Determining sub-catchment contributions to the suspended sediment load of the Tsitsa River, Eastern Cape, South Africa

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Session SSS2.5: Soil erosion and driving factors of soil carbon distribution: A worldwide threat

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DISCLAIMER

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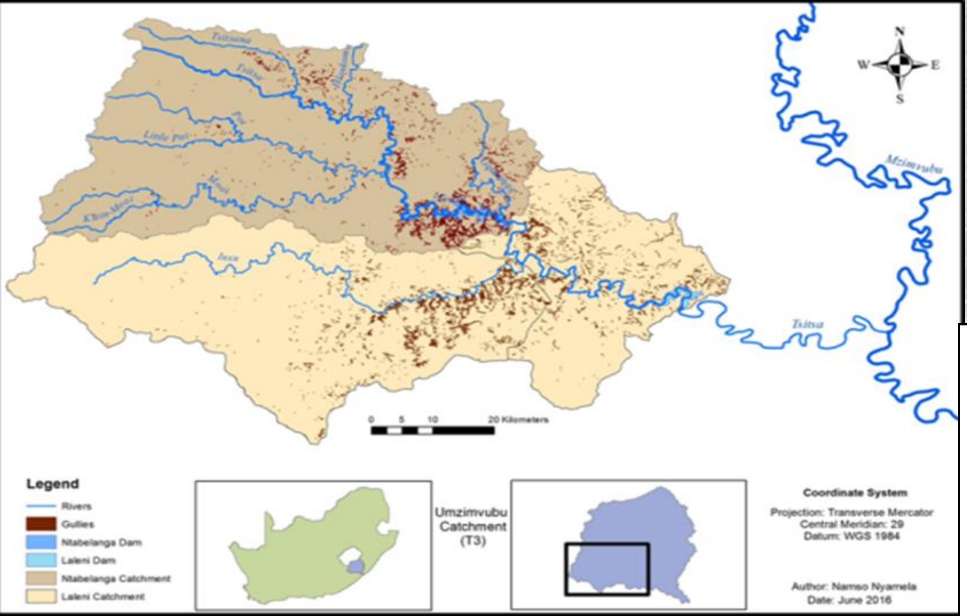
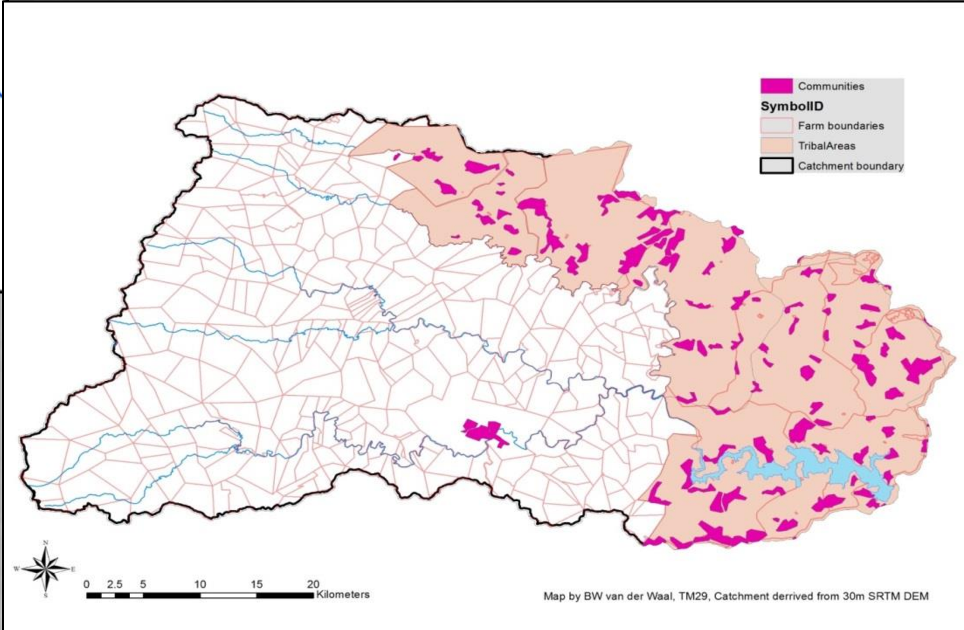
STUDY AREA

The Tsitsa River rises in the Drakensberg (2730 m amsl) and flows into the Mzimvubu River (600 m amsl). The catchment is 4000 km^2 and experiences summer rainfall. Geology is igneous in the headwaters, sedimentary elsewhere, with dolerite intrusions.

The catchment is 500 km from the research base at Rhodes University in Grahamstown



In addition to commercial agriculture and forestry (upper catchment), the Tsitsa River catchment has large rural communally-owned areas (lower catchment) typified by dispersive soils that are prone to the formation of soil pipes and major gully systems



Soil pipes form due to highly dispersive soils and may lead to the “overnight” appearance of major gullies

The Department of Environment, Forestry and Fisheries is co-ordinating and funding catchment-scale community-based hillslope rehabilitation and restoration initiatives, intended to support rural livelihoods through soil erosion and sediment transport mitigation

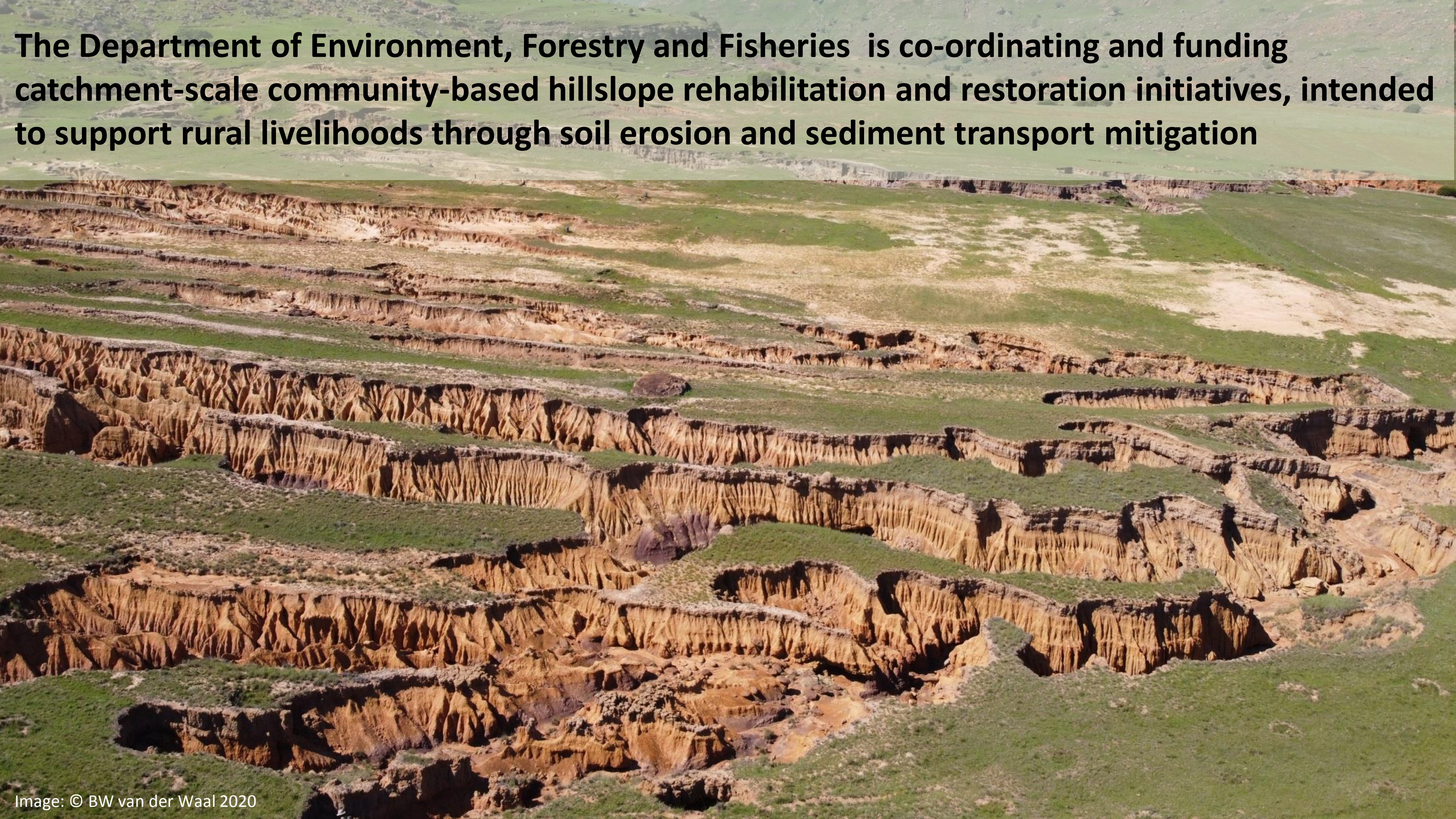


Image: © BW van der Waal 2020


Image: © BW van der Waal 2020
(Yes, these are HOUSES!)
Suspended sediment data are required to inform and prioritise hillslope restoration and rehabilitation

Highly variable rainfall and steep catchments lead to unpredictable “flashy” flows with high sediment loads, especially “first flush” flows early in the dry season. Clearance of alien invasive tree species leads to log jams and erosion. Installed monitoring equipment is likely to be damaged by debris, or vandalised. Roads and rivers in the wet season are hazardous and inaccessible.

Research overview

PhD aim: investigate SS data uncertainty, and consider the implications for catchment management decision-making

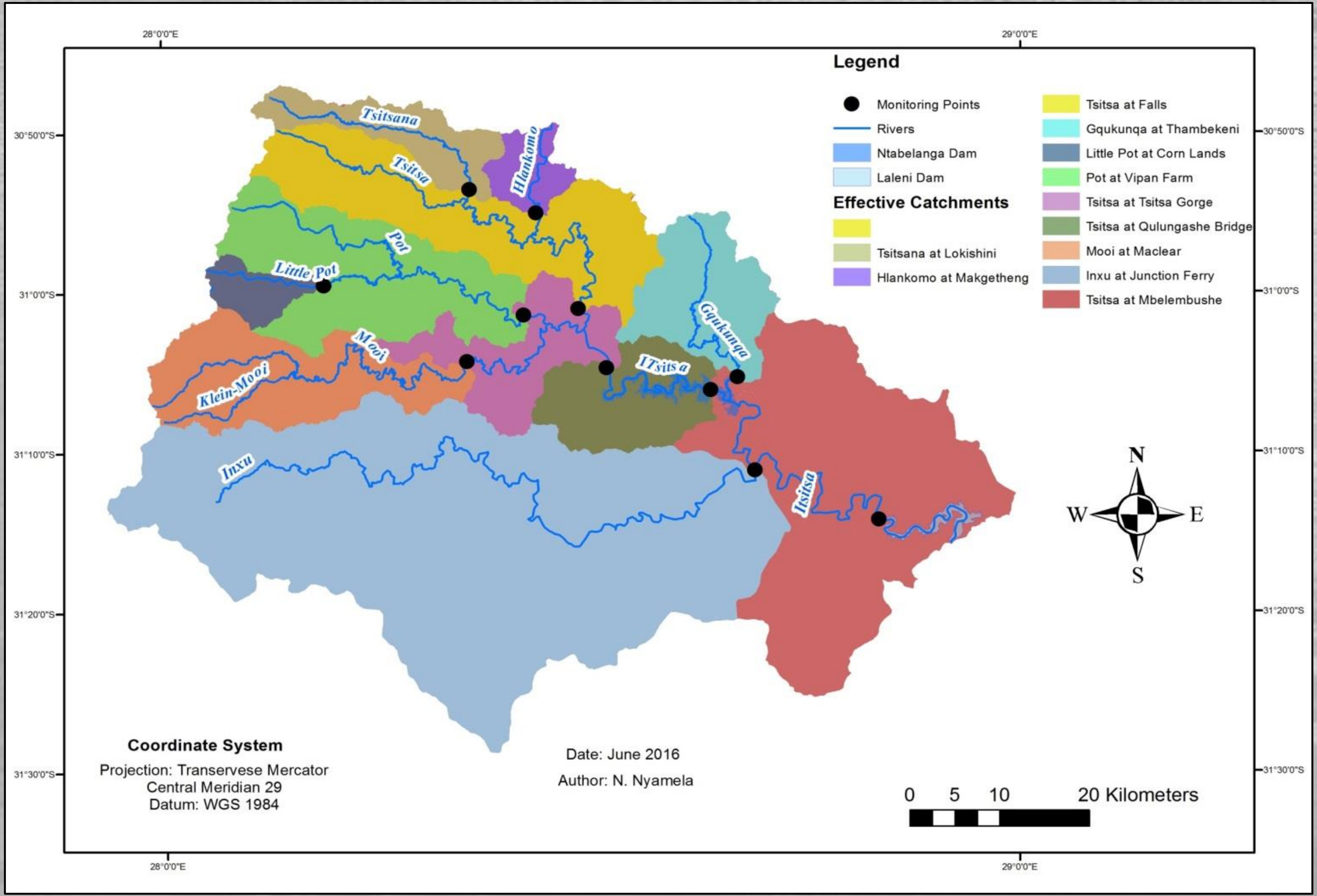
Objective 2) Estimate the SS yields for each sub-catchment with a measure of the uncertainty in the estimate

- **Use monitored SS and discharge to derive annual loads and yields at each monitoring site (2015 – 2019)**
- **Use sediment fingerprinting and source apportionment to determine the relative contributions of sub-catchments (Snapshot: Nov 2018)**

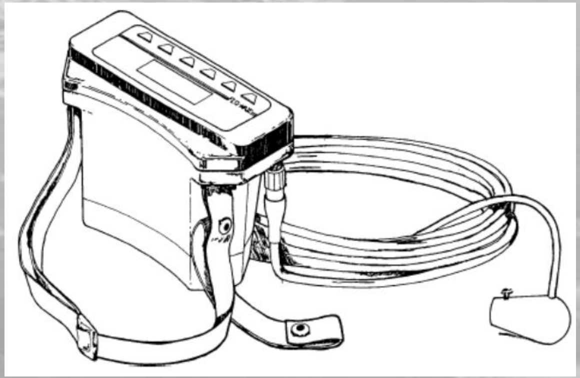
SSC monitoring

- Dec 2015 – June 2019
- Local residents as citizen scientists
- Sub-daily time-step data
- Direct suspended sediment sampling
- Focus on flood flows
- Locally appropriate field equipment and techniques PLUS
- Sophisticated data reporting and management

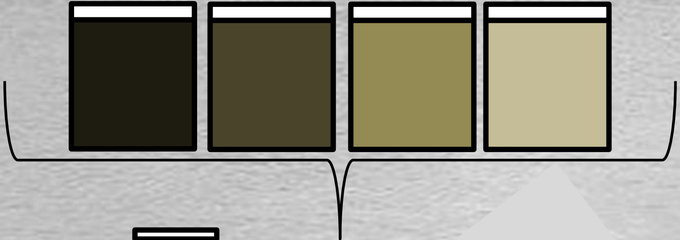
SSC and discharge was monitored at 11 sites around the Tsitsa River catchment



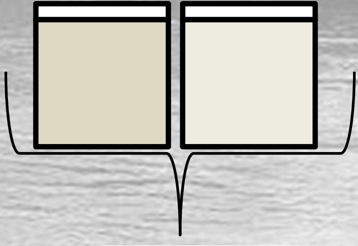
Citizen technicians used poles and plastic jars to collect suspended sediment samples, clarity tubes to record turbidity. **Researchers** installed loggers and did flow metering to determine discharge

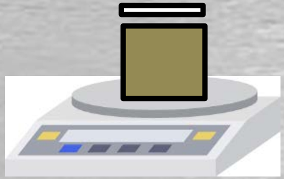


- Smartphones and Open Data Kit forms recorded time, date, weather, river condition, sample number, coordinates
- ODK Aggregate and ODK Briefcase collated, stored and managed data



Clean and dry outside of jars





Weigh whole sample to 2 decimal places

Test turbidity

Settle 1 month

Remove excess water with pump and J-tube

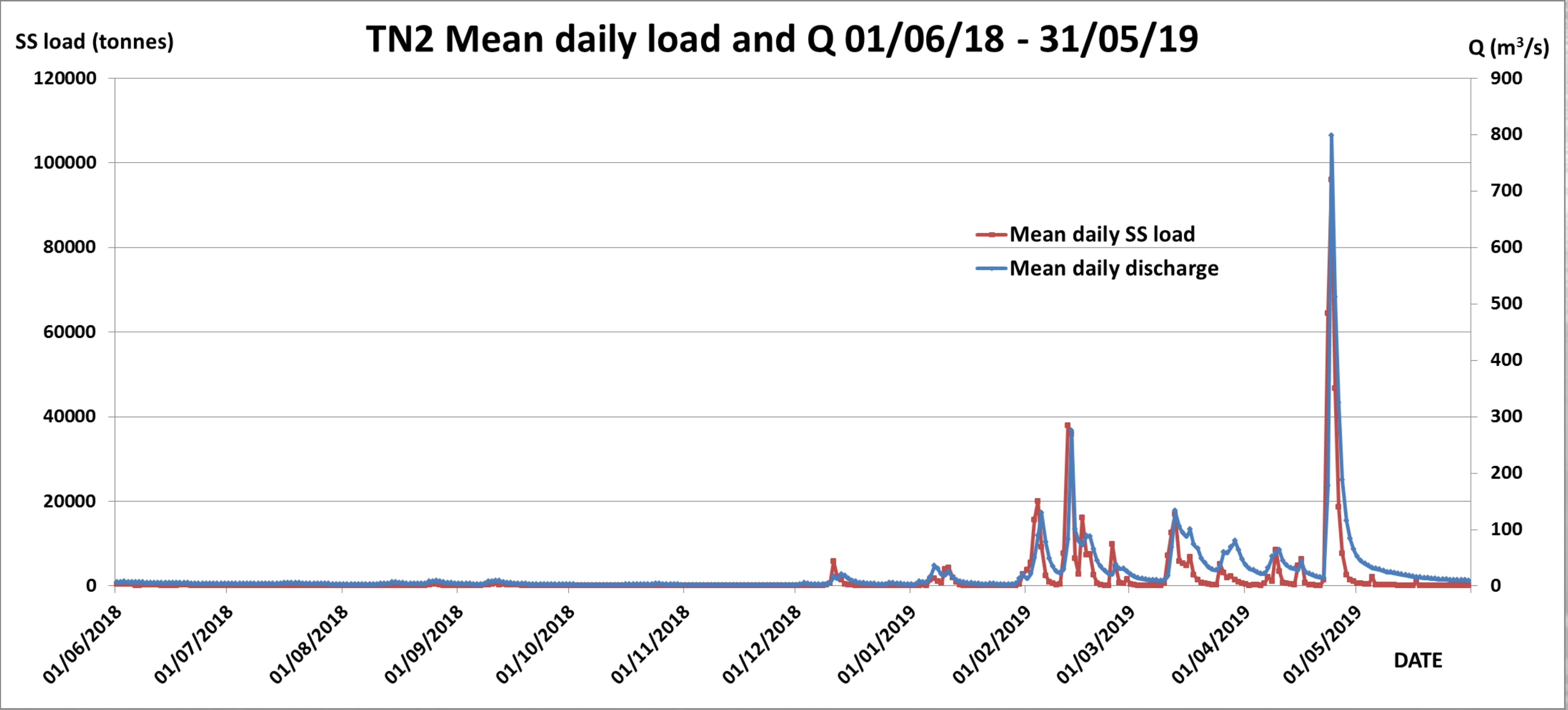
Laboratory analysis

Evaporate in oven

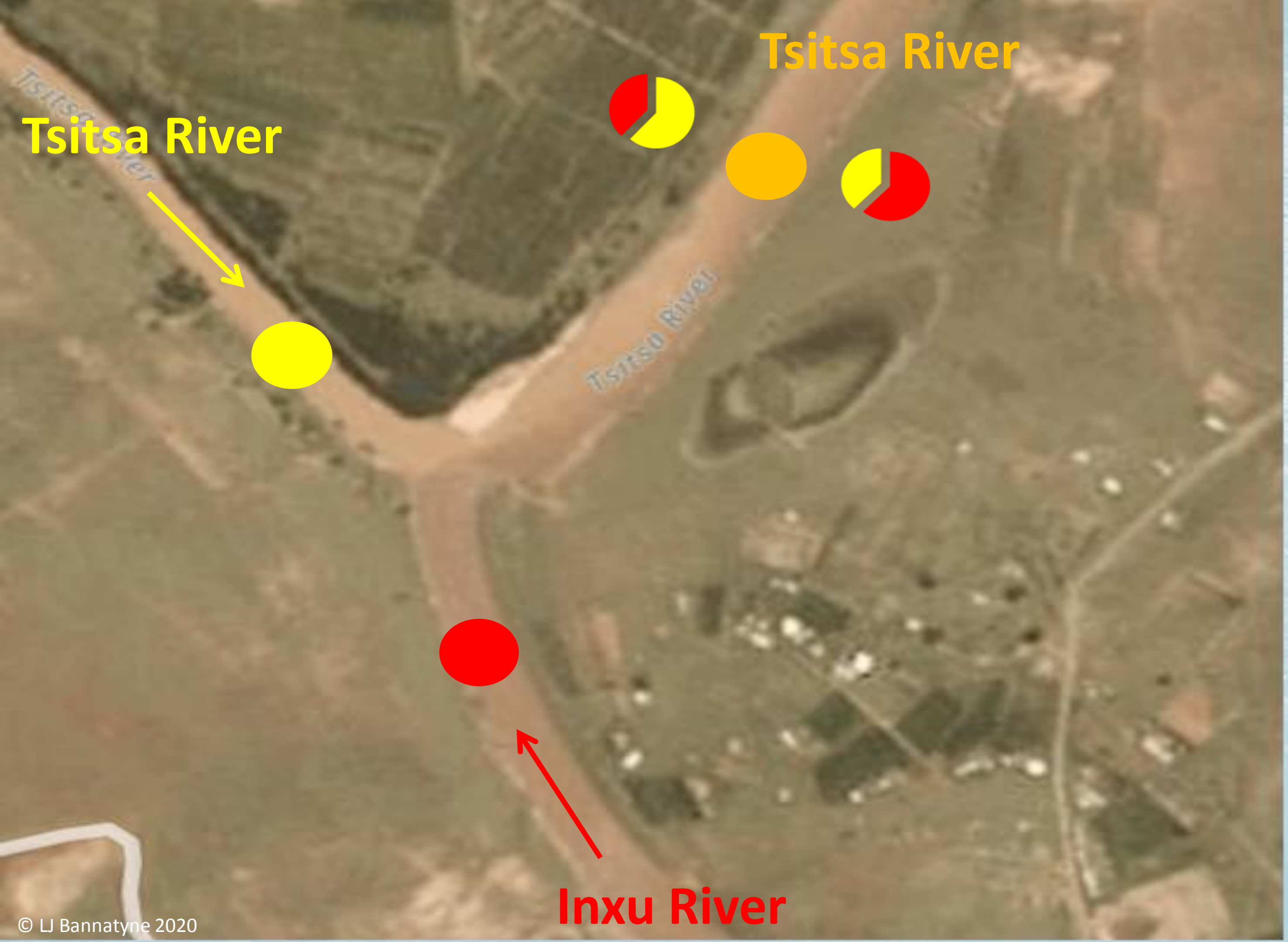
Weigh jar + sediment to 4 decimal places

Wash jar and weigh to 4 decimal places

Preliminary results



Confluence-based sediment fingerprinting and source apportionment



Distinguishable physicochemical properties of deposited fine sediment are used as tracers to apportion the contribution of the two sources at a confluence to sediment in the downstream channel

Background

Fine sediment trapped between gravels in channel beds represents upstream catchment characteristics

Three principles:

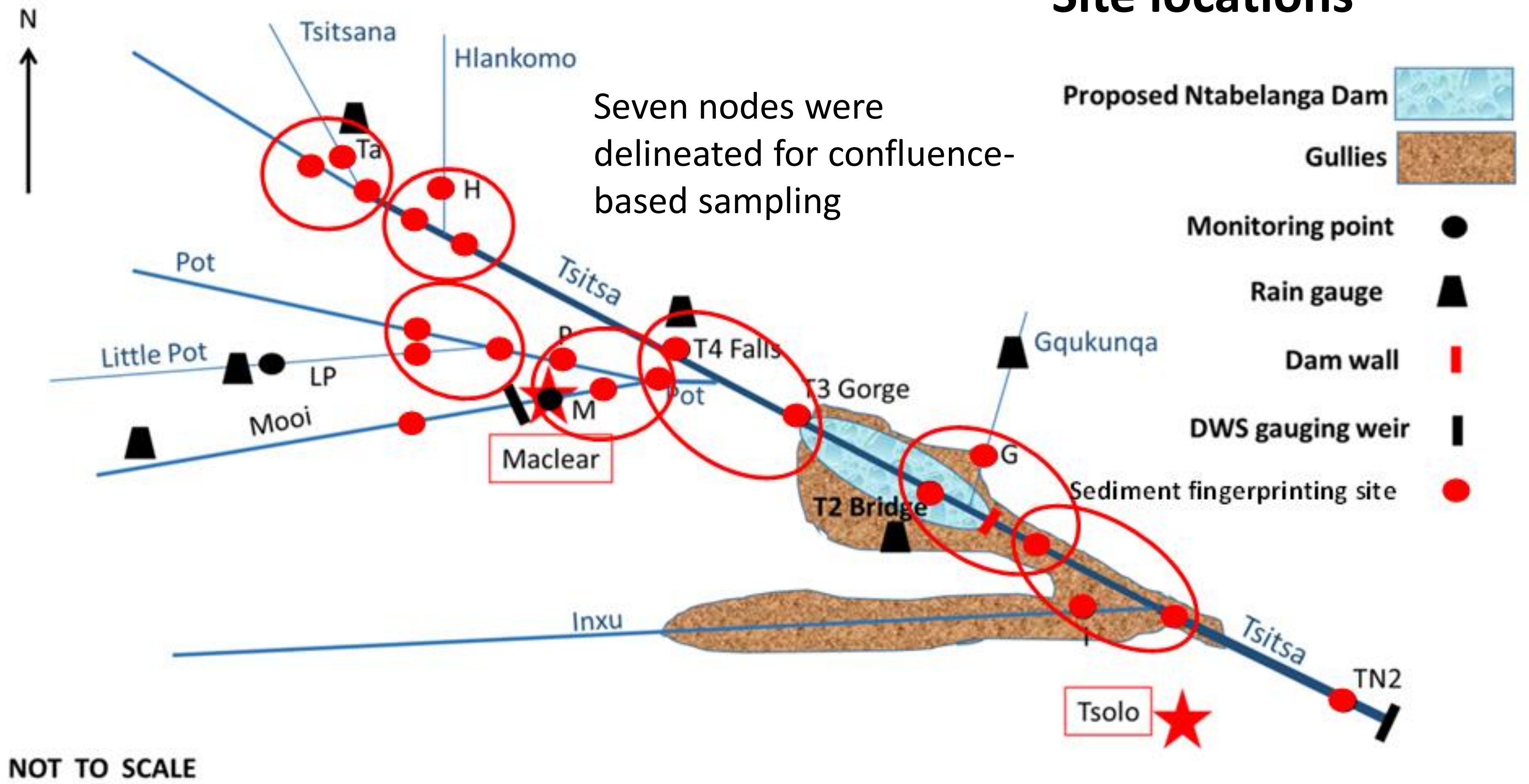
- **Heterogeneity of source catchments**
- **Distinguishable physicochemical sub-catchment SS signatures**
- **Spatiotemporal constancy of SS delivery and deposition on channel beds**

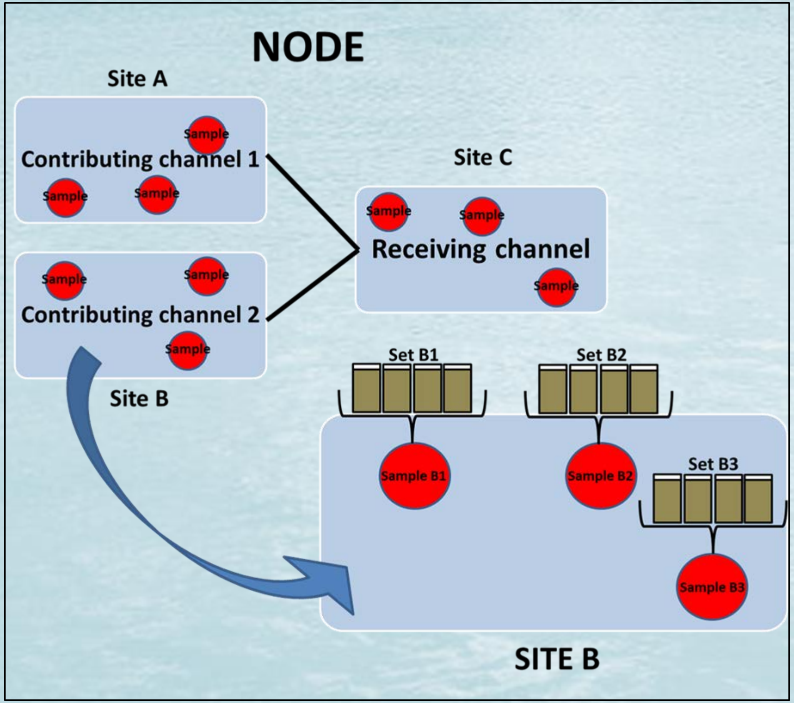
Four steps:

- **Sample deposited/sequestered fine sediment during dry season**
- **Analyse samples to quantify potential tracers**
- **Select suitable tracers**
- **Apportion tracer/sediment contribution from sources by statistically "unmixing" the tracer proportions measured in the sample taken downstream**

Site locations

Seven nodes were delineated for confluence-based sampling





Fine sediment sequestered in bed gravels was resuspended by stirring within an open-bottomed vessel.

The resuspended sediment sample was quickly collected in plastic jars

Image: © K Rowntree 2020

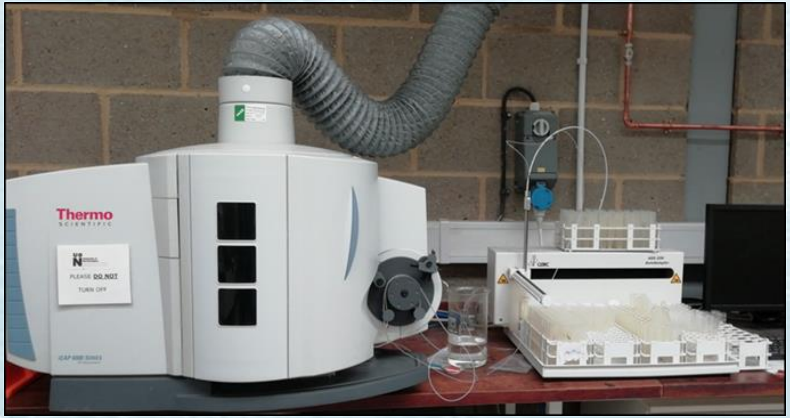
Nodes had two contributing sites (above the confluence) and one receiving site below.

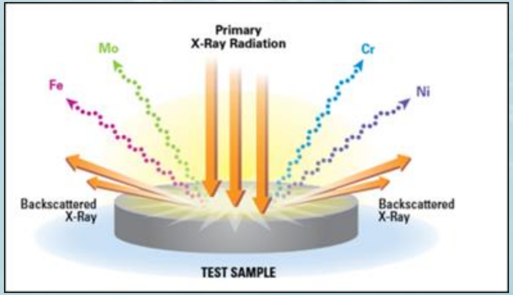
Three samples were taken at each site.

Sample analysis (Sediment fingerprinting)

- **Magnetic parameters**: Susceptibility (χ_{lf}, χ_{hf}), χ_{ARM}, IRM, SIRM, HIRM
- **Gamma spectrometry**
- **Geochemistry (ICP spectrometry)**
- **X-ray defraction**
- **LOI**
- **Colour**

(Alas, all orange…)

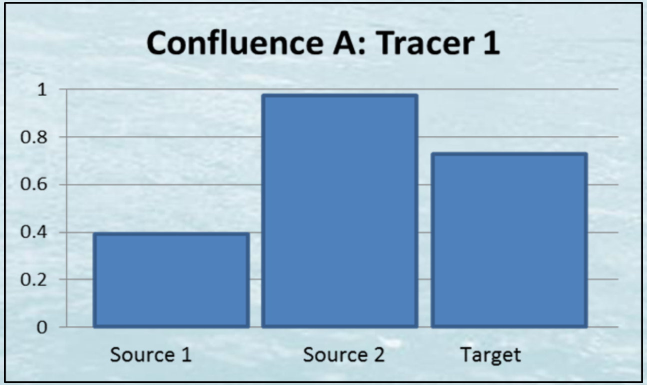




Tracer selection

Sample analysis provided ~60 parameters. Two routes were taken to tracer selection:

A. (Coarse approach) Select ALL tracers where the source sample values bracketed the value measured in the target sample



B. (Refined approach) Select only tracers with:

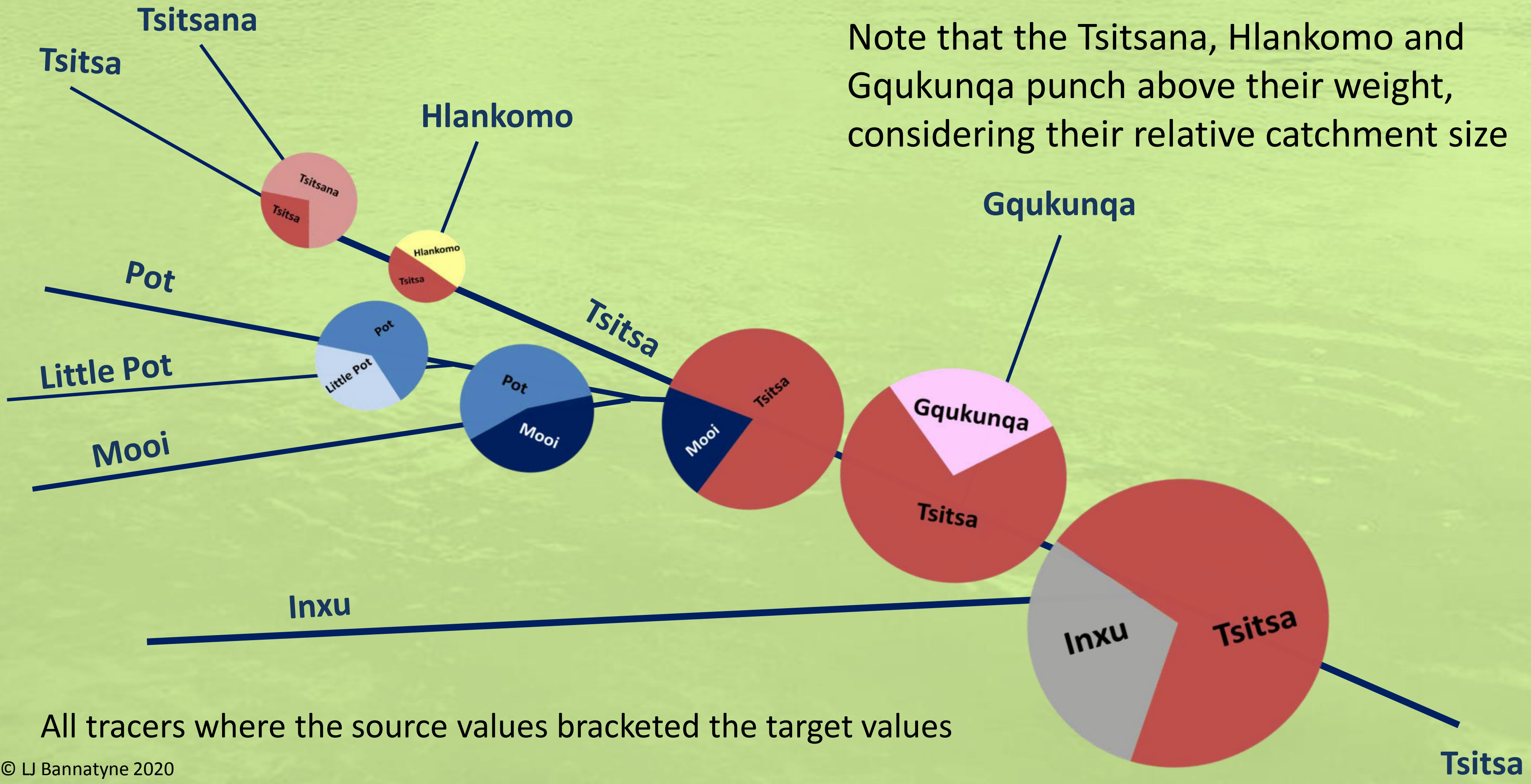
- < 10% analytical error
- >1.5 or <0.7 ratio between source values (Optimising fingerprints)
- No correlation between tracers (reduce co-linearity that may skew "unmixing")

Source apportionment

- Source apportionment was undertaken using an "unmixing" model, Mixmods.xls
- uses the "Solver" routine in the data analysis toolpack in Excel
- Minimises the sum of squared differences between the observed and modelled concentrations in the target mixture for the tracers input to the model.

Results for Approach A (coarse)

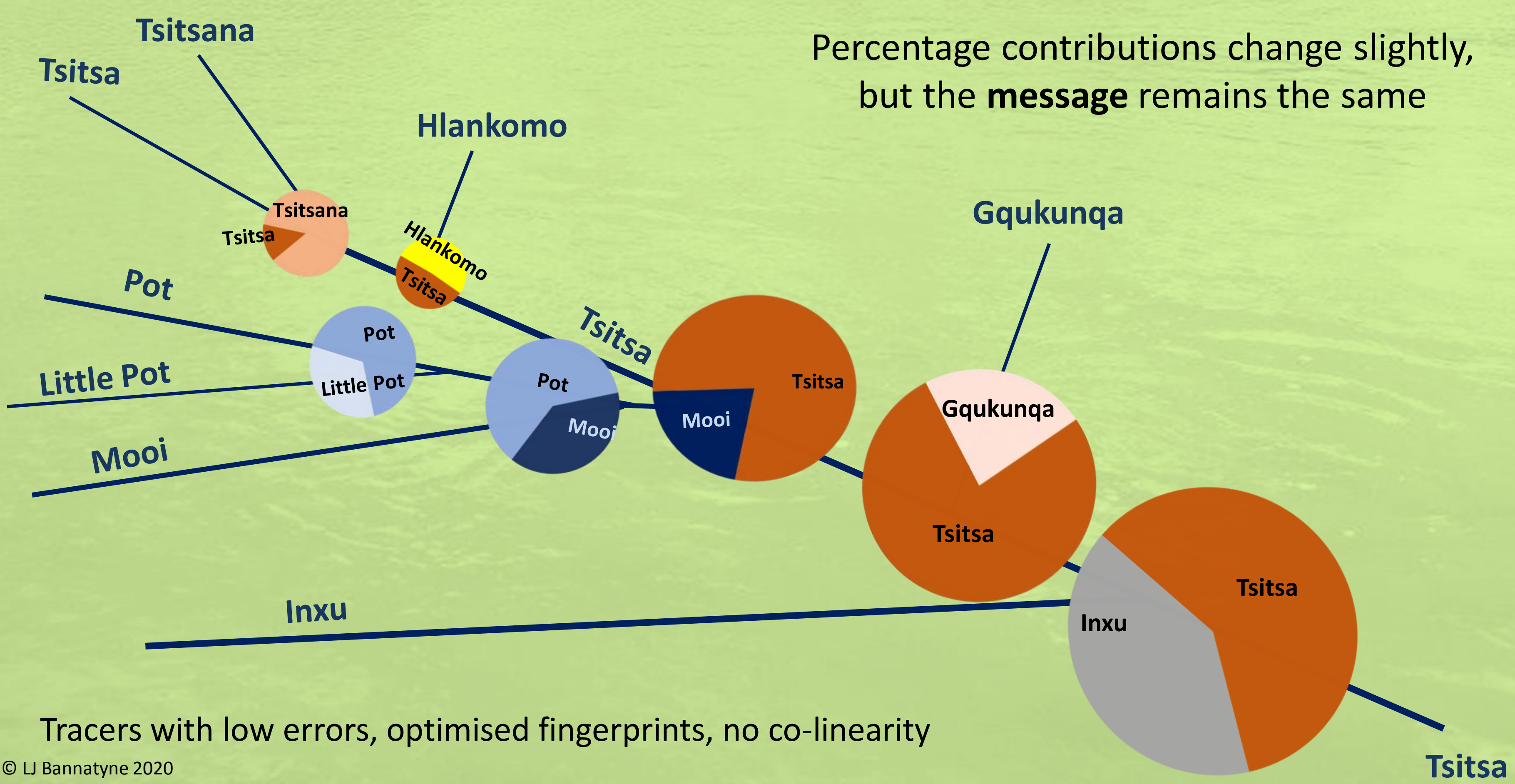
Note that the Tsitsana, Hlankomo and Gqukunqa punch above their weight, considering their relative catchment size



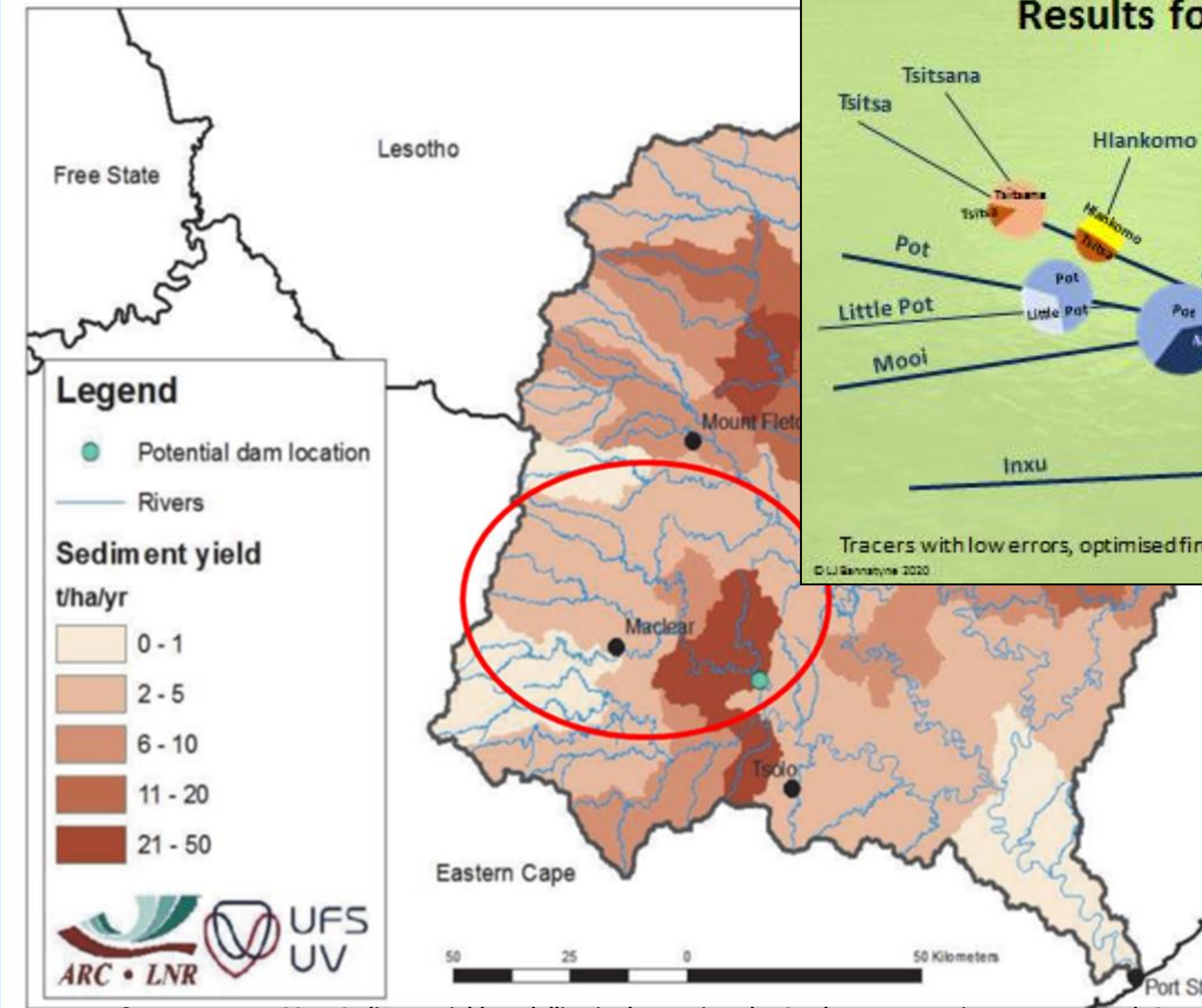
All tracers where the source values bracketed the target values

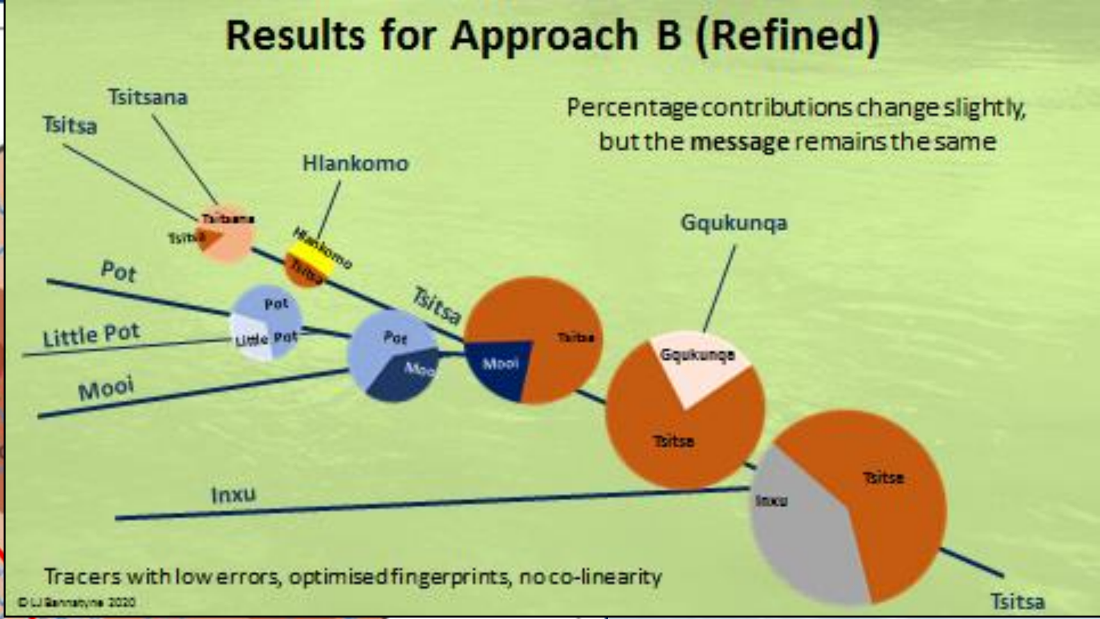
Results for Approach B (Refined)

Percentage contributions change slightly, but the **message** remains the same



Tracers with low errors, optimised fingerprints, no co-linearity





The pattern of these results are in broad agreement with those of Le Roux and Weepener (2015).

NB. Measured loads and yields are not yet available for direct comparison

Le Roux, J. & Weepener, H. 2015. Sediment Yield Modelling in the Umzimvubu Catchment. Pretoria: Water Research Commission.

Discussion

- Measured loads for 2015 – 2019 are being estimated
- Both measured loads, and source apportionment from fingerprinting, are subject to uncertainty: Neither is "correct"
- Monitoring SSC and discharge is relatively expensive, complicated, and resource intensive: less accessible to catchment managers?
- Source apportionment using the confluence-based method is relatively cheap and simple: more accessible to catchment managers?
- Source apportionment represents a single "snapshot" – but for what time period?
- Even the "coarse" source apportionment provides useful information

Going forward:

- Compare the results, cost, complexity, and uncertainty of measuring and fingerprinting, and the impact of these on decision-making
- Repeat sampling for fingerprinting during subsequent dry seasons?
- Time-integrated samplers?

More information on the Tsitsa Project https://sites.google.com/view/tsitsa-project/home?authuser=0

More information on Citizen Technician-based SS monitoring https://wrc.org.za/wp-content/uploads/mdocs/3388.pdf

Thank you

With thanks to Ruth Copeland-Philips, Simon Pulley, Kate Rowntree, and Art Horowitz

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