EVALUATING SOIL PARAMETERS USING PROXIMAL SOIL SENSORS (EM38, MSP3)

#11090

[1,2*]H. Hajjaj, [1]K. Ibno Namr, [2]C. El khalif, [2]A. El-Aissaoui
[1]Laboratory of Geosciences and Environmental Techniques, Department of Geology, Faculty of Sciences, Chouaïb Doukkali University, BP.20, El Jadida 24000, Morocco
[2]Laboratory of Agricultural Engineering and Precision Agriculture, National Institute of Agronomic Research, CRRAS, PO 586, Settat,26000, Morocco
e-mail: hajjaj.hasna@ucd.ac.ma

INTRODUCTION

Site-specific farming requires an accurate information on soil spatial variability. In fact, by using digital mapping of physical, biological and chemical soil parameters, some indicators and pedotransfert functions can be developed for evaluating not only soil quality but also for monitoring performances of agricultural system, natural resource management, climate modelling and environmental science (Liu et al.2006; Robinson & Metternicht, 2006; Bhunia et al. 2018). Thus, adequate information on the status behaviour of soil parameters is required for spatiotemporal monitoring and assessment. However, direct measurements are precise but expensive, time-consuming and labour-intensive (Bhunia et al.2018). Otherwise, better planning and management of soil data cannot be systematically effective using interpolation at unsampled sites.

According to the technological progress, today's spatial data analysis methods and tools allow the monitoring of spatiotemporal changes in almost all soil attributes at various levels (Mabit and Bernard 2010; Dai et al. 2014; Bhunia et al. 2018). In fact, proximal soil sensing refers to the use of sensors in the field to obtain signals from the soil when the sensor detector is either in contact or close to soil matrix (Viscarra Rossel et al., 2011).

This paper aims to review the proximal soil sensing technologies mainly the **MSP3 and EM38 ECa meter** and to evaluate both technologies for their ability to predict soil parameters under arid conditions

On the go soil sensor (MSP3)

On-the-go soil sensors such as MSP3 (Fig 1), equipped with GPS, is designed to effectively delineate soil differences across fields, capturing data that other technologies might miss (Adamchuk et al., 2004). It utilizes dual wavelength optical sensors to measure organic matter and pH, along with coulter electrodes for direct electrical conductivity readings at depths of 0-12 inches and 0-36 inches. As the implement is pulled behind a tractor at speeds up to 6 mph, data is logged on GPS maps, which can inform fertility management decisions such as split fertilizer applications and variable rate seeding. The system records digital reflectance data and GNSS coordinates at a rate of 1 Hz, averaging 260 reflectance data points per hectare while ensuring effective sensing through self-cleaning optical module (Kweon & Maxton, 2013; Bönecke et al., 2020).

Figure 9. a) MSP3 sensor, b) pH,OM and EC coulters c) MSP3 prepared to map in the field d) MSP3 in the field (Veris Staff; Mackowiaket al., 2016).

Electromagnetic induction sensor (EM38 SENSOR)

Non-contact electrical conductivity sensors use electromagnetic induction and do not need to come into contact with the ground. These sensors measure the change in mutual impedance between the coils (McNeill, 1980). This measurement is then converted into an estimate of the EC known as the apparent EC (ECa). These units are capable of monitoring at greater depths than contact sensors.

The EM38 sensor (Fig 2), designed for versatile use on the ground, in the air, and in boreholes, is a hand-held instrument that can also be mounted and directed using GPS for automated data logging in a Geographic Information System (McDaniel et al., 2018) The standard EM38-MK2 model measures 1.05 m in length and weighs 3.5 kg, powered by a 9-volt battery with a life of up to 20 hours. It records soil electrical conductivity (EC_a) in both horizontal (H-mode) and vertical (V-mode) dipole modes, providing measurements at depths of 0.375 m and 0.75 m in H-mode, and 0.75 m and 1.5 m in V-mode. ((Kitchen et al., 2005; Geonics, 2012).

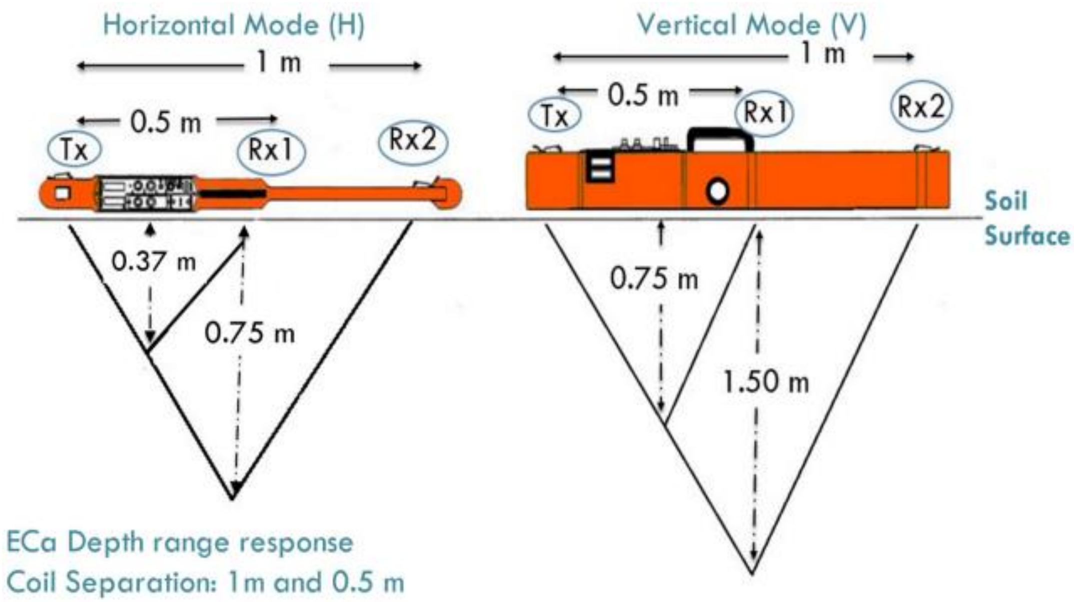

Figure 10. The EM38 sensor in horizontal (H) and vertical (V) mode with the effective depth range responses of ECa for coil separation of 1 m and 0.5 m when placed on the soil surface. (Petsetidi & Kargas, 2023).

EM38 AND MSP3 USE IN ARID LAND CONDITIONS

The MSP3 sensor has been used and proved its effectiveness in analysing soil properties in arid and semi-arid regions. Several studies (Kweon, 2012a, 2012b; Mackowiak et al., 2016; Novais et al., 2019) showed that this sensor could be effective to distinguish soil textures and organic matter variability, with moderate to strong correlations compared to laboratory results. Its potential use for precise soil management in challenging environments has been emphasized, particularly for detecting small-scale spatial variability and controlling variable rate inputs management with reference to established prescription maps.

Similarly, EM38 sensor has been used in arid lands to produce valuable data for assessing soil properties, particularly in understanding soil electrical conductivity (ECa) and its behaviour and relationship with the soil parameters according to the occurring soil water content. Several Studies (Rhoades et al., 1976,1989,1990,1997,1999; Corwin & Lesch, 2005b, 2013, 2017; Molinl et al,2005) indicated that ECa measurements could effectively differentiate between dry and saturated soils, which is crucial to approach soil parameters in arid regions having irregular soil water content due to intermittent rainfall.

Table 6. Some studies based on using MSP3 sensor in arid land context.

Study	Objective	Location	Key Findings	Recommendations
Novais et al. (2019)	Calibrate and validate the MSP3 in rainy conditions	Guanacaste, Costa Rica	Correlations established for soil texture and organic matter ($R^2 \geq 0.55$) at 0-30 cm; varied textures observed.	Alternative calibration methods needed for deeper measurements (30-90 cm).
Mackowiak et al. (2016)	Improve soil mapping for nutrient and water management using MSP3	Florida USA	Organic matter (OM) values help distinguish soil texture differences; dark colors correlated with higher OM.	Use MSP3 to delineate differences for variable rate management rather than achieving specific OM or EC targets.
Kweon (2012a, 2012b)	Evaluate MSP3 performance across multiple fields in the Midwest USA	Midwest USA	Proximal sensor measurements correlated well with lab samples; detected small-scale variability not seen in traditional methods.	Multi-sensor approach increases chances of identifying soil property variations; improve CEC predictions through data integration.

Table 7. Studies based on using EM38 in arid land context.

Years	Objective	Study Area	Findings	Recommendations
(Rhoades et al., 1976; 1989a; 1990a; 1997; 1999a; 1999b)	Obtain empirical coefficients used in equations to predict ECa by depth intervals within the soil profile from EM readings taken above ground.	California, USA	The authors stated that electromagnetic measurements on soils with less than 10% water by weight are not a reliable indication of salinity, and for very sandy soils, the limiting value of moisture content is probably higher. Proximity to the water table also influences EM38 readings.	Predictions were found to be more accurate using the new coefficients rather than those previously available.
(Corwin & Lesch, 2005a, 2005b, 2013, 2017)	Applications of ECa measurements in agriculture, particularly site-specific crop management	Arizona, USA	It appeared to be a stronger than normal water content influence on the EM38 signal data, consistent with typical surveying conditions encountered because of the prevalence of lighter textured soils.	Evaluates site-specific management from a holistic perspective of environmental, crop productivity, and economic impacts.
Molinl et al 2005	to perform spatial monitoring of soil moisture in two different experimental fields over two consecutive years and evaluate the influence of moisture on soil ECa.	Brazil	demonstrated the potential of ECa sensors for understanding soil characteristics and their impact on crop yields, particularly in no-till fields.	ECa is a qualitative indicator in areas with high spatial variability in soil texture. In the field, where soil moisture range was lower, ECa was not associated to moisture levels.

CONCLUSION AND RECOMMENDATIONS

This paper outlines a comprehensive approach to assessing soil parameters using two proximal soil sensor tools, mainly the MSP3 and EM38 tools.

This review showed several studies highlighting importance of using the Veris MSP3 mapping tool in improving land management decisions. The MSP3's electrical conductivity (EC) package could effectively track nutrient variations, while its pH tool can show promise, though further calibration is required to confirm its accuracy. Challenges such as technical glitches with inexperienced operators and the underdevelopment of the organic matter (OM) tool emphasize the need for enhanced data support and interface improvements to facilitate research.

Additionally, while the EM38 performs well under conventional irrigation systems, it faces challenges with micro-irrigation due to localized salinity variations, highlighting the need for updated research protocols. The growing adoption of inverse modelling for soil salinity profiling is crucial for managing water resources in cash crops, especially in the context of climate change. (Corwin & Scudiero, 2016, 2019)

Ultimately, while the MSP3 excels in data integration and the creation of management zones, the EM38 remains valuable for rapid field assessments. The combined use of both tools could significantly enhance soil management practices.

REFERENCES

Bhunia, G.S., Shit, P.K., Maiti, R. 2018. Comparison of GIS-based interpolation methods for spatialdistribution of soil organic carbon (SOC). Journal of the Saudi Society of Agricultural Sciences, 17(2),114–126. DOI: 10.1016/j.jssas.2016.02.001 (PDF) Modelling and Mapping of Soil Organic Matter in Doukkala Plain Morrocan Semi-Arid Region.

Bönecke, E., Kling, C., Kramer, E., Lück, K., Philipp, G., Rühlmann, J., Schröter, I., & Gebbers, R. (2022). Direct prediction of site-specific lime requirement of arable fields using the base neutralizing capacity and a multi-sensor platform for on-the-go soil mapping. Precision Agriculture, 23(1), 127–149. https://doi.org/10.1007/s11119-021-09830-x

Corwin, D. L., & Lesch, S. M. (2005a). Apparent soil electrical conductivity measurements in agriculture. Computers and Electronics in Agriculture, 46, 11–43. https://doi.org/10.1016/j.compag.2004.10.005

Corwin, D. L., & Lesch, S. M. (2013). Protocols and Guidelines for Field-scale Measurement of Soil Salinity Distribution with EC a -Directed Soil Sampling . Journal of Environmental and Engineering Geophysics, 18(1), 1–25. https://doi.org/10.2113/jeeg18.1.1

Corwin, D. L., & Lesch, S. M. (2017). Validation of the ANOCOVA model for regional-scale ECa to ECe calibration. Soil Use and Management, 33(2), 178–190. https://doi.org/10.1111/sum.12262

Corwin, D. L., & Scudiero, E. (2016). Field-Scale Apparent Soil Electrical Conductivity. Methods of Soil Analysis, 1(1), 0. https://doi.org/10.2136/methods-soil.2015.0038

Corwin, D. L., & Scudiero, E. (2019). Review of soil salinity assessment for agriculture across multiple scales using proximal and/or remote sensors. In Advances in Agronomy (Vol. 158, pp. 1–130). Academic Press Inc. https://doi.org/10.1016/bs.agron.2019.07.001

Kweon, G. (2012a). Delineation of site-specific productivity zones using soil properties and topographic attributes with a fuzzy logic system. Biosystems Engineering, 112(4), 261–277. https://doi.org/10.1016/j.biosystemseng.2012.04.009

Kweon, G., Lund, E., & Maxton, C. (2013). Soil organic matter and cation-exchange capacity sensing with on-the-go electrical conductivity and optical sensors. Geoderma, 199, 80–89. https://doi.org/10.1016/j.geoderma.2012.11.001

Kitchen, N. R., Sudduth, K. A., Myers, D. B., Drummond, S. T., & Hong, S. Y. (2005). Delineating productivity zones on claypan soil fields using apparent soil electrical conductivity. Computers and Electronics in Agriculture, 46, 285–308. https://doi.org/10.1016/j.compag.2004.11.012

Mackowiak, C., Pi, L., & Wright, D. (2016). Soil Mapping Enhancements via Veris MSP3.

McDaniel, P., Ross, M., Jimenez, J., Strawn, D. G., Valerio, M., Kimsey, M. J., Campbell, S., & Falen, A. (2018). Pedogenic Pathways in Andic Soils of the Northern Rocky Mountains (USA). Soil Science Society of America Journal, 82(6), 1308–1318. https://doi.org/10.2136/SSSAJ2018.05.0186

McNeill, J. D. (1980). Electromagnetic Terrain Conductivity Measurement at Low Induction Numbers. In Technical note TN (Vol. 6, Issue TN--6, p. 13). http://www.geonics.com/pdfs/technicalnotes/tn6.pdf

Novais, W., Rodríguez-Mejías, J. C., Perret, J., Soto, C., Villalobos, J. E., Fuentes, C. L., & Abdalla, K. (2019). Calibration and validation of Veris MSP3 on two soils in Guanacaste, Costa Rica. Agronomia Mesoamericana, 30(2), 535–551. https://doi.org/10.15517/am.v30i2.33579

Petsetidi, P. A., & Kargas, G. (2023). Assessment and Mapping of Soil Salinity Using the EM38 and EM38MK2 Sensors: A Focus on the Modeling Approaches. In Land (Vol. 12, Issue 10). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/land12101932

Rhoades, C. C., Brosi, S. L., Dattilo, A. J., & Vincelli, P. (n.d.). Effect of soil compaction and moisture on incidence of phytophthora root rot on American chestnut (Castanea dentata) seedlings. https://doi.org/10.1016/S0378-1127(03)00147-6

Robinson, T. P., & Metternicht, G. (2006). Testing the performance of spatial interpolation techniques for mapping soil properties. Computers and Electronics in Agriculture, 50(2), 97–108. https://doi.org/10.1016/j.compag.2005.07.003

Veris Technologies Inc. (2016). Quantifying the Value of Precise Soil Mapping. 1–8.

Viscarra Rossel, R. A., A., K., & Schulze, P. (2011). Sensor Fusion for Precision Agriculture. *Sensor Fusion - Foundation and Applications*, *May 2014*. https://doi.org/10.5772/19983