Making Soil Science Accessible:

Low-Cost Soil Analysis Using Digital Image Colorimetry (DIC)

Dr Michael Muir (M.I. Soil Sci, MRSC),
University of Glasgow, School of Interdisciplinary Studies
Rutherford/McCowan Building, Crichton University Campus, Dumfries, DG1 4ZL
Michael.Muir@glasgow.ac.uk

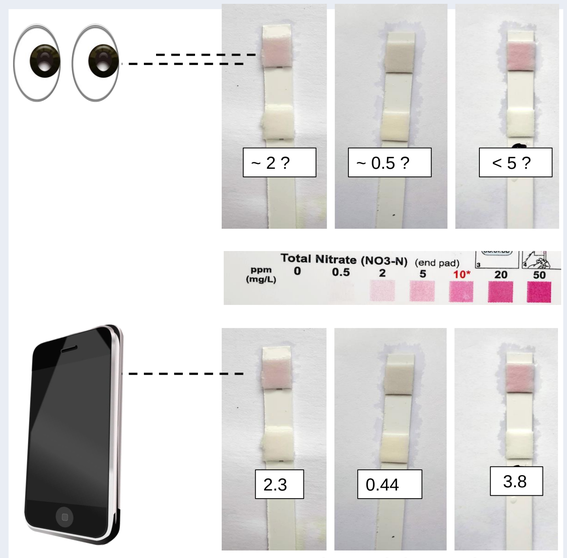
Introduction:

- Access to **fast**, **low-cost, robust** and **portable** soil analysis techniques is vital in many sectors such as:
  - agriculture[1], research in remote areas[2], responding to pollution events, and education[3].
- **Smartphones** with digital cameras can replace traditional detectors in colorimetric analysis techniques.
- This approach is called **digital image colorimetry (DIC)[4].**

DIC has the potential to:

- ✓ Improve reproducibility and precision of soil test kits compared to estimates by eye
- ✓ Reduce or eliminate the need for expensive specialist instrumentation
- ✓ Reduce the costs associated with collecting precise and accurate data
- ✓ Make easy-to-use soil analysis methods available to a broad range of users

Coloured images can easily be converted to RGB data using apps like ImageJ[5], JustColorPicker[6], or Color Analyzer[7]. This allows images to be converted to useable numeric data.



Improved precision using DIC

Nitrate in agricultural soils

Monitoring nutrient levels in agricultural soils allows farmers to:

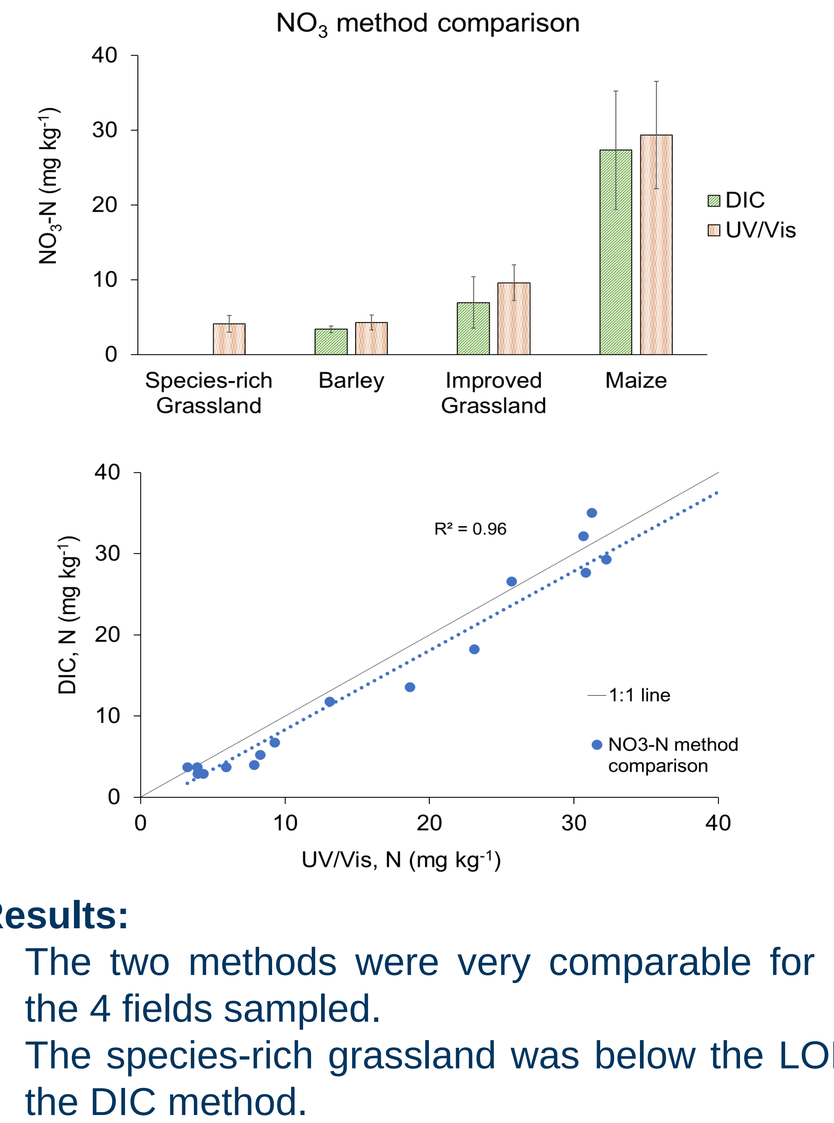
- Apply fertilizers at appropriate rates
- Minimise fertilizer wastage and pollution

Method:

Compare soil Nitrate analysed by two methods:

1) DIC using nitrate test strips
2) Direct UV/Vis instrumental method

- Soils from 4 field types were air dried and extracted with 0.01 M $CaCl_2$ (1:5 ratio.)
- Six replicates of each soil were measured.



Results:

- The two methods were very comparable for 3 of the 4 fields sampled.
- The species-rich grassland was below the LOD of the DIC method.
- The methods showed good correlation.

Method	Setup cost	Cost per sample	LOD (mg L^{-1})	RSD %
DIC	0	£0.30	1.0	~15 %
Test Kit	>£500	~£1.00	0.5	~10 %
Lab Methods	>£2000	£0.50 - £2	<0.2	<5 %

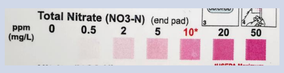
Steps in DIC analysis:

1. Collect samples and extract analyte

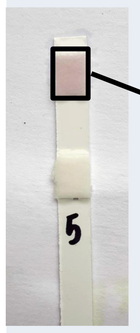
2. Conduct colorimetric Reaction

In this example, by using a test strip for Nitrate

3. Collect digital image of samples and calibration standards



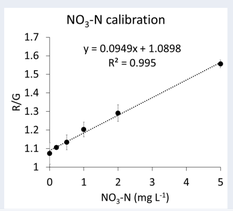
(standard solutions = improved accuracy over colour cards)



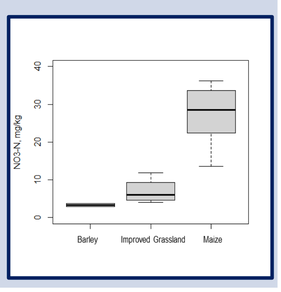
4. Convert images into RGB data

R	G	B	R/G
153	129	126	1.186

Make calibration graph:



5. Calculate concentration of unknown samples



Salinity of coastal soils

Salinization (increasing salt content) is a cause of soil degradation globally.

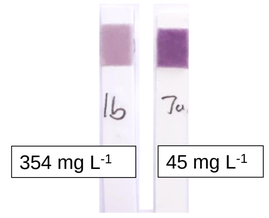
- Crops can't be grown on soils with high salinity
- Salt responsible for increasing salinity of soils may come from:
  - The sea (Sea level rise could increase soil salinization around coastal areas)
  - Using salt-rich groundwater for crop irrigation

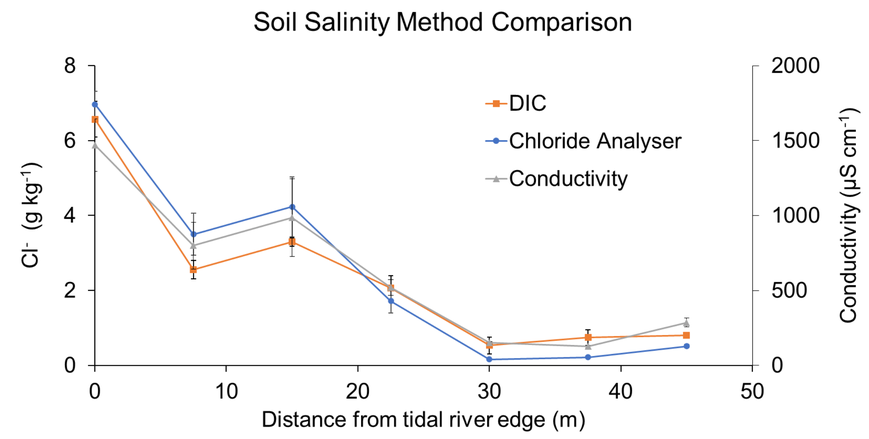
Method:

Investigate soil salinity using DIC with chloride test strips

1) Collect soils along a transect with increasing distance from a tidal river cliff
2) Measure 4 replicates each point
3) Compare results with a lab chloride analyser and portable conductivity meter

Examples of pictures used to collect DIC data:





Results:

- There was a significant decrease in soil salinity with increasing distance from the tidal river edge.
- DIC method showed excellent agreement with the lab and conductivity methods ($R^2 > 0.9$)

Method	Setup cost	Cost per sample	LOD (mg L^{-1})	RSD %
DIC	0	£0.30	~20	~15 %
Conductivity	~£100	£0		<5 %
Chloride meter	>£2000	~£0.50	1	<5 %

Summary:

- Digital Image Colorimetry enables low cost, portable analysis of soils, and can be used to improve the precision of test-strip methods to give fully quantitative results.
- Results compare favourably with conventional analysis methods, however the method is susceptible to variables such as changing lighting conditions and camera quality.
- Data captured as images can be easily transferred as an image file and can be easily converted to RGB data using a computer or smartphone app.
- The DIC method benefits from low set up costs and low cost per sample, making this an affordable and accessible analysis option

References: [1]Golicz K, Hallett S, Sakrabani R, Ghosh J. "Adapting smartphone app used in water testing, for soil nutrient analysis." *Comput Electron Agric.* 2020;175(May):105532. doi:10.1016/j.compag.2020.105532; [2]Mallory A, Golicz K, Sakrabani R. "An analysis of in-field soil testing and mapping for improving fertilizer decision-making in vegetable production in Kenya and Ghana." *Soil Use Manag.* 2020;38(1):164-178. doi:10.1111/sum.12687; [3]Destino JF, Cunningham K. "At-Home Colorimetric and Absorbance-Based Analyses: An Opportunity for Inquiry-Based, Laboratory-Style Learning." *J Chem Educ.* 2020;97(9):2960-2966. doi:10.1021/acs.jchemed.0c00604; [4]Fan, Y., Li, J., Guo, Y., Xie, L., Zhang, G., 2021. "Digital image colorimetry on smartphone for chemical analysis: A review." *Meas. J. Int. Meas. Confed.* 171, 108829. https://doi.org/10.1016/j.measurement.2020.108829; [5]Schneider CA, Rasband WS, Eliceiri KW. "NIH Image to ImageJ: 25 years of image analysis." *Nat Methods.* 2012;9(7):671-675. doi:10.1038/nmeth.2089; [6]https://annystudio.com/software/colorpicker/; [7]https://play.google.com/store/apps/details?id=jp.kamusoft.coloranalyzer&hl=en_GB&gl=US