# Groundwater recharge in sub-humid drylands under different agricultural systems

Daina Mudimbu[1] *, Kawawa Banda[2], Bentje Brauns[3], Dan J. Lapworth[4], Alan M. MacDonald[5], Willy Namaona[6], Richard Owen[7], and Mabvuso Sinda[8]

[1]Department of Chemistry and Earth Sciences, Faculty of Science, University of Zimbabwe, Harare, Zimbabwe
[2] Department of Geology, School of Mines, University of Zambia, P.O. Box 32379, Lusaka, Zambia
[3]British Geological Survey, Keyworth, NG12 5GG, UK
[4]British Geological Survey, Wallingford, OX10 8BB, UK
[5]British Geological Survey, Edinburgh, EH14 4AP, UK
[6] Lilongwe University of Agriculture and Natural Resources, Malawi
[7] Department of Civil Engineering, School of Engineering, University of Zimbabwe, Harare, Zimbabwe
[8]Department of Soil Science, School of Agricultural Sciences, University of Zambia, P.O. Box 32379, Lusaka, Zambia

1973 50th 2023 IAH CONGRESS
CAPE TOWN | SOUTH AFRICA
12-22 SEPTEMBER 2023
The International Association of Hydrogeologists

CEPHaS Capacity for Conservation Agriculture Research

GCRF Global Challenges Research Fund

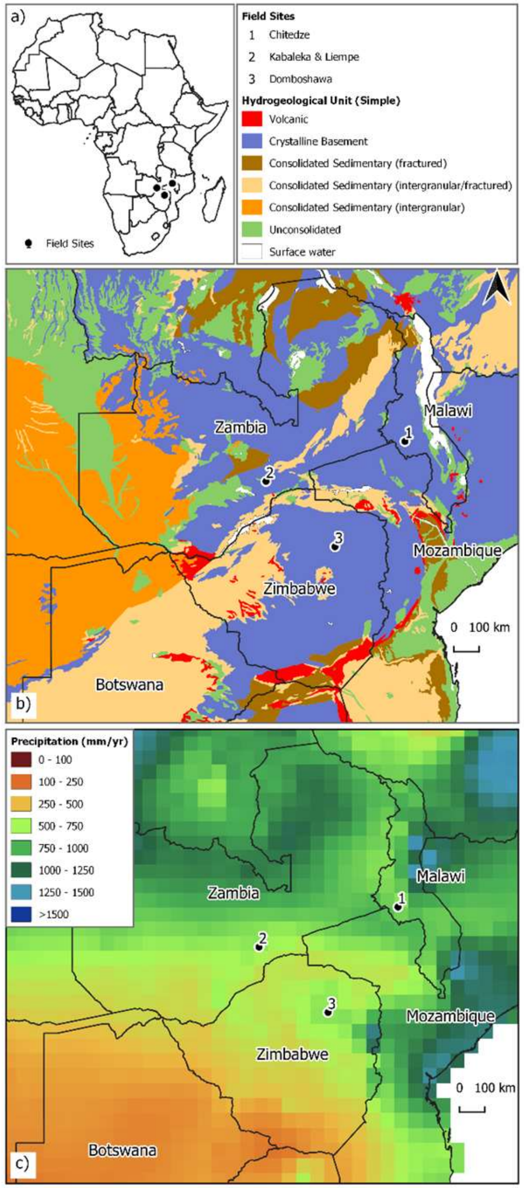
UK Research and Innovation

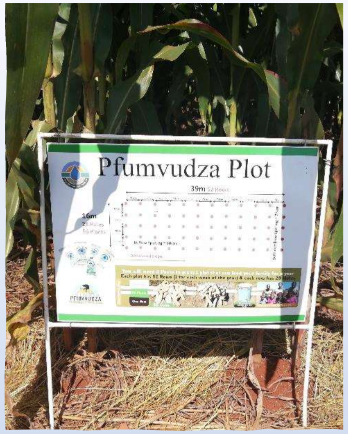
# Key Questions

How does CA influence groundwater (GW) recharge?

Possible effects on:

- timing
- amount
- pathways





CEPHaS
Capacity for Conservation Agriculture Research

GCRF
Global Challenges Research Fund

UK Research and Innovation

# Specific Objectives

i) Use high-frequency rainfall and **groundwater level observations** from a network of sensors to assess groundwater recharge responses to **rainfall** over 3 consecutive recharge seasons

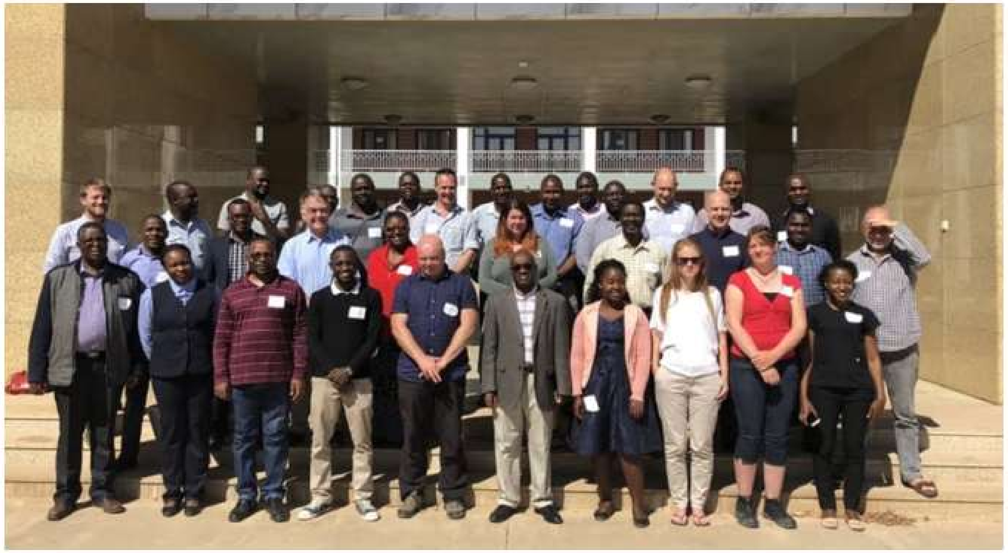
ii) Compare recharge estimates using **water table fluctuation** and **chloride mass balance** methods

iii) Employ a range of hydrochemical **tracers** (water isotopes and $SF_6$) to assess recharge sources and groundwater **residence times**.

CEPHaS
Capacity for Conservation Agriculture Research

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

The CEPHaS project is a joint undertaking between colleagues in Zambia, Zimbabwe, Malawi and the UK to strengthen our shared capacity among **statisticians, soil scientists, geophysicists, hydrogeologist, agriculturalists** and **social scientists**.



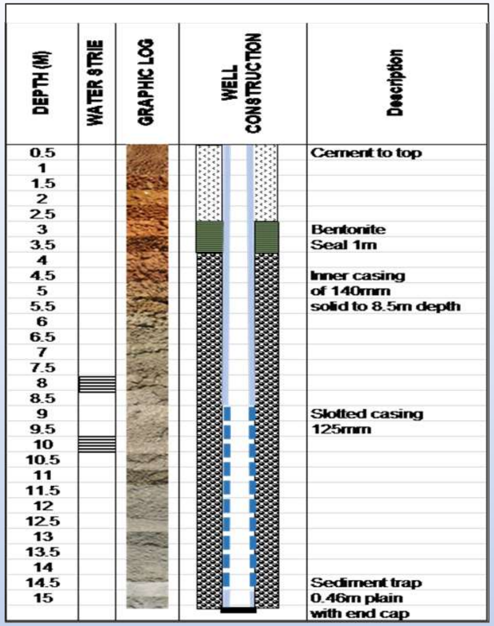
A GCRF UKRI Collective Fund project

GCRF Global Challenges Research Fund
UK Research and Innovation

# Study design: Set-up of monitoring boreholes

- Shallow boreholes finished 5 m below RWL
- Slightly deeper boreholes finished 10-15 m below RWL
- Deeper boreholes finished c.30 m below RWL
- All screens approximately 3-6 m at the bottom section

Drilling site in Zimbabwe

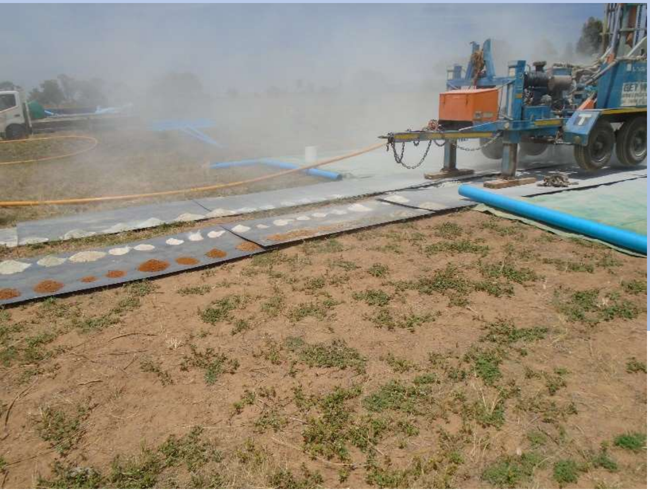



top: example of BH design

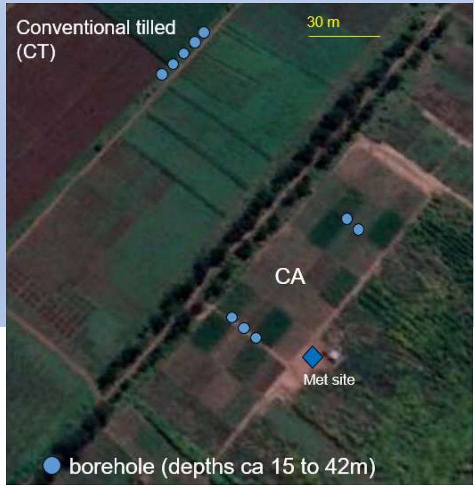
In addition: At least one of the deep borehole with longer screen for pumping tests

Geology and RWLs: mostly schist & granitic bedrock with RWLs c.7-11 m bgl, MW encountered a confining silcrete later at 1-2m bgl

Drilling activity in Zimbabwe; protecting the site against runoff & compaction



Example of BH set-up in Malawi

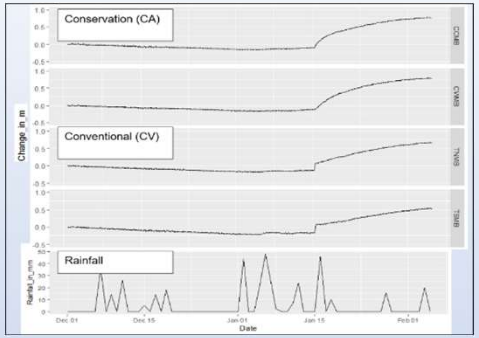



left & bottom:
equipping BHs with pressure transducers (30-min resolution)

# Study Design

## Installation of boreholes


## Water level observations




Comparison of time series

Quantification of recharge

## Water sampling

Residence time tracers (water age)

Isotopic changes (d2H, d18O)

Changes in hydrochemistry

ZM, ZW | 2019 | MW, ZM | 2020 | 2021

water level observations (30 minute interval)

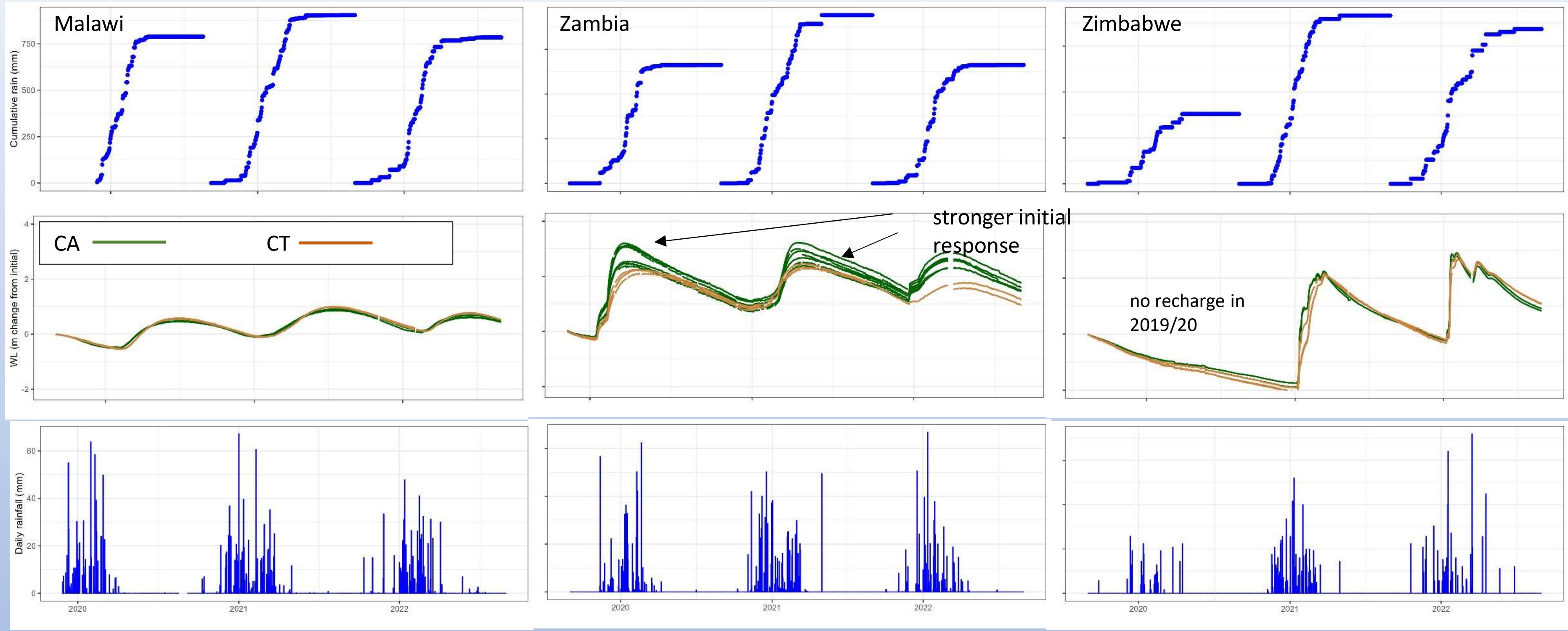
Water sampling: Water chemistry & stable isotopes (montly intervals)

CEPHaS
Capacity for Conservation Agriculture Research

GCRF Global Challenges Research Fund

UK Research and Innovation

# Results: Rainfall & WTF



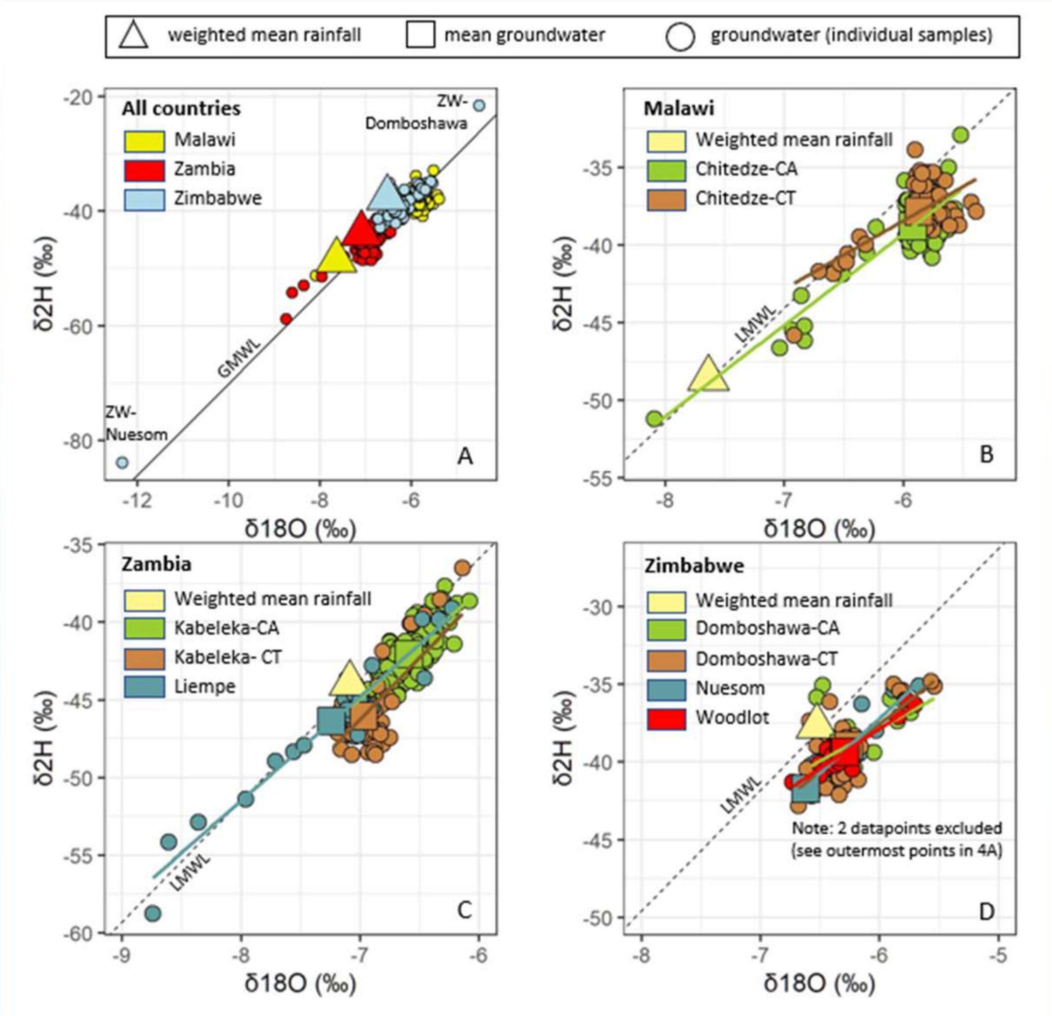

- Time of peak WLs
- MW: Jun/Jul yet others: Mar/Apr

CEPHaS
Capacity for Conservation Agriculture Research

GCRF Global Challenges Research Fund

UK Research and Innovation

# Results: Stable isotope data



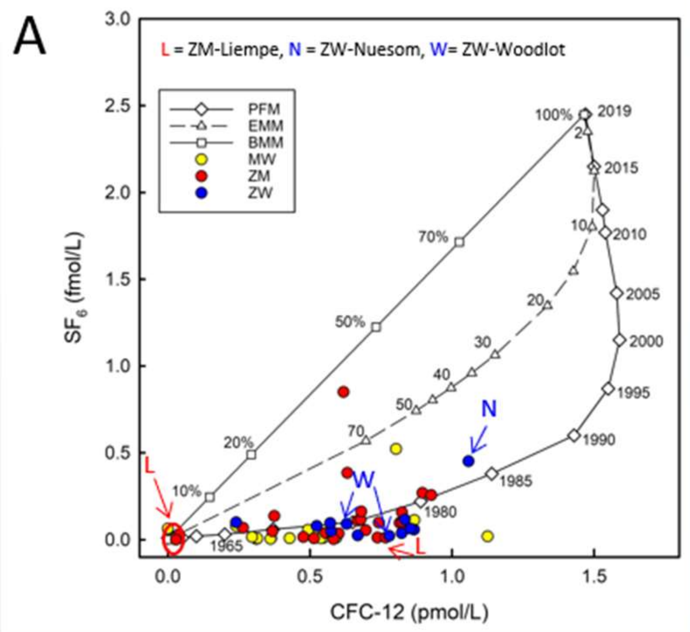

- No statistically significant differences between CA vs CT at Chitedze or Domboshawa.
- GW recharge dominated by isotopically depleted heavier water/rainfall events
- For Kabeleka (Figure 4c)
    - both cultivation techniques capture ‘depleted’ heavy rainfall events,
    - CA plots may also capture the more ‘enriched’ lighter rainfall.
    - CA samples show a greater scatter - a broader range of rainfall events.
- CA groundwater samples plot more closely to the LMWL
- CT samples plot further away from the LMWL with

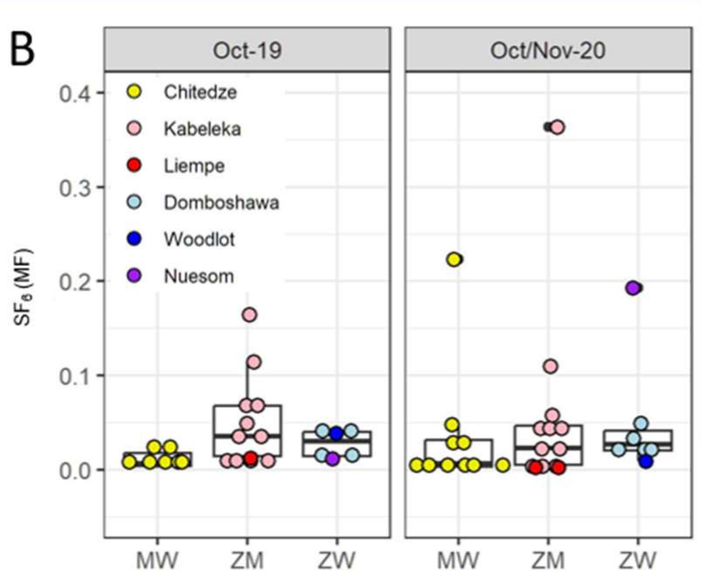
CEPHaS
Capacity for Conservation Agriculture Research

GCRF Global Challenges Research Fund

UK Research and Innovation

# Results: GW residence time data




- Low modern fractions (MF) of recharge were found across all sites (typically <0.05, using $SF_6$ results)
- No significant difference in the MF between the field sites.
- Significantly lower CFC and $SF_6$ tracer concentrations and MFs were found in this study compared to results from pumped wells in published studies (pumping may enhance groundwater capture within those basement settings).

GCRF Global Challenges Research Fund

UK Research and Innovation

# Groundwater Recharge Estimates

WTF method

| | Recharge mm/a | | Recharge as % rainfall | |
|---|---|---|---|---|
| **Site** | Mean | SD | mean | SD |
| **MW Chitedze-CA** | 8 | 1.5 | 1 | 0.1 |
| **MW Chitedze –CT** | 8 | 1.5 | 1 | 0.1 |
| **ZM Kabeleka-CA** | 26 | 7.8 | 3 | 1.3 |
| **ZM Kabeleka-CT** | 22 | 4.9 | 3 | 0.9 |
| **ZM Liempe** | 15 | 6.2 | 2 | 0.7 |
| **ZW Dom-CA** | 28 | 24.6 | 3 | 2.8 |
| **ZW Dom-CT** | 28 | 24.3 | 3 | 2.7 |

CMB method

| | | Rainfall Cl mg/l | | Groundwater Cl mg/l | | | Recharge as % rainfall | |
|---|---|---|---|---|---|---|---|---|
| **Site** | Year | Weighted | Average | Median | P25 | P75 | Median | Range |
| **MW Chitedze** | 19/20 | 0.13 | 0.24 | 0.26 | 0.18 | 0.67 | 94 | 36-134 |
| **ZW Dom** | 20/21 | 0.78 | 0.63 | 1.76 | 1.53 | 1.96 | 36 | 32-41 |
| **ZM Liempe** | 20/21 | 0.15 | 0.15 | 2.99 | 2.61 | 11.2 | 5 | **1-6** |
| **ZM Kabeleka** | 20/21 | | 0.15 | 1.71 | 1.09 | 4.76 | 9 | **3-13** |

- WTF method: average recharge was found to be **2.9± 2.2% rainfall** across all sites the
  - No statistically significant differences in recharge (expressed % rainfall) was found between the Zimbabwe and Zambian sites.
- Chitedze had significantly lower recharge (0.9± 0.13% rainfall) compared to the other three (4.1± 1.8 % rainfall).
- In terms of absolute average recharge values (mm/a) Domboshawa (48±10)>Kabeleka (21±4)>Liempe (15±4)>Chitedze (8±2).

Recharge estimates (as % rainfall) using CMB were considerably higher, and unrealistic, for all sites

- exception of Liempe and Kabeleka

CEPHaS
Capacity for Conservation Agriculture Research
GCRF Global Challenges Research Fund
UK Research and Innovation

# Summary on GW recharge findings

- Annual recharge totals **do not differ** significantly under CA vs CT .
- Changes in groundwater levels, and annual recharge, are controlled by :
    - **I.** **rainfall totals**,
    - II. the nature and timing of larger **rainfall events**,
    - III. the local **hydrogeological conditions** in the shallow subsurface and the presence of low permeability horizons.
- With CA farming groundwaters are recharged from a wider range of rainfall events and may have an **earlier recharge response** during the onset of the rainy season.
- There is a **limited impact of nature-based solutions** (NbS) such as mulching and zero tillage on annual recharge totals in humid dryland settings in the SADC region.

# Acknowledgements

**GCRF UKRI Collective Fund for funding this research**

**CEPHaS colleagues and supporting staff and farmers**

**The greater CEPHaS network with members from the following institutions**

**All of you for listening to this presentation**

Contact us at cephas@bgs.ac.uk

More information & project briefs:

@CEPHaS_Soil , https://www2.bgs.ac.uk/CEPHaS/index.html