Comparison of Different Color Space Model's Performance for Estimation of Nitrate and Phosphate in Soil and Water Using a Developed Smartphone-Integrated Imaging Device

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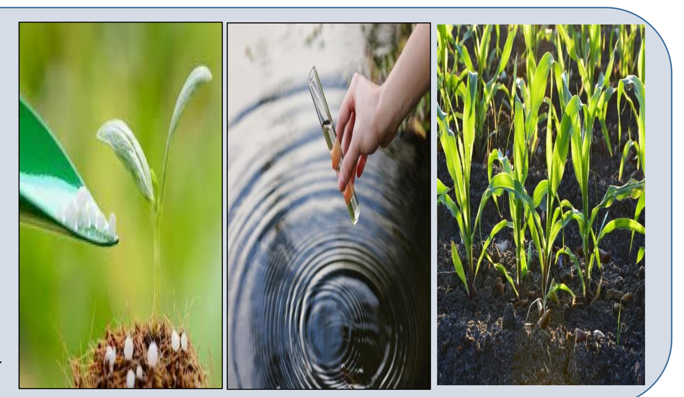
Introduction

Nitrate and Phosphate



- Critical determinants of plant growth and productivity
- Essential nutrients for aquatic plants
- Key parameters of water quality

Impact of NO_3^- and PO_4^{3-} level increase (soil and water):

- Increases the osmotic concentration of the soil solution
- Health hazards to the human body
- Eutrophication

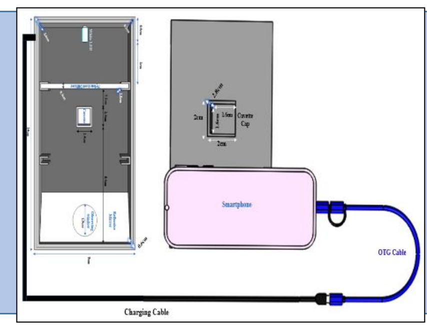
Estimation of Nitrate and Phosphate (Existing methods):

- Spectroscopic methods
- Colorimetric methods
- Electrochemical methods

- Bulky
- Costly
- Sophisticated
- Non-portable
- Time -consuming
- Labor intensive

Alternative approach

Smartphone-Integrated Imaging Device

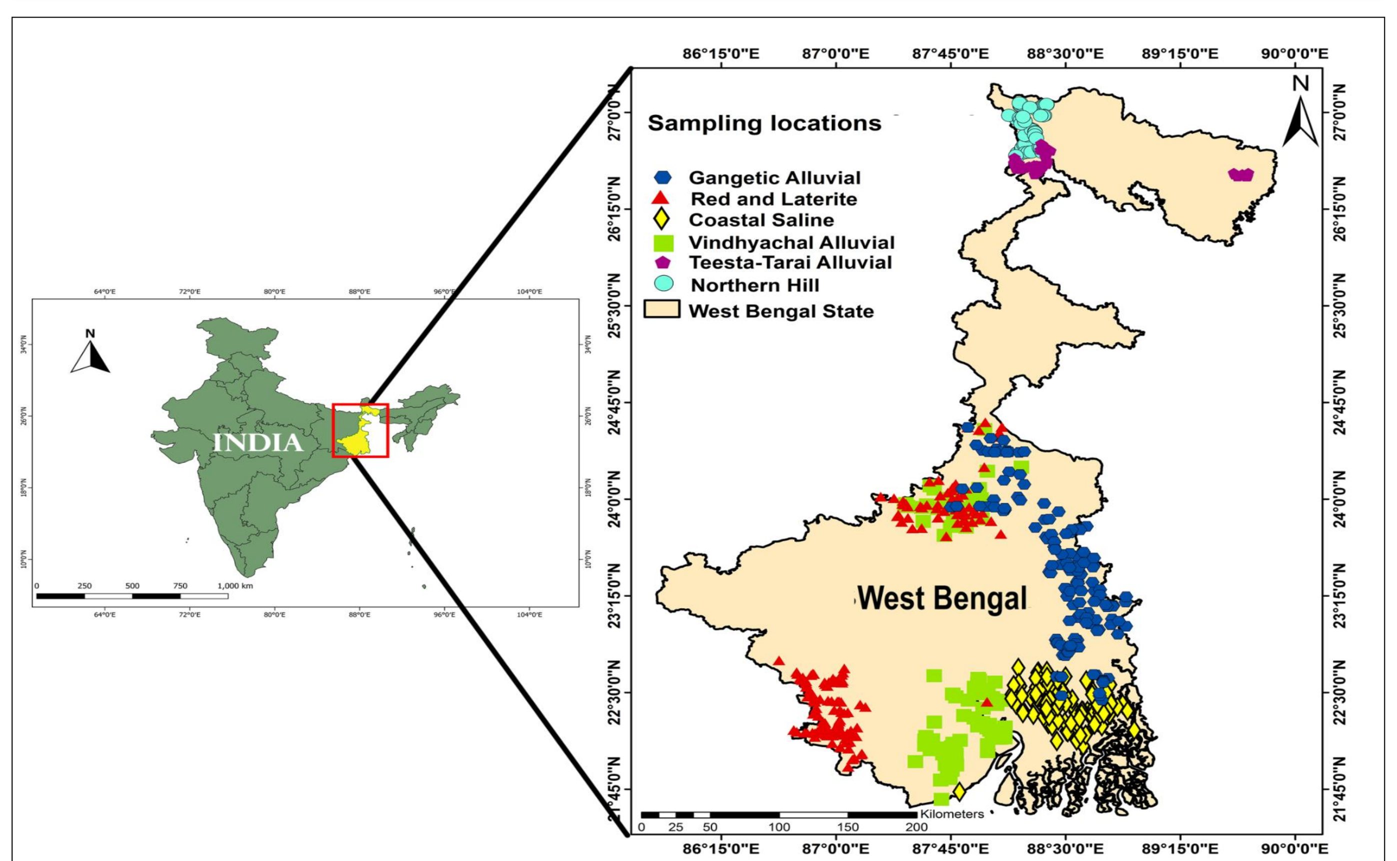


- Compact
- Portable
- Rapid
- Cost-effective

Objectives

- To determine the device's performance for predicting NO_3^- and PO_4^{3-} in soil and water samples using an integrated smartphone device and other color models, including RGB, CIELAB, and CMYK

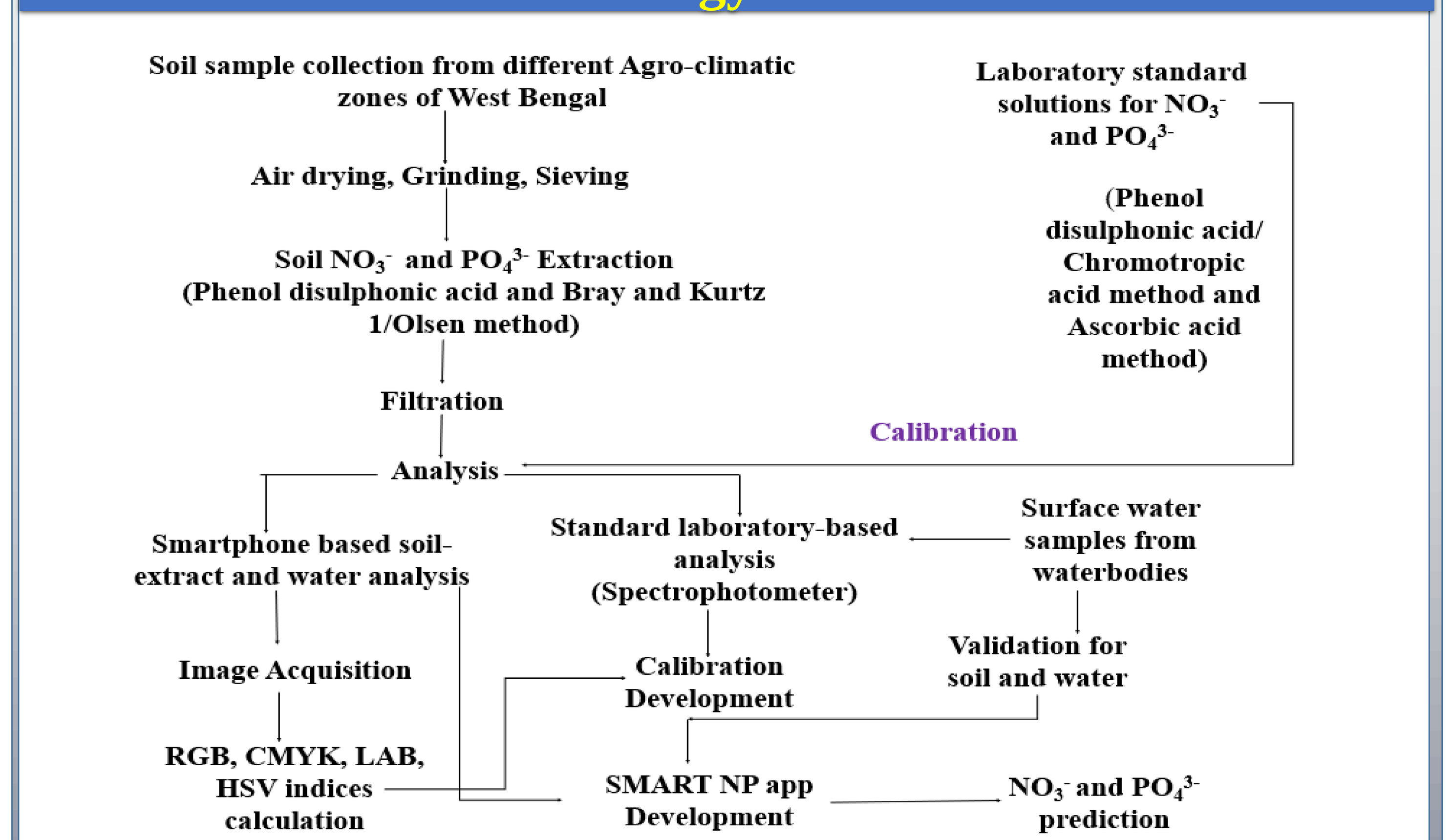
Study Area



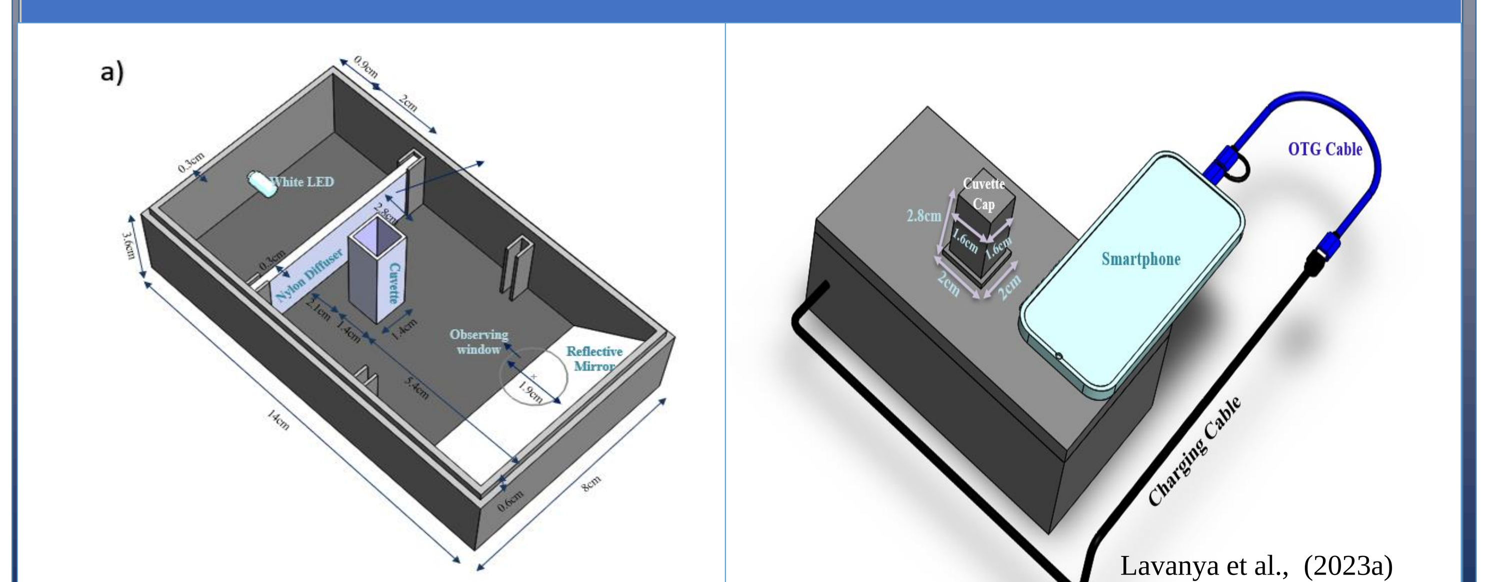
Soil and Water Sample Collection

Districts (Total 6)	Blocks	Soil Samples (Total no. 550)	Water Samples (Total no. 15)
Darjeeling (Hilly Zone)	Matigara , Phansidewa, Kharibari , Naxalbari, Karseaung	75	Surface water samples from Kharagpur, West Bengal
Birbhum (Red and Lateritic Zone)	Rampurhat-I, Mohammadbazar, Sainthia, Labpur, Nanur, Nalhati-I, Rajnagar, Khoirasole, Illambazar	115	
Jhargram (Red and Lateritic Zone)	Gopiballavpur-1, Gopiballavpur- 2, Nayagram, Jhargram, Sankrail, Jambani	100	
Midnapur (East) (Old Alluvial Zone)	Tamluk, Pashkura, Kolaghat, Chandipur, Contai, Deshopran, Egra-I, Nandakumar, Khejuri	90	
Nadia (New Alluvial Zone)	Haringhata, Chakdah, Ranaghat, Shantipur, Hanskhali, Krishnanagar, Krishnaganj	130	
South 24 Parganas (Coastal Saline Zone)	Gosaba, Canning-I, Kultali, Basanti	40	

Methodology Flowchart

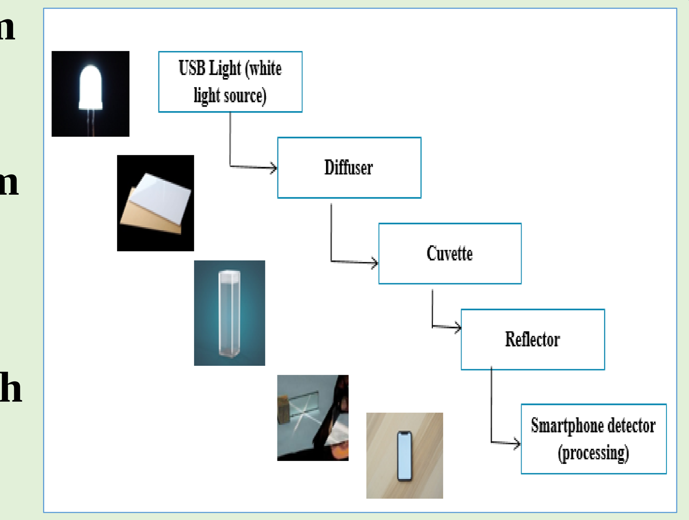


Developed Smartphone-Integrated Imaging Device Setup



Lavanya et al., (2023a)

- Black box = 14cm x 8cm x 4.2cm
- Nylon sheet diffuser = 6.8 cm x 2.8cm x 0.3cm
- Cuvette = 4.4cm x 1.2cm x 1.2cm
- Reflector = 2-mm thickness
- Cuvette cap = 2.8 cm x 1.6cm x 1.6cm
- HONOR-20i (CMOS sensor with f/1.8 aperture and 1920 × 1080 pixel resolution)



Laboratory Extraction and Device Calibration

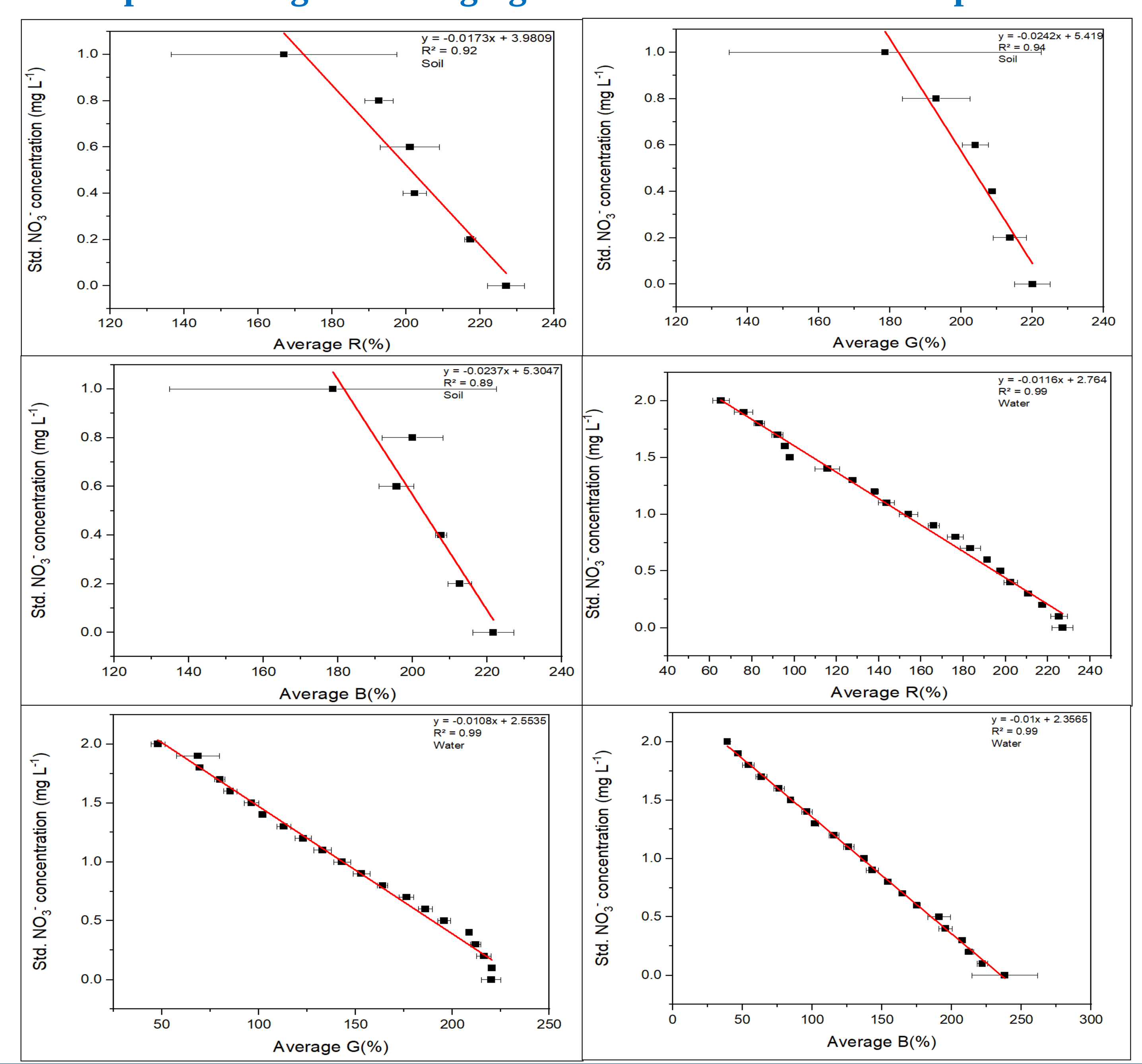
Calibration of NO_3^- and PO_4^{3-} :

- **Soil samples:** 6 standard solutions (0.0–1.0 mg L^{-1})
- **Water samples:** 20 NO_3^- standard solutions (0.0–2.0 mg L^{-1}) &13 PO_4^{3-} standard solutions (0.0–30.0 mg L^{-1})

- **HSV** color space model's **average V-value** was obtained to calibrate NO_3^- and PO_4^{3-} levels in water and soil samples (Lavanya et al., 2023a ; Lavanya et al., 2023b).
- The average of the **R, G, B, C, M, Y, K, L, A, and B** components of the **RGB, CMYK, and CIELAB** color space models were also obtained to calibrate NO_3^- and PO_4^{3-} in soil and water samples.

Results and Discussion

Calibration curves of Nitrate in soil and water media based on smartphone-integrated imaging device-extracted RGB components



Evaluation of other color space models for predicting NO_3^- and PO_4^{3-} in soil and water

Color models		Media	R^2		Equation	
			NO_3^-	PO_4^{3-}	NO_3^-	PO_4^{3-}
CMYK	C	Soil	-	0.97	-	$PO_4^{3-} = 0.0894x - 0.0561$
	M		0.70	0.95	$NO_3^- = 0.6369x - 1.6585$	$PO_4^{3-} = 0.2009x - 0.2813$
	Y		0.88	-	$NO_3^- = 0.4112x - 0.7563$	-
	K		0.96	0.81	$NO_3^- = 0.0964x - 0.9571$	$PO_4^{3-} = 0.0858x - 0.8632$
CIELAB	L		0.98	0.87	$NO_3^- = -0.0759x + 6.7784$	$PO_4^{3-} = -0.0534x + 5.0189$
	A		0.99	0.93	$NO_3^- = -1.5366x + 4.2537$	$PO_4^{3-} = 0.2907x - 0.0115$
	B		0.95	0.96	$NO_3^- = 1.3761x + 0.0956$	$PO_4^{3-} = -1.1916x + 1.8843$
RGB	R		0.92	0.97	$NO_3^- = -0.0173x + 3.9809$	$PO_4^{3-} = -0.0427x + 10.084$
	G		0.94	0.92	$NO_3^- = -0.0242x + 5.419$	$PO_4^{3-} = -0.0423x + 9.5789$
	B		0.89	0.98	$NO_3^- = -0.0237x + 5.3047$	$PO_4^{3-} = -0.0668x + 15.198$
HSV	V		0.98	0.96	$NO_3^- = -0.1702x + 16.939$	$PO_4^{3-} = -0.0259x + 2.4853$
CMYK	C	Water	-	0.95	-	$PO_4^{3-} = 0.603x - 4.2021$
	M		0.47	0.96	$NO_3^- = 0.6574x - 1.4835$	$PO_4^{3-} = 0.8341x - 6.986$
	Y		0.91	-	$NO_3^- = 0.4885x - 1.1713$	-
	K		0.88	0.99	$NO_3^- = 0.1893x - 1.7946$	$PO_4^{3-} = 1.1234x - 29.188$
CIELAB	L		0.97	0.99	$NO_3^- = -0.0816x + 7.2703$	$PO_4^{3-} = -0.5558x + 38.817$
	A		0.98	0.95	$NO_3^- = -1.1089x + 3.2134$	$PO_4^{3-} = 1.6487x - 6.337$
	B		0.97	0.72	$NO_3^- = 1.0445x + 0.2174$	$PO_4^{3-} = -1.4511x + 9.8734$
RGB	R		0.99	0.93	$NO_3^- = -0.0116x + 2.764$	$PO_4^{3-} = -0.3006x + 66.588$
	G		0.99	0.92	$NO_3^- = -0.0108x + 2.5535$	$PO_4^{3-} = -0.2846x + 61.016$
	B		0.99	0.97	$NO_3^- = -0.01x + 2.3565$	$PO_4^{3-} = -0.7184x + 152.25$
HSV	V		0.97	0.98	$NO_3^- = -0.1175x + 11.874$	$PO_4^{3-} = -0.4878x + 45.742$

Conclusions

- **The comprehensive analysis of RGB, CMYK, and CIELAB color space models, compared to the V component of the HSV color space model, yielded robust results, establishing the device's reliability in predicting NO_3^- and PO_4^{3-} concentrations in soil and water.**
- **The potential impact extends beyond research, as this cost-effective sensing method assists scientists and farmers in efficiently gauging NO_3^- and PO_4^{3-} concentrations in soil and water, fostering a more accessible and sustainable approach to environmental monitoring.**

Publications related to this study

- Lavanya, V., Nayak, A., Dasgupta, S., Urkude, S., Dey, S., Biswas, A., Li B., Weindorf D. C., & Chakraborty, S. (2023a). A smartphone-integrated imaging device for measuring nitrate and phosphate in soil and water samples. Microchemical Journal, 193, 109042.
- Lavanya, V., Nayak, A., Deb Roy, P., Dasgupta, S., Dey, S., Li, B., Weindorf, D.C., & Chakraborty, S. (2023b). A Smartphone-Enabled Imaging Device for Chromotropic Acid-Based Measurement of Nitrate in Soil Samples. Sensors, 23(17), 7345.

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