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Council for Tropical and Subtropical Agricultural Research

# ATSAF - CGIAR++ Junior Scientists Program
# Final Report

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| **Start and end date of stay at IARC: 19 Sep 2021 - 19 Nov 2021** |
| **Start and end date of remotely supervised project: 01 Jun 2021 - 31 May 2022** |
| **Title: Soil carbon and nitrogen emissions under farmer managed conservation agriculture and conventional farming in Zimbabwe** |

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**Context, Objective and Methods of the Field Study**

Agriculture operates under the threefold challenge of climate change adaptation and mitigation while pursuing sustainable intensification to meet raising food demands. Conservation agriculture (CA), an agricultural practice combining the management principles of no-tillage, crop residue retention and crop rotations, represents an avenue aiming at addressing all three aspects. However, major knowledge gaps on CAs mitigation potentials – especially in a Sub-Saharan context – remain. This study amid to generate basic data on the latter systems soil emissions and soil carbon (C) sequestration (negative emissions).

A mobile, closed chamber system was used to conduct *in-situ* measurements, of soil borne C- and nitrogen derived emissions, in farmer managed CA fields and conventionally managed controls, in northern Zimbabwe. Measurments were carried out under contrasting soil fertilities (on low fertility *Arenosols* and high fertility *Luvisols*) and in contrasting environmental conditions (cold-dry, cold-wet, warm-dry, warm-wet). The flux rates of $CO_2$, $N_2O$ and $NH_3$ (mg $m^{2-1}$ $h^{-1}$) were quantified for both CA and CONV systems under each of the latter environmental conditions.

Further, the study executed the fractionation and quantification of soil C pools. Thus, aiming for a better understanding of soil C composition, its functions, and the different fractions correlations to soil emissions. The approach of fractionating soil organic matter into particulate organic matter (POM particles > 63 µm) and mineral-associated organic matter (MAOM particles < 63 µm) was chosen as the most informative approach, when addressing questions of soil C sequestration and climate change mitigation. The POM fraction is considered labile only having residence times of < 10 years up to decades, yet the POM pool can be increased without reaching a C saturation ceiling. The MAOM pool is considered recalcitrant with residence times of decades up to centuries, however this pool can be saturated.


**M: Madziva**
**S: Shamva**

*Location of the study sites Shamva and Madziwa, north of the capital Harare in Zimbabwe*


*Off-grid power supply from a solar-battery system (left); The mobile-closed chamber system (right)*

**Key Findings**

A positive correlation between all investigated gases, soil temperature, and soil moisture was evident. Differences in field-emission from CA and CONV fields were not significant. Nevertheless, strong tendencies were evident. Field emissions were highest under warm-wet conditions, which are prevailing for large parts of the season. Here, for $CO_2$ emissions a reduction of 3 % from mean 601 mg $CO_2$ $m^2$ $h^{-1}$ (CONV) to 583 mg $CO_2$ $m^2$ $h^{-1}$ under CA practice was recorded on *Luvisols*, while a reduction of 7.6 % from 502 mg $CO_2$ $m^2$ $h^{-1}$ (CONV) to 464 mg $CO_2$ $m^2$ $h^{-1}$ under CA practices was noted on *Arenosols*. For $N_2O$ emissions (global warming potential = 265 CO2eq), a reduction of 17.5 % from mean 0.274 mg $N_2O$ $m^2$ $h^{-1}$ (CONV) to 0.226 mg $N_2O$ $m^2$ $h^{-1}$ under CA practice was recorded for *Luvisols*, on *Arenosols* emissions were reduced by 54.7 % from a mean of 1.16 mg $N_2O$ $m^2$ $h^{-1}$ (CONV) to 0.526 mg $N_2O$ $m^2$ $h^{-1}$ under CA.

Data from the soil organic matter fractionation showed that on *Luvisols*, the mean C pool based on labile POM was increased by 16.8 % to 4.31 g $kg^{-1}$ and by 19.4 % to 3.15 g $kg^{-1}$ in the respective 0-10 cm and 10-20 cm soil horizons compared to CONV controls. In *Arenosols*, slight reductions of 8.7 % and 1.8 % in POM-C were found in CA plots at 0-10 cm and 10- 20 cm. The recalcitrant, MAOM C pool was on average consistently higher for CA systems. MAOM-C under CA management increased by 10.3 % to 3.11 g $kg^{-1}$ and by 12.1 % to 2.81 g $kg^{-1}$ in the 0-10 cm and 10-20 cm horizon of *Arenosols*. In *Luvisols* the MAOM-C was increased by 9.7 % to 15.8 g $kg^{-1}$ and by 8.3 % to 14.3 g $kg^{-1}$ in the respective 0-10 cm and 10- 20 cm horizon, compared to CONV controls.

Considering the high variability both in-field, same as intra-field, a follow up study with an increased number of replicates is required. The trends point towards CA having a moderate, and site-specific climate change mitigation potential. However, if deployed on large areas they may yield a substantial mitigation effect, along with advantageous impacts on adaptive capacity and yield levels, supporting several Sustainable Development Goals.

**Organisation and Logistic of the Research Stay**

It is my personal interest and passion, to engage in the process of finding solutions to the global climate crisis. In spring 2021 I contacted several working groups of the University of Kassel and the University of Göttingen, to inquire relevant contacts to working groups engaging in projects, tackling research questions at the climate change – land-use nexus.

I was interested in finding a research network already engaging in this field of work, which is willing to host an incoming master student, while providing the opportunity for the student to incorporate own interests and ideas. For me it was very important to also engage in the development of the research objective and study design; not simply consuming a readily provided master thesis topic.

This search was successful. My supervisor Prof. Dr. Andreas Bürkert (University of Kassel) provided a contact to Dr. Bruno Gérad (CIMMYT Mexico) and again Dr. Gérad to Dr. Christian Thierfelder (CIMMYT Zimbabwe), who became my second supervisor. The team in Zimbabwe was interested in generating more data on the climate change mitigation potential of conservation agriculture in Sub-Saharan Africa, thus we jointly developed a framework to measure field emissions and soil C sequestration in the latter systems.

The research focus, location and network of collaborators provided for the opportunity to apply to the ATSAF-CGIAR JSP program, to acquire funding for the envisioned study. The respective grand application was finished in summer 2021.

Perusing official fieldwork with CIMMYT Zimbabwe requires the application for a residence permit and temporary employment permit - to be obtained from the government of Zimbabwe. These bureaucratic steps require substantial funding and several months of preparation (multiple notarized certificates, translations, and health certificates). The application documents were successfully compiled and submitted in in late summer 2021. Soon after, in September 2021, I arrived in Zimbabwe.

After arrival, the first two weeks were spent in the capital Harare and at the CIMMYT campus. This time was used to construct the mobile-closed chamber system, to be used for the field emission measurements, also the execution of test measurements was carried out here. Further, field-visits to potential research locations were conducted and research plots selected. Lastly, since the selected locations had no grid access, a solar battery system to power the required equipment was conceptualized and constructed. During this time, I also had the opportunity to gain insights into other CIMMYT projects, as e.g. the smallholder mechanisation program.

Following the completion of all on-site preparations, I moved to the villages of Chavakatzi in Shamva and later to the village Nyarikunda in Madziwa, where I conducted the field measurements until mid-November 2021. Consecutive to the field-work, further organisational matters as i.a., the soil sample export permissions, were organized. Required soil analytics were conducted in winter 2021/2022 in Germany.

The high costs implied by the administration and material acquisition for this study, represent the main reason for the rather limited duration of on-site field work. Yet, considering the whole process from conceptualization, logistical planning, field work and data processing to

laboratory work and writing; the project lasted for nearly one year. Large parts of the material were left at CIMMYT Zimbabwe, this provides a good basis for a more cost-effective follow-up study/ M.Sc. thesis.

**Daily Life during the Field Work in Zimbabwe**

In each village, I was hosted by a farmer family being part of CIMMYTs demonstration network. I am thankful for their hospitality and them letting me be part of their daily life.

To facilitate work, in each village, I employed a field assistant for support in material transport and translations. Although, over time, I also learned some basic *Shona*, which is the local language in northern Zimbabwe. Our Working routine was tightly scheduled, starting at 5:00am in the morning with the setup of the solar system, followed by the morning and afternoon field measurements 6:00am-9:00am and 12:00am – 3:00pm. In-between, same as afterwards, material transport, plot preparation, equipment maintenance, collection of supplementary data and the generation of data backups took place. Each day was finished 14 hours later, with dinner and breakdown of the solar system at 7:00 pm. Sometimes, when there were some free hours in between, we went for long walks exploring the area, visited the village gardens, tobacco nurseries or small local goldmines.

*The central well of the village Chavakatzi (left); A traditional kitchen in Chavakatzi (right)*

**Learnings and Outlook**

Beside the subject specific learnings on conservation agriculture, and agriculture in southern Africa in general, many appreciated lessons for life were gained during my time in the villages. It was interesting and insightful to join the daily life of this smallholder communities and learn about the often harsh circumstances of their livelihoods.

Overall, life is very simple in such villages without any electricity- or water grid, without access to a tar-road and without good communication networks. The dietary patter in this region is plain. *Satza* (maize porridge) being the main staple, served several times a day, sometimes supplemented with some beans or kale. Certainly, maize is the main staple crop in the region;

however, most farmers also grow an additional chas-crop. In the Shamva region this is tobacco in the Madziwa region this is cotton. Yet, also these additional income streams are tied to a range of challenges. The tobacco purchasing companies often have mafia-like structures and the curation of the tobacco is requiring a lot of wood – this turned tobacco cultivation into the leading cause of deforestation in the region. The cotton purchasing company is state owned and - in the last season - did not pay any money to the farmers at all.

Just in the last season, most of the cattle in both communities died, due to a disease conveyed by ticks, leaving some farmers with a number of cattle, not even sufficient to operate a plough. Facing these unfavourable conditions in agriculture, more and more young people are shifting towards gold-mining, disregarding the fact, that this illegal and often dangerous work is destroying their agricultural fields. Often it was possible to gain insight in this challenges and conflicts.

In the global north, many people have an over romanticised image of rural smallholders. While this maybe holds true for some, most experience severe struggles and are quite vulnerable in this world of global change. Many farmers have little financial means and thus limited access to external inputs. Depending fully on rain fed agriculture - for literally their whole existence - is a disadvantaged position, when facing proceeding climate change.

For my part, I am very thankful, for the experience of walking one kilometre, to the top of a hill, to catch enough reception for sending out a WhatsApp message, of adopting my daily rhythm to the rhythm of the sun, for the simple life full of maize porridge, bucket showers and hard nights on the floor. I think everyone, who truly wants to engage in tackling the challenges of sustainable (agricultural/ rural) development, with all its facets of adaptation, mitigation, and intensification, is well advised to experience and thus understand the current "*baseline situation*", many smallholders call their daily life.

ATSAF/CGIAR facilitated thesis options, in such locations, are a very valuable experience for all students. I hope that a longer lasting cooperation with CIMMYT Zimbabwe will persist, and that building on the contacts established, materials prepared, and knowledge gaps identified another thesis study will be conducted here in the future.