GEOSTATISTICAL METHODS BOON IN SMART AGRICULTURE

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Global population expected to reach 9.7 billion by 2050 and estimations show that along with population growth the demand for agriculture produce also increase by 50% (U.N., 2017). This situation demands substantial improvements in crop production as well as sustainable use of agricultural resources. In land resource management particularly, site specific nutrient management, basic data on soil fertility of the location play an important role. Meeting this demand, while avoiding further deterioration of agricultural lands, will require a radical change in the way farmers manage their farms. It is then necessary to abandon practices that do not sustain the environment and open up to new methods and technologies that are based on rational use of resources. Geostatistical methods provide many supporting tools which are mapping; exploratory spatial data analysis tools can be used to assess the statistical properties of the data.

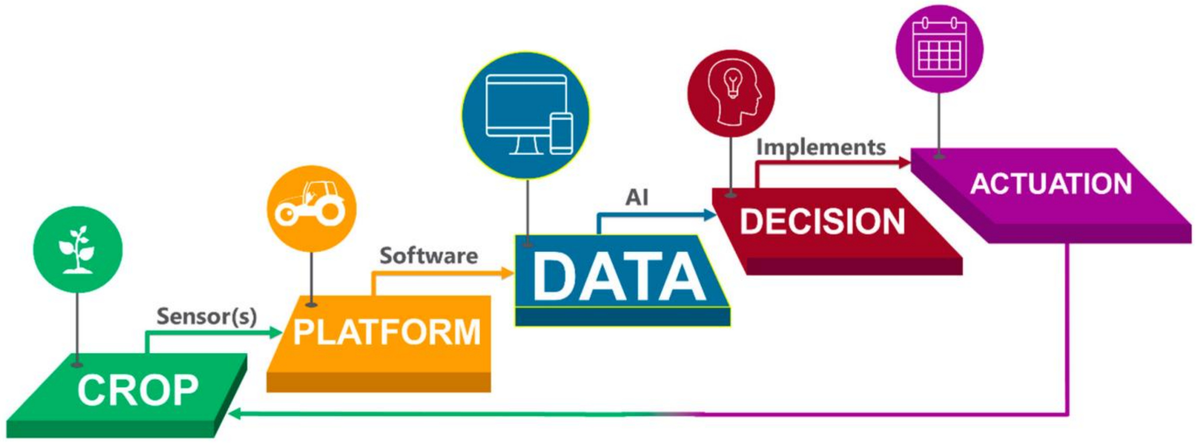

Figure 1. Flowchart of geostatistics in agriculture (*Source: Saiz-Rubio and Rovira-Más, 2020*)

WHAT IS GEOSTATISTICS?

Geostatistics is a class of statistics used to analyze and predict the values associated with spatial or spatiotemporal phenomena. It incorporates the spatial coordinates of the data within the analyses. Many geostatistical tools were originally developed as convenient methods for describing spatial patterns and interpolation for unsampled locations. These tools and methods were developed not only provide interpolated values, but also to measure uncertainty of these values. The measurement of uncertainty is critical to informed decision making, because, it provides information on the possible values (outcomes) at each location, not just an interpolated value. Geostatistical analysis has also evolved from univariate to multivariate, providing mechanisms to incorporate auxilary data sets to supplement the main variables of interest, thus allowing more accurate interpolation and uncertainty models to be constructed. Geostatistical methods are based on statistical models that include autocorrelation. These techniques are able to generate forecast surfaces and also measure of the accuracy of these forecasts.

APPLICATIONS OF GEOSTATISTICAL METHODS IN AGRICULTURE

Soil Samplings: Although analytical procedures for determining the general physical properties and chemical composition of agricultural soils have been optimized and faster and cheaper techniques have emerged, such as the use of the NIRS technique (Nie et al., 2017), primary analyzes are not always soil sampling. Although many studies have shown the importance of sampling procedures, improved procedures inspired by the specific characteristics of measurements are often overlooked in favor of long-term practice or ease of use. This resulted in suboptical laboratory samples and subsequent analytical results (Clay et al., 1997; Hennart et al., 2004). Soil mapping, on the other hand, is the process of collecting, describing, processing, classifying and predicting soil properties. It also provides up-to-date information on landforms, terraces and vegetation. It is important to note that this renewed soil inventory is reliable in policy and decision making for precision agriculture.

Soil Salinity Management: Soil salinity management relies on the difficult task of identifying appropriate techniques and methods to assess and monitor soils affected by salinity. Traditional soil salinity methods based on soil ECe provide accurate soil salinity information, but on the other hand, they are time-consuming and often expensive, making them unsuitable for mapping of significant changes at the landscape scale. The determination of salinity using different remote sensing data has shown promise, but only in the later stages of the salinization process, especially in semi-arid and arid agro-ecological zones where vegetation does not cover the ground completely. Partial least squares regression (PLSR) is a general chemometric method for estimating regression models from spectral information and analytical reference data.

Soil Mapping: The Geographic information systems (GIS) are effective and valuable tools for estimating the spatial distribution of environmental variables. Spatial prediction and surface modeling of soil properties have become common topics in soil science research. Spatial distribution patterns of soil properties vary widely depending on soil type, topography, climate, vegetation, and human activities. Surface modeling is a useful tool for interpolating soil properties in precision agriculture and land management. For example, a map showing soil distribution and characteristics, and a soil survey report are the end products of a soil mapping project. Paper maps, an outgrowth of traditional land mapping, seem increasingly irrelevant to many users, and there is no market for land managers and policy makers of all sizes. As the traditional role of surveying diminishes, the need for land information is becoming increasingly important in terms of sustainable land management. There are many policy issues that require good background information; such include erosion, salinization, organic matter content and heavy metal pollution.

Soil Pollution Control and Management: Underground pollution is characterized by localized pollution hotspots and trends that are exacerbated by anthropogenic activities such as industrial growth and rapid urbanization (Lark, 2002). Mapping concentrations of pollutants of concern (COCs) across sites provides a better understanding of contaminated sites and combines a robust risk assessment with the possibility of targeted remediation programs. The three dimensional characterization of soil contamination plumes is now recognized as an indispensable tool to support decision-making for the remediation of contaminated sites (Liu et al., 2015), the design of adaptive sampling strategies (Leung et al., 2018) or litigation support. However, three factors hinder the application of three dimensional soil pollution mapping. Ordinary kriging interpolation, combined with 3D visualization methods, to characterize contaminated soils

Real-time Irrigation Scheduling: Irrigation schedules determine when and how much water is applied to a field, directly affecting water use efficiency. Estimate how much water to apply using criteria that determine irrigation needs and strategies that dictate how much to apply with a wireless sensor network (WSN). Effective application of irrigation water requires an understanding of the dynamics of plant water use, which is related to weather, soil, and plant conditions

Opportunities for Improving Water Use Efficiency in Open Field Smart Irrigation Systems: The need to improve water use efficiency in irrigated agriculture has gained serious attention from researchers in recent years. This is because agriculture has been reported to be a significant water user sector and yet spatiotemporal water scarcity indices are on the rise leaving little or no water for agricultural production. Producing more crop per drop requires that soil and weather parameters are precisely monitored and irrigation scheduled to meet the crop water demand.

Weather Forecasting: Forecasts are made by collecting quantitative data about the current state of the atmosphere, land and ocean by geostatistical methods GPS and GIS. Forecast on rainfall and temperature helps farmers to plan what to plant and when to do it, it also helps them to put measures in place to reduce the devastating impacts of extreme events on their livelihood.

Improving Agriculture Economics: As the integrated agricultural systems requires information for sustainable crop production, precision agriculture aims to provide high end technological solutions to improve the efficiency and profitability of these production system while minimizing the environmental impact on the agro-ecosystems. Geostatistical techniques are technological innovations that incorporate the latest advances in modern agriculture, providing evidence of lower production costs, improved agricultural efficiency and reduced impacts. However, some problems have been encountered with then adoption of geostatistical techniques, such as additional application or management costs and investment in new equipment and trained personnel. Some of these cutting-edge technologies have proven to be effective, providing tangible benefits at a lower cost, and are therefore rapidly attracting the interest of the scientific community.

REFERENCES

Bwambale, E., Abagale, F.K., Anornu, G.K. 2022. Smart irrigation monitoring and control strategies for improving water use efficiency in precision agriculture: A review. *Agricultural Water Management*, 260(C).

Clay, D., Carlson, C., Brix-Davis, K., Berg, B., J.O. 1997. Soil sampling strategies for estimating residual nitrogen. *Journal of Production Agriculture,* 10(3): 446–452.

Hennart, S., Stilmant, D., Vandenberghe, C. 2004. Accuracy of the nitrate sampling scheme, proposed in walloon area, for grazed grasslands. Proceedings of the 14th N Workshop. Maastricht, the Netherlands, pp. 300–302.

Koutsos, T., Menexes, G. 2019. Economic, Agronomic, and Environmental Benefits From the Adoption of Precision Agriculture Technologies: A Systematic Review. *International Journal of Agricultural and Environmental Information Systems*, 10(1):40-56.

Lark, R.M. 2002. Modelling complex soil properties as contaminated regionalized variables. *Geoderma,* 106(3-4): 173-190.

Leung, Y.F., Liu, W., Li, J. S., Wang, L., Tsang, D.C.W., Lo, C.Y., Leung, M.T., Poon, C.S. 2018. Three-dimensional spatial variability of arsenic-containing soil from geogenic source in Hong Kong : Implications on sampling strategies. *Science Direct*, 633:836-847.

Liao, X., Zhao, D., Yan, X. 2011. Determination of potassium permanganate demand variation with depth for oxidation–remediation of soils from a PAHscontaminated coking plant. *Journal of Hazardous Materials*, 193:164-170.

Nie, P., Tao, D., Yong, H., Fangfang, Q. 2017. Detection of soil nitrogen using near infrared sensors based on soil pretreatment and algorithms. *Sensors*, 17(1102).

Saiz-Rubio, V. and Rovira-Más, F. 2020. From Smart Farming towards Agriculture 5.0: A Review on Crop Data Management. *Agronomy*, 10. 10.3390/agronomy10020207.

United Nations. 2017. The Future of Food and Agriculture – Trends and Challenges. FAO, Rome

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