Application of a Novel **Digital Image Colorimetry** Method for Assessment of **Soil Salinity**

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Soil Salinization affects **>1 billion hectares** of land globally

- **Soil salinization** is a major global cause of **soil degradation**[1]
  - Use of salt-rich groundwater for irrigation can increase soil salinity[2,3]
  - Climate change is predicted to increase the area of salt-affected soils due to increased sea-water intrusion and decreased precipitation[4-6]
  - Arid and semi-arid regions of the world are particularly at risk from soil salinization[6]
- **Elevated soil salinity** can **decrease crop yields**
  - Targeted land management practices can mitigate the impacts of soil salinization
  - Data-driven "precision agriculture" practices[7] are often not accessible to farmers due to high cost and requirement for specialist equipment[8]

Smartphone-based methods can **broaden access** to **precision agriculture** techniques[8,9]

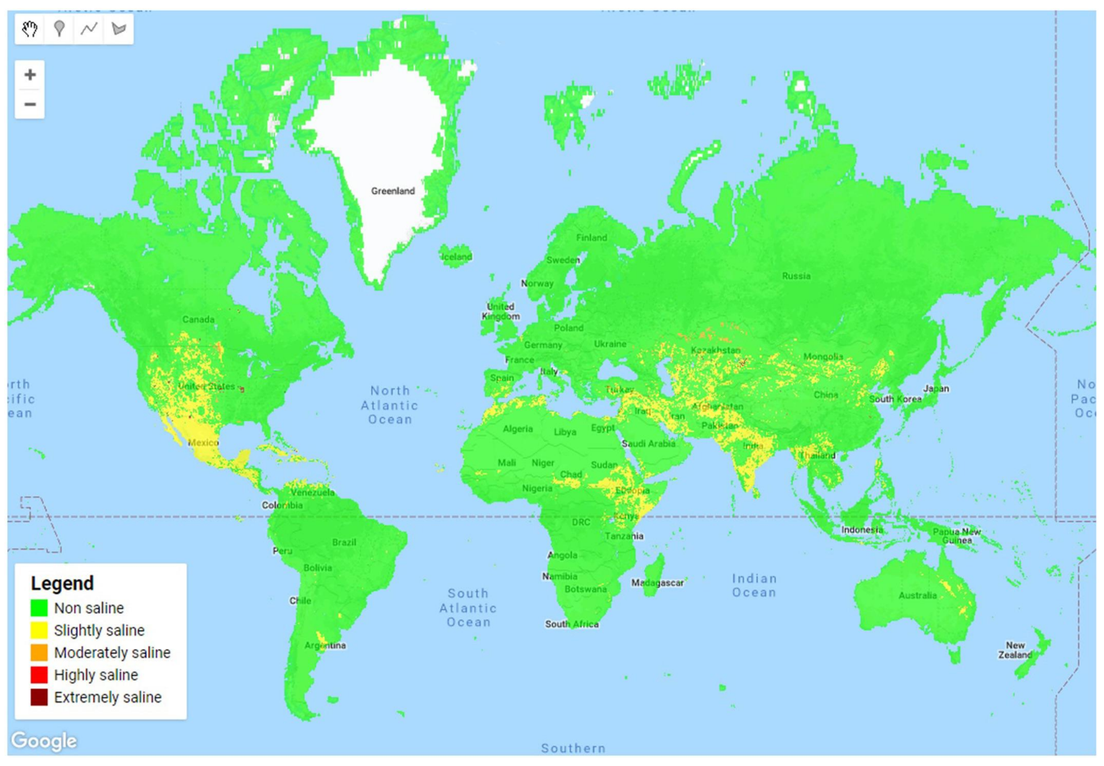
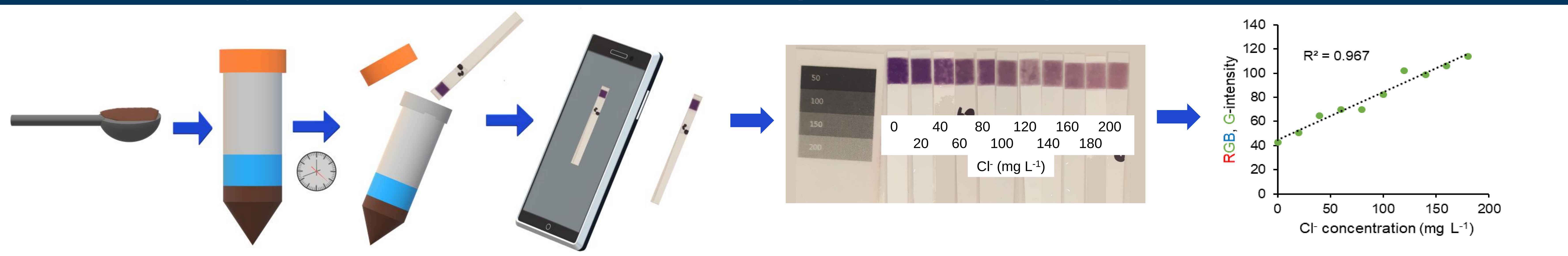


Figure 1. Global extent of salt-affected soils (Ivushkin et al., 2019)[4]

Smartphone **digital cameras** can be used to **replace** expensive analytical instruments or low-precision **by-eye** estimates



1. A 4 ml scoop of field-wet soil is added to 20 ml of deionised water, shaken for two minutes and left to settle for three minutes (5 minutes total extraction time)
2. A chloride test strip (ITS Europe) is used to analyse the supernatant liquid
3. A digital image of is taken of the test strip, and the RGB intensity is measured. The grayscale card accounts for varying picture quality.
4. The G-intensity is linearly related to chloride conc. from 0 – 200 mg L^{-1}.

Digital Image Colorimetry using images from a **smartphone camera** is a **cost-effective** alternative to traditional methods for **rapid** assessment of **soil salinity**

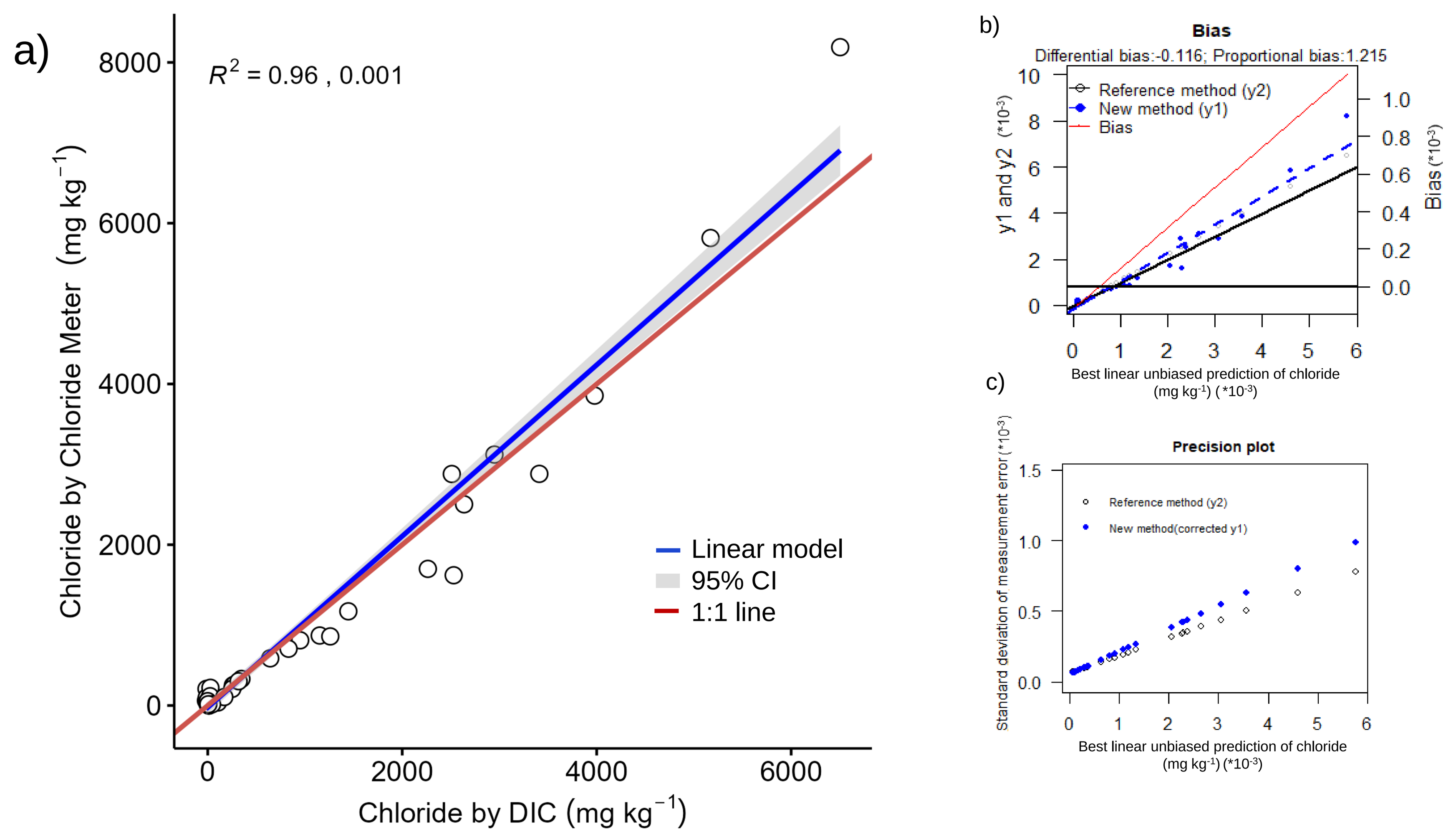


Figure 2. a) The Digital Image Colorimetry (DIC) method showed strong agreement with the standard chloride analyser method (n = 64, R^2= 0.96, p <0.001). b) The DIC method showed only a moderate positive bias and c) only moderately poorer precision than the reference method, particularly at higher Cl^- concentrations.

Soil samples (n = 69) from the RSPB Mersehead nature reserve, SW Scotland, were collected and analysed by using A) a chloride analyser and B) the novel DIC method.

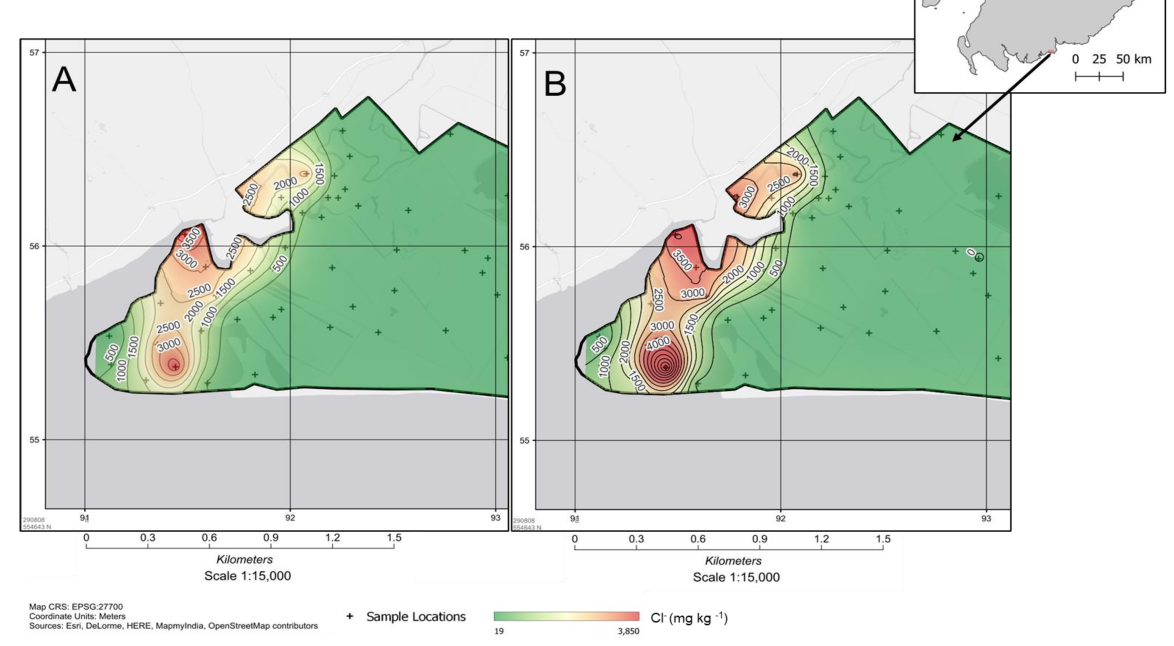


Figure 3. Spatially interpolated maps of the chloride concentration in an area of saltmarsh show considerable variation over distances of a few metres. The results of DIC analysis (B) identified the same regions of high chloride concentration as the reference method (A).

Table 1. Comparison of cost, sensitivity and precision of methods for analysis of soil salinity

Method	Setup cost	Cost per sample	LOD (mg L^{-1})	RSD %
DIC	0	£0.30	~20	~15 %
Conductivity	>£100	£0	< 1	<5 %
Chloride meter	>£2000	~£0.75	< 5	<5 %

The results from the novel DIC method compare favourably with standard methods.

The method is **low-cost**, **fast** and **simple** to use.

This example highlights the potential for use of **smartphones** in **analytical applications** for **precision agriculture**.

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References: [1]Hopmans, J. W. et al. Critical knowledge gaps and research priorities in global soil salinity. Advances in Agronomy 169, 1–191 (2021). [2]Corwin, D. L. Climate change impacts on soil salinity in agricultural areas. Eur J Soil Sci 72, 842–862 (2021). [3]Abbas, A., Khan, S., Hussain, N., Hanjra, M. A. & Akbar, S. Characterizing soil salinity in irrigated agriculture using a remote sensing approach. Physics and Chemistry of the Earth, 55–57, 43–52 (2013). [4]Ivushkin, K. et al. Global mapping of soil salinity change. Remote Sens Environ 231, (2019). [5]Schofield, R. V. & Kirkby, M. J. Application of salinization indicators and initial development of potential global soil salinization scenario under climatic change. Global Biogeochem Cycles 17, (2003). [6]Eswar, D., Karuppusamy, R. & Chellamuthu, S. Drivers of soil salinity and their correlation with climate change. Curr Opin Environ Sustain 50, 310–318 (2021). [7]Gebbers, R. & Adamchuk, V. I. Precision agriculture and food security. Science (1979) 327, 828–831 (2010). [8]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 38, 164–178 (2020). [9]Fan, Y., Li, J., Guo, Y., Xie, L. & Zhang, G. Digital image colorimetry on smartphone for chemical analysis: A review. Measurement, 171, 108829 (2021).