Strengthening Capacity in Environmental Physics, Hydrogeology and Statistics for Conservation Agriculture Research

CEPHaS Project Briefing

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CONSERVATION AGRICULTURE EXPERIMENT AT CHITEDZE, MALAWI

Chitedze Agricultural Research Station was established in 1948, located 16 km west of the capital city, Lilongwe. It lies on an altitude of 1146 m above sea level, representing the medium altitude areas of the Central Region of Malawi. Chitedze has a mean annual temperature of 20°C (maximum temperatures of more than 24°C in November and lowest below 16°C in July). The Station receives a mean annual rainfall of 892 mm, 85% which falls between November and March and mean annual temperature ranges from 18°C to 21°C. The typical depth to groundwater at Chitedze from June 2019 to February 2020 was 10.8 to 12.6 m below ground level. The soils at Chitedze represent the majority of the fertile soils that occur on the Lilongwe plain: Luvisol and Ferralsol.

The Conservation Agriculture (CA) experiment at Chitedze was established in 2007 by the Department of Agriculture Research Services (DARS) in collaboration with CIMMYT with the aim to assess the efficacy of climate-smart agriculture practices in improving soil fertility and crop yields. In 2018, we started installing soil moisture and potential sensors (i.e. soil physics), ERT arrays (i.e shallow geophysics) and we sunk monitoring boreholes. The installation of soil physics, shallow geophysics and hydrogeological instrumentation at the Chitedze experiment under the CEPHaS project allows us to examine long- to medium-term effects of CA practices on soil water dynamics and groundwater recharge. To add value to the trial the CEPHaS statistics working group has also undertaken an analysis of the maize yield data from the first ten years of the trial.

Prior to trial establishment, the site was under fallow for more than five years. The dominant natural fallow bush was *Tithonia diversifolia* (Deliya) and *Acacia polyacantha* (Mthethe). After land clearance, a uniform maize crop was grown across the site in 2006 after which the trial plots were laid out and treatments were implemented. The trial is laid out in a randomized complete block design (RCBD) comprising a wide range of CA treatments as follows; conventional tillage (CT), reduced tillage with direct seeding, planting basin with residue retention or mulch, rotations involving maize and legumes (cowpea, groundnuts, velvet bean), and maize intercropped with cowpea. There are in total 10 treatments each on plots of dimensions 24 m x 13.5 m. CEPHaS is focussing on three of the treatments: T1 (conventional management with cultivation and removal of crop residues), T3 (direct seeding into undisturbed soil with residues retained and T8 (maize intercropped with velvet bean (mucuna), soil undisturbed and residues retained).

Figure 1a *Figure 1a Aerial photo of the experiment. CEPHaS plots (T1, T3 and T8) are shown in colour in Figure 1b below.*

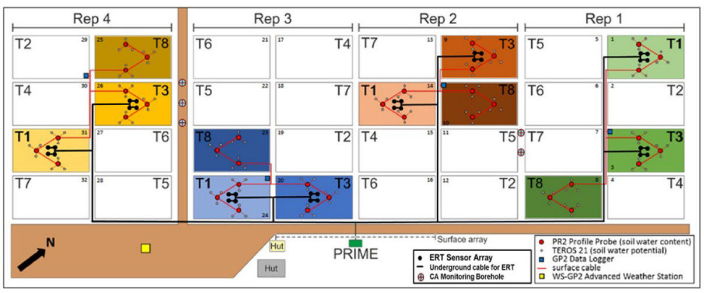

Figure 1b *Field layout of the plots showing the shallow geophysics (ERT) sensor arrays, soil physics sensor probes and groundwater monitoring boreholes. Each plot is 24 m x 13 m.*

Equipment installation and training

CEPHaS team members from Lilongwe University of Agriculture and Natural Resources (LUANAR) have participated in formal and informal training in the field instrumentation and its establishment along with DARS staff. Some LUANAR staff also participated in the installation of soil physics equipment at the CEPHaS site in Lusaka, Zambia, as part of CEPHaS training prior to establishment at Chitedze.

Figure 2a Training in installation of ERT sensor arrays and connecting the sensor arrays to the monitoring equipment at Chitedze.

Soil physics

Soil moisture, matric potential and soil temperature sensors were installed at different soil depths to enable monitoring of the profiles on regular basis (Figure 2). The Delta-T data logger and controllers (GP2) were installed in each plot and networked with uninterrupted solar-powered supply for data measurement and retrieval. The installed three soil profile probes in each plot measure soil moisture profiles at 0.10, 0.20, 0.30, 0.40, 0.60 and 1.00 m depth. In addition, five Delta-T sensors (Theta probes) were installed at depths of 0.10, 0.20, 0.40, 0.60 and 1.00 m to measure both soil moisture and soil temperature. A further three sensors to measure the matric potential of the soil water and soil temperature were installed at 0.10, 0.40 and 1.00 m. In addition, soil samples are regularly collected for chemical (soil organic carbon, nitrogen, soil reaction) and physical analysis (aggregate stability, water infiltration, moisture retention, penetrometer resistance).

Shallow geophysics

A telemetric resistivity measuring system was installed in the field to soil electrical resistance using the PRIME system designed and developed by BGS. The monitoring network comprises a total of 32 Electrical Resistivity Tomography (ERT) sensor arrays, each having a set of 8 electrodes that extends to 1 m depth (Figure 2). Four arrays were installed in T1 and T3 for each of REP 1, REP 2, REP 3 and REP 4 of the field. Also connected to the system is a 30 m long surface ERT array comprising of 30 pin electrodes. Using underground cables, the ERT is linked to wireless telemetry for remote measurement control and data retrieval housed in the PRIME cabin.

First monitoring data were acquired during October 2018. Continuously repeated measurements are captured which will be used to determine resistivity changes over time. Assuming that the soil composition doesn't change, this will allow us to visualize the movement of water in the soil and below the rooting zone to the water table, alongside sensors which allow direct measurement of soil water properties from the surface to 1 m depth.

Figure 2b Training in drilling supervision and logging at Chitedze.

Hydrogeology

A network of boreholes has been drilled to monitor the water table and to understand how this fluctuates through the growing season. One pumping well, 3 multi-level wells and one single monitoring well with data loggers were installed in each of the CA (Figure 2) and CT plots, with on-the-job-training in drilling supervision and sample logging. Groundwater monitoring (water levels) started in June 2019.

WHO ARE WE?

We are soil scientists, agronomists, hydrogeologists, geo-physicists, statisticians and agricultural economists from the University of Zimbabwe, the University of Zambia, Lilongwe University of Agriculture and Natural Resources, the University of Nottingham, Rothamsted Research, Liverpool School of Tropical Medicine and the British Geological Survey. We are working with the Kasisi Agricultural Training Centre, Zambian Agriculture Research Institute, the Department for Agricultural Research Services (Malawi), and our commercial partner, Delta-T Devices (UK).

To find out more, visit our webpages at https://www2.bgs.ac.uk/CEPHaS and follow us on twitter @CEPHaS_Soil

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