Progress report: Quantification of carbon sequestration trough conservation agriculture in the Mexican Bajío

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Introduction

In the Bajío region CIMMYT operates an innovation hub that investigates, validates, demonstrates and promotes conservation agriculture, amongst other sustainable practices (Monjardino et al., 2021). In the hubs there are research platforms, where conservation agriculture is studied under a scientific design, and modules and extension areas where conservation agriculture is evaluated at the field scale (Gardeazabal et al., 2021). In the Bajío, there are currently 9 research platforms, with different experimental treatments and different times under conservation agriculture (Fonteyne et al., 2021). Therefore, these research platforms are ideal to quantify carbon sequestration with conservation agriculture in the region. Additionally, the farmers' fields in the hub with conservation agriculture allow to validate the carbon sequestration determined in the research platforms under field conditions.

In 2022, CIMMYT initiated the soil sampling in the research platforms and farmers' fields to generate the database that will be used to derive a model of carbon sequestration by conservation agriculture in the Mexican Bajío. In the research platforms soil is sampled per plot from 0 to 30 cm and from 30 to 60 cm depth. Two soil cores are taken per experimental plot to determine bulk density. The soil samples are analyzed by Fertilab soil laboratory (Celaya, Guanajuato). Apart from soil organic matter, pH, nitrate, phosphorus and potassium concentration are measured and soil texture is determined using the Bouyoucos method.

The following research platforms were sampled in 2022 for a total of 123 soil samples for chemical soil analysis and 246 samples for bulk density measurements:

- Irapuato I, Guanajuato
- Valle de Santiago, Guanajuato
- Acámbaro, Guanajuato
- Ocotlán, Jalisco
- Apaseo el alto, Guanajuato
- Epitacio Huerta, Michoacan
- Villagran, Guanajuato
- Pénjamo, Guanajuato

Additionally, 3 farmer's fields were sampled using the same sampling protocols.

In 2023, soil sampling continued in research platforms and in farmers fields under conservation agriculture.

The following research platforms were sampled in 2023:

- Soledad de Graciano Sanchez, San Luis Potosí
- Iguala, Guerrero

While the Iguala, Guerero Research platform is not located in the Bajío, it has treatments with a similar two cycle irrigated winter crop – rainfed summer crop cropping sequence as is common in the Bajío region.

To evaluate how the results from experimental conditions translate to on-farm conditions, farmers' fields were sampled. Fields under conservation agriculture (maize-wheat rotation, permanent beds, leaving crop residues) were identified by the local team. As a control, a nearby field under conventional management was sampled. Fields were sampled from 0 to 30 cm depth. Three soil cores per field were taken to determine bulk density. In the Bajío, the fields are under almost constant cultivation, wheat is sown in December and harvested in May, while maize is sown in May and harvested in December. Therefore, there are only a couple of weeks each year when fields can be sampled, which has complicated the sampling campaign. In 2023, after the wheat crop, we sampled 30 farmers' fields and after the maize crop we sampled 25 farmers' fields.

Image 1: Soil bulk density sampling after maize harvest in farmers' field.

Image 2: Collection of composite sample for chemical analysis in farmers' field after wheat harvest.

Preliminary results

Carbon content in research platforms

The research platforms in the Bajío offer the possibility to evaluate the effects of different types of tillage and residue management in the same field, with a complete record of all operations.

In Villagran the data indicate an increase in soil organic carbon content of approximately 6.1 t CO_2 equivalent per hectare per year (Fig. 1), while in Acambaro the data indicate an increase of only 2.2 6 t CO_2 equivalent per hectare per year (Fig. 2). The data do not indicate a lower carbon concentration under conservation agriculture at lower depths, as the carbon content in the 30 – 60 cm layer was not generally lower under CA than under conventional agriculture.

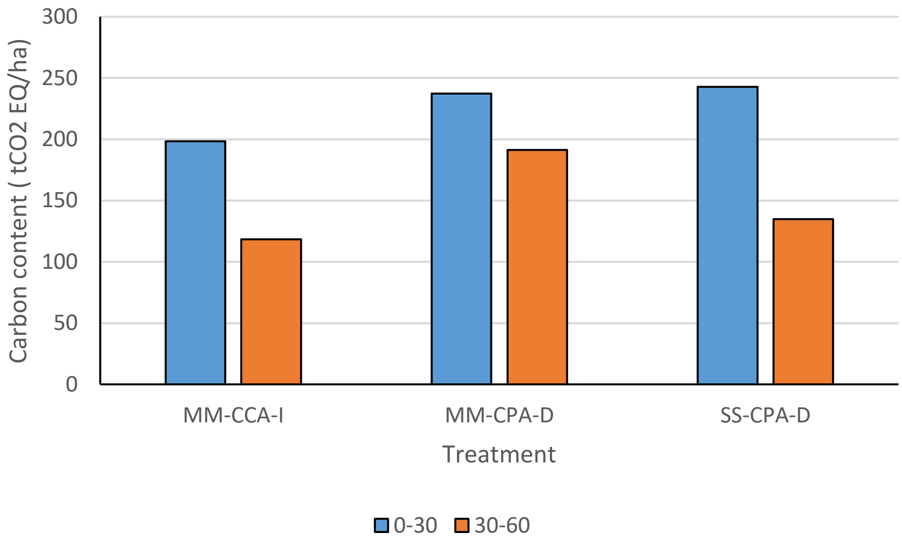

Fig. 1: Carbon content in the Villagran, GTO research platform. Abbreviations: MM: Maize-Maize rotation, SS: Sorghum-Sorghum rotation, CCA: Broad conventionally tilled beds, CPA: Broad Permanent Beds, I: Incorporate crop residues, D: Remove crop residues.

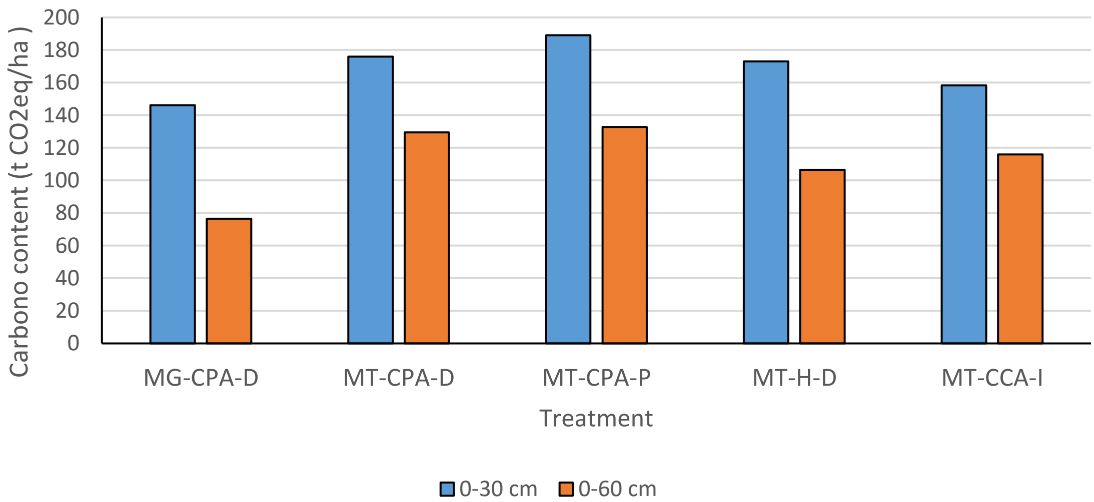

Fig. 2: Carbon content in the Acambaro, GTO research platform. Abbreviations: MG: Maize-Chickpea rotation, MT-Maize-Wheat rotation, CCA: Broad conventionally tilled beds, CPA: Broad Permanent Beds, H: Hybrid system with tillage for wheat and direct seed maize, I: Incorporate crop residues, D: Remove crop residues, P: Partial residue retention.

Carbon content in farmer’s fields

The data from farmers’ fields indicate an upward trend in soil organic matter in farmers fields in relation to the time the field has been managed under conservation agriculture of about 0.1% increase per year (Fig. 3), which at an average bulk density of 1.2 t/m^3 would amount to an increase in carbon of about 8.7 t CO_2 equivalents per hectare per year. This would be higher than the carbon sequestration rate reported by Follett et al., (2005) but similar to the rate reported by Dendooven et al. (2014). However, there is significant variability in the data and not all fields under conservation agriculture are higher in organic matter than the neighboring field under conventional agriculture. In 2024, we will revisit the fields to ensure that field management has been accurately captured, as there is sometimes confusion about the meaning of conventional and conservation agriculture. At the moment of reporting, not all bulk density samples of the autumn sampling campaign had been weighed, this data will become available in early 2024, to provide a complete picture of carbon sequestration in farmers field and the variation in bulk density within fields, across neighboring fields and within the Bajío region.

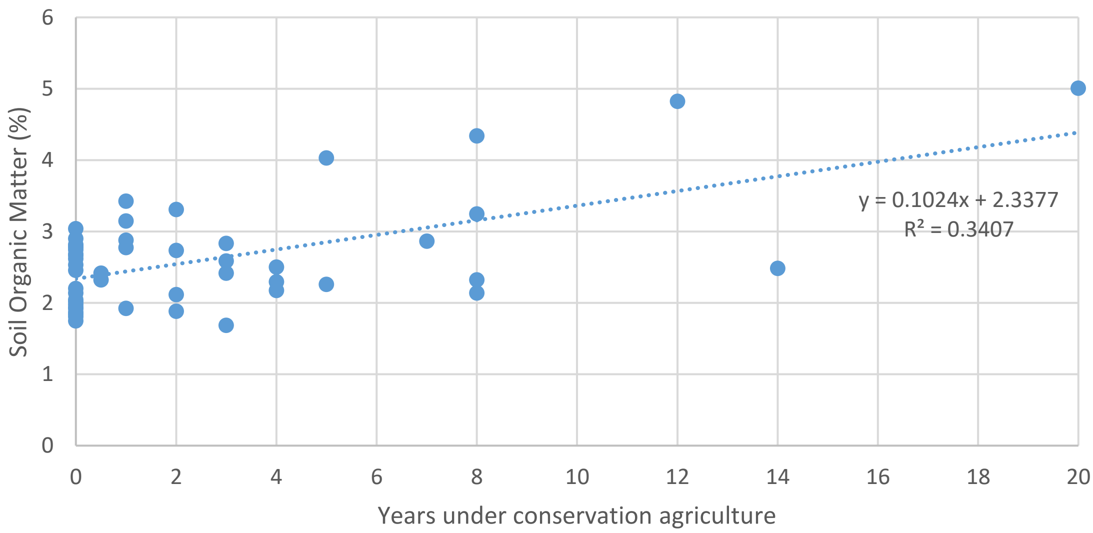

Fig. 3: Soil organic matter concentration in the 0 to 30 cm soil layer in 50 farmers fields in the Bajío region of Mexico in relation to the time the field has been managed under conservation agriculture.

Next steps

In early 2024 the determination of soil bulk density in farmer's fields will be finished. This will allow us to generate the final database to use for statistical analysis. The data will be used to establish an empirical model to indicate the rate of carbon sequestration in the Mexican Bajío. This empirical model will then be linked to the remote sensing model detecting the (potential) extent of conservation agriculture in the Bajío, to quantify current and potential carbon sequestration.

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