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Copernicus Publications

# Novel use of portable gamma sensors to rapidly assess soil status and recovery in degraded East African agro-pastoral land

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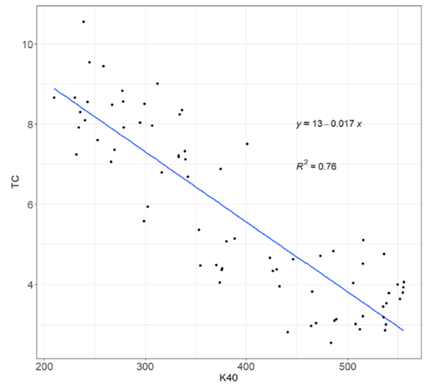
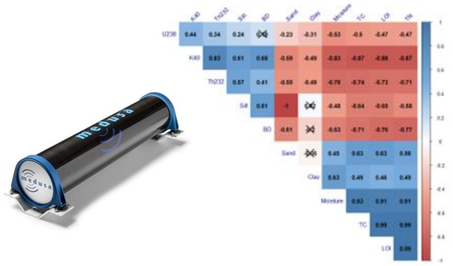
## Sensor tech for soil health

***Combining sensor technology with citizen science to support soil and food security, combat the climate crisis, promote biodiversity, and drive economic prosperity***

- Soil resources in East African agro-pastoral lands are being rapidly depleted by erosion, threatening food, water and livelihood security (Blake et al., 2018; Wynants et al., 2020).
- Here we explore the utility of innovation in portable gamma sensors to rapidly assess soil health.
- Spatial variability in naturally occurring radioactivity (NORM) is used as a proxy measurement of soil organic matter (SOM) .
- This provides (i) visual information that enables local communities (as citizen scientists, Kelly et al., 2022) to take local sustainable land management action to mitigate land degradation and (ii) quantitative evidence to inform policy makers for longer-term planning and regeneration of soil health

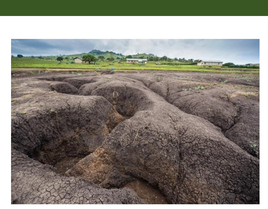
## Portable gamma spectrometry (Medusa Radiometrics MS700) as a proxy measure of soil organic carbon

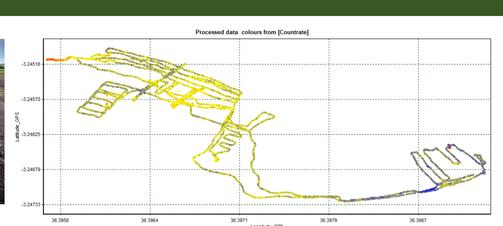


Taylor et al (2023) demonstrate relationship between NORM measured using Medusa Radiometrics MS700 and soil organic carbon in agricultural soil

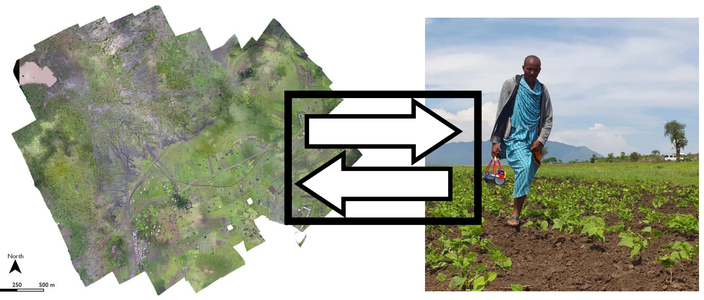
## Qualitative link between NORM and degree of land degradation



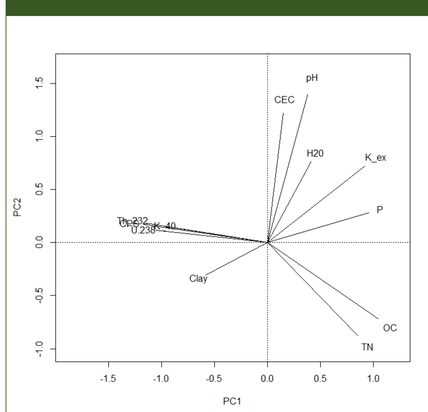


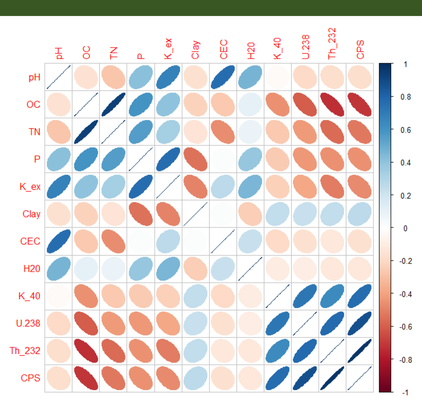

- Good correlation between NORM measurements and qualitative evaluation of land degradation status was observed
- Severely gullied soil/subsoil, heavily grazed surface soil, recovered grazed soil (ca 3 years exclusion of livestock) and conservation agriculture plots showed a clear gradient in raw total gamma count rate (bright colours = higher counts per second (cps), dark = lower cps).
- CPS at 1200 ± 100, 980 ± 70, 814 ± 60 and 720 ± 60 counts per second across the above four areas respectively.

- Portable gamma sensors offer a powerful visual in situ tool to inform local agricultural communities about relative status of soil health.
- This study suggest evidence can detect soil recover from rotational grazing and vice versa to support livestock management
- Quantification of the relationship between NORM and soil properties is, however, essential to demonstrate the process linkage for full confidence in data




## Quantifying relationship between NORM and soil properties




| | pH | OC | TN | P | K_ex | Clay | CEC | H20 | K_40 | U.238 | Th_232 | CPS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 1.00 | -0.16 | -0.28 | 0.41 | 0.68 | -0.17 | 0.76 | 0.46 | | -0.19 | -0.18 | -0.17 |
| OC | -0.16 | 1.00 | 0.94 | 0.59 | 0.41 | -0.22 | -0.26 | 0.11 | -0.45 | -0.60 | -0.74 | -0.72 |
| TN | -0.28 | 0.94 | 1.00 | 0.55 | 0.34 | 0.14 | -0.46 | | -0.27 | -0.42 | -0.56 | -0.52 |
| P | 0.41 | 0.59 | 0.55 | 1.00 | 0.76 | -0.54 | | 0.38 | -0.25 | -0.43 | -0.46 | -0.45 |
| K_ex | 0.68 | 0.41 | 0.34 | 0.76 | 1.00 | -0.50 | 0.27 | 0.45 | -0.24 | -0.38 | -0.51 | -0.48 |
| Clay | -0.17 | -0.22 | -0.14 | -0.54 | -0.50 | 1.00 | | -0.24 | 0.24 | 0.23 | 0.25 | 0.26 |
| CEC | 0.76 | -0.26 | -0.46 | | 0.27 | | 1.00 | 0.23 | -0.19 | -0.17 | -0.12 | -0.16 |
| H20 | 0.46 | -0.11 | -0.09 | 0.38 | 0.45 | -0.24 | 0.23 | 1.00 | -0.11 | -0.09 | -0.12 | -0.12 |
| K_40 | | -0.45 | -0.27 | -0.25 | -0.24 | 0.24 | -0.19 | -0.11 | 1.00 | 0.72 | 0.64 | 0.77 |
| U.238 | -0.19 | -0.60 | -0.42 | -0.43 | -0.38 | 0.23 | -0.17 | -0.09 | 0.72 | 1.00 | 0.78 | 0.88 |
| Th_232 | -0.18 | -0.74 | -0.56 | -0.46 | -0.51 | 0.25 | -0.12 | -0.12 | 0.64 | 0.78 | 1.00 | 0.97 |
| CPS | -0.17 | -0.72 | -0.52 | -0.45 | -0.48 | 0.26 | -0.16 | -0.12 | 0.77 | 0.88 | 0.97 | 1.00 |

- Principle components analysis (left) of NORM data and basic soil properties, determined by Near Infra Red Spectroscopy (NIRS; Amasi et al., 2021; Kelly et al., 2022), supports modification of NORM signal in this landscape by SOM wherein influence of other factors needs exploring.
- Negative correlation (centre and right) between specific radioisotopes and soil properties suggest that in this context the closest proxy to SOM/SOC is negative correlation with Th-232, which is also closely correlated to cps.
- Further analysis of soil samples to quantify gamma emitting radioisotopes (HPGe Gamma Spectrometry) and major and minor elemental analysis (WD-XRF) will permit deeper multivariate analysis of the relationship between in situ NORM measurements and soil composition.

## Conclusion and prospects

- Feedback from community members underpins the value of the sensor as a qualitative assessment tool e.g. using visual colour coding in the live data feed in the field.
- Quantitative comparison of sensor and laboratory data will permit protocols for ground-based and airborne (drone) gamma spectrometry for soil health evaluation at scale
- Portable gamma spectrometry is a promising tool to support evaluation, mitigation and reversal of soil erosion impact in rangeland socioecological systems.

## References and acknowledgements

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