1.32 tCO_2e ha^{-1} $year^{-1}$, or 0.25 and 0.24 tCO_2e per ton of product, respectively. Differences in GHG emissions per ton of popcorn and white maize are related to differences in crop yields (5.1 and 5.6 t ha^{-1}, respectively). Approximately 55% of emissions for corn production are due to the use of nitrogen fertilizers, followed by crop residue decomposition (18%), limestone (17%) and diesel from machinery (11%) (Figure 3).

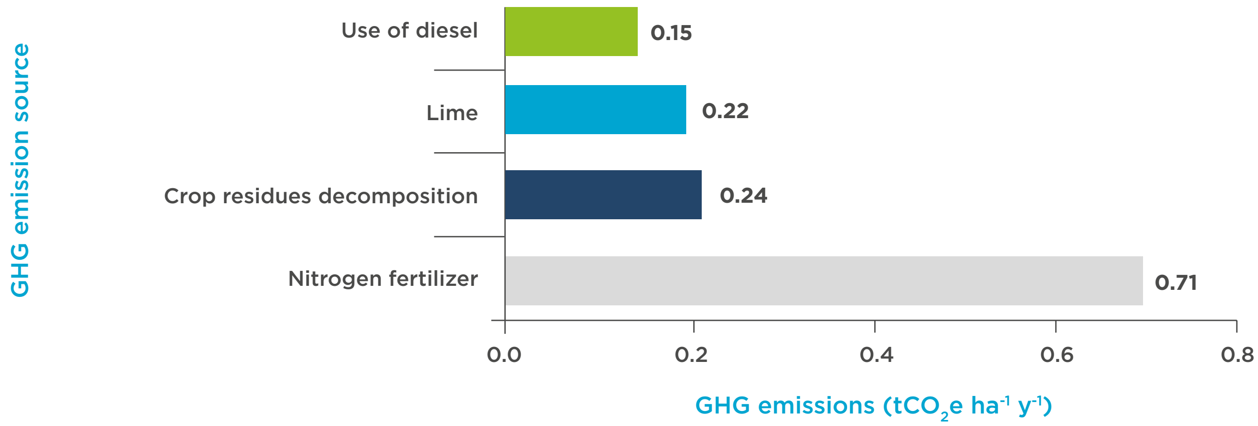

Figure 3. *Average greenhouse gas emissions from the production of white maize and popcorn (at farm scale) in Campo Novo do Parecis (MT).*

Globally, the average GHG emissions for corn production are estimated at 1.7 tCO_2e per ton of product, to which emissions from the farm contribute almost 50% or 0.81 tCO_2e per ton of grain produced (Poore & Nemecek, 2018). Thus, based on the estimates found in this study, emissions of white maize and popcorn produced in Campo Novo do Parecis (MT) are potentially rank among the 10 most efficient corn production systems globally (Figure 4).

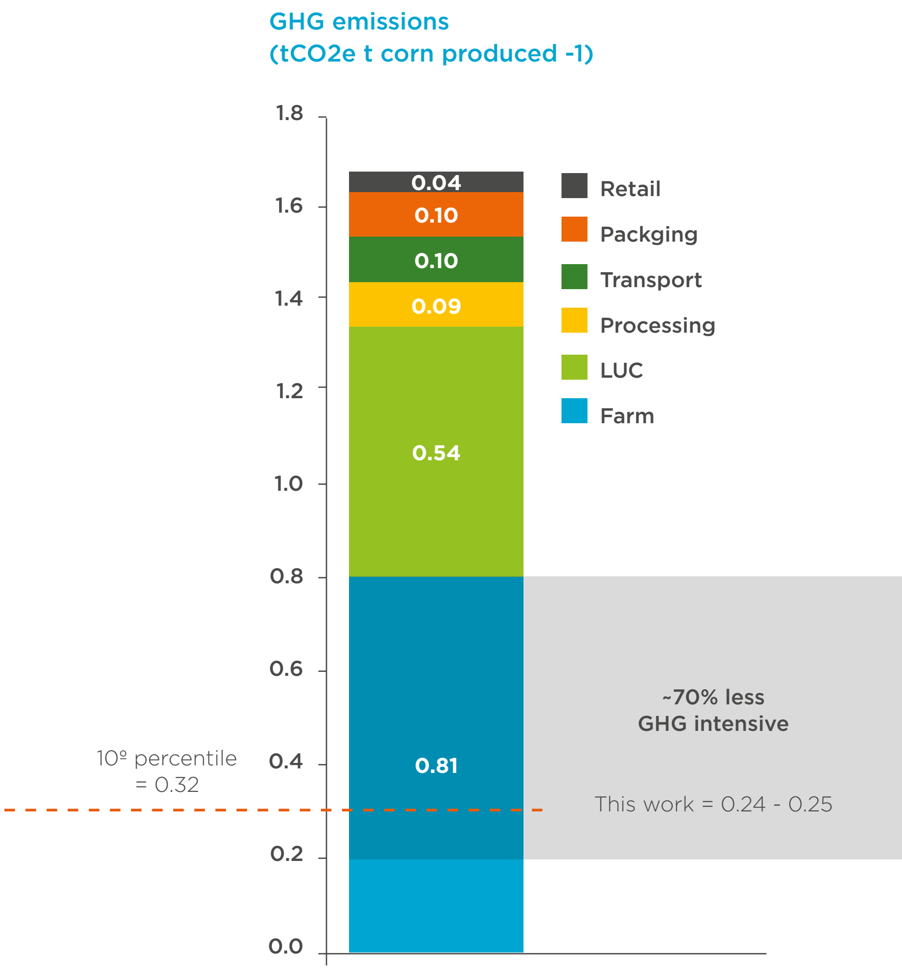

Figure 4. *Global average greenhouse gas emissions intensities to produce a ton of maize compared to the production of popcorn and white maize in Novo Campo dos Parecis (MT) (based on Poore and Nemecek, 2018).*

CONCLUSIONS

Degraded pasture areas have significantly lower soil carbon stocks compared to native vegetation, while no-tillage and livestock crop integration systems have the potential to maintain original levels. However, for some areas, a more diversified and long-term crop rotation pattern is necessary.

The emissions caused by white maize and popcorn production are lower than the values for yellow maize. The analysis of the balance of GHG emissions of these varieties in Campo Novo dos Parecis potentially places them among the most efficient 10% of such crops globally, presenting competitiveness and production attractiveness based on national and world averages. If production systems are improved to sequester carbon in soils even more efficiently, white corn and popcorn crops can potentially become a GHG sink.

Considering that the discussed improvements in soil carbon stocks and low GHG emissions can also be translated into improvements in production efficiency, Brazil has an opportunity, given that over 60 million hectares of pasture, of which 10 million are located in the state of Mato Grosso, display some level of degradation and are underutilized from the point of view of agricultural production (LAPIG, 2019). For this reason, the recovery of degraded pasturelands and the implementation of integrated agricultural systems are at the heart of Brazil's commitments to the Paris Agreement (Brazil, 2015).

Based on the data from this study, which show reductions of about 30 tC ha^{-1} (0-30 cm of soil) due to pasture degradation compared to the native Cerrado (Figure 2), the scaling of direct planting and crop-livestock integration at sufficient levels to recover these degraded areas, and increase the soil carbon levels compared to those of the original vegetation, in Mato Grosso alone, could enable the sequestration of about 300 million tons of soil carbon (or 1,100 tCO_2e) - which corresponds to almost 120% (925 $MtCO_2e$) of the reductions promised by Brazil by the year 2030 (Brazil, 2015; SEEG, 2019), while simultaneously increasing fertility and productivity and meeting market demands. The results of this study suggest that maintaining or expanding no-tillage systems and, especially, the integration of crops and livestock on degraded lands in the region are important strategies to meet food production demands in the future, while reducing the country's GHG emissions.

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