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The Role of Soil Physics as a Discipline on Soil and Water Conservation during the Past 75 Years

Francisco J. Arriaga, DeAnn R. Presley, and Birl Lowery

Changes in Agriculture Have Affected Soil Physical Properties

Soil physics is at the heart of soil and water conservation, with much of the work focusing on soil erosion and water quality. Land management affects physical properties such as bulk density, infiltration, aggregation, and hydraulic conductivity, which are crucial for soil and water conservation efforts. In the past 75 years, there have been significant changes in how agricultural and natural resources (soil and water) are viewed and used. These changes have occurred in soil and water conservation, from attempts to reduce soil erosion by implementing terraces, contour farming, and crop rotations, and in some areas installing structures to stop gully formation. During this period of time, an extensive development of numerous agricultural chemicals (herbicides, insecticides, fertilizers, and other amendments) allowed for soil conservation-friendly farming, such as reduced- and no-tillage (with significant surface crop residue cover). However, also during this time the pressure on our natural resources has increased. Somewhat ironically, along with the positive aspects of agricultural chemicals that made soil conservation farming possible, come concerns for soil health and water quality. The increased use of agricultural chemicals has resulted in decreased soil health, including

Francisco J. Arriaga is an associate professor in the Department of Soil Science, University of Wisconsin, Madison, Wisconsin. **DeAnn R. Presley** is an associate professor in the Department of Agronomy, Kansas State University, Manhattan, Kansas. **Birl Lowery** is a professor emeritus in the Department of Soil Science, University of Wisconsin, Madison, Wisconsin.

physical parameters (Hussain et al. 2001; Karaca et al. 2010; Reganold 1988). A decrease in physical soil health parameters, including structure (causing slaking, surface crusting, and decreased porosity), bulk density, water, and thermal regimes, can result in increased surface water and groundwater contamination. While there has been removal of some of the aforementioned conservation practices established 75 to 20 years ago, adoption of other conservation practices has increased (Hellerstein et al. 2019; Magleby et al. 1985). Cover crop use and reduced tillage techniques have helped soil conservation efforts and improved soil physical properties (Hellerstein et al. 2019). Another trend affecting soil physical properties and soil and water conservation during the past 75 years is the increasing size and mass of farm machinery (Kim et al. 2005). Larger farm equipment allows for improved productivity, but larger farm equipment can also result in increased soil bulk density because of soil compaction and therefore decreased yields (Bakken et al. 2009; Sohne 1958). This means a reduction in soil porosity, which reduces water infiltration and storage, resulting in increased soil erosion. Additionally, removal of conservation structures has occurred in order to allow for the larger equipment to operate more freely within fields.

Methods for Assessing Soil Physical Properties

Many of the methods used to measure soil physical properties from 75 years ago are still being used. However, there have been many new methods developed and major changes to the measurement techniques of many older methods. The advent of electronics in other disciplines has transferred to soil physics as well. Some methods are more complex than in the past, with the use of sensors, computers, data-logging, and wireless communication capabilities, which allow for real-time data collection. The analyses of data have become more complex as well, with more advanced analysis techniques and application of complex computer model simulations (Huang et al. 2017; Zhang et al. 2020). An important development in soil physics was the application of time domain reflectometry (TDR) to nondestructively and rapidly determine soil water content (Topp and Davis 1985; Topp and Reynolds 1998). This application of TDR in soil physics has resulted in the development of other simpler, faster, and more cost-effective approaches for soil water content measurements using similar principles, making this once-difficult measurement now almost commonplace. These advances have allowed for soil water content and matric potential measurements in small time steps (Baker and Allmaras 1990; Lowery et al. 1986), which allows for improved irrigation scheduling for more efficient water use. This reduces the potential for runoff and groundwater contamination.

The development and application of geophysical techniques, such as electrical conductivity for soil mapping, has also helped advance soil and water conservation goals. Field maps of electrical conductivity can be used to develop management zones that can relate to soil organic carbon, different textural classes, soil depth, and other physical properties and features (Johnson et al. 2001; Kitchen et al. 2005; Luck et al. 2009). Depending on the application, these management zone maps developed with geophysical techniques can be used for precision agriculture or irrigation management to improve resource utilization.

Currently it is possible to log soil water and matric potential in real time using wireless telecommunications; together with rapid sophisticated computer analyses, this allows for assessing water drainage for a field or watershed. These detailed analyses were not possible 75 years ago, as such measurements were not possible and the necessary computer processing power was not available. Computed tomography (Gantzer and Anderson 2002) has been used to scan soil columns to assess soil density, porosity, and preferential flow caused by insect activity (Petrovic et al. 1982; Grevers et al. 1989; Bailey et al. 2015). These advanced techniques are in contrast to older devices for in situ water content, matric potential measurements, and drainage collection, including resistance gypsum and fiberglass blocks, gamma ray and neutron probes, tensiometers with manometers or gauges, and lysimeters (Dane and Topp 2002). An advantage of advanced techniques for measuring soil physical properties and processes is that information collected about different properties can be used to generate three-dimensional representations of soil properties at a field or landscape level that can be helpful for studying and determining management impacts for soil and water conservation efforts (Grunwald et al. 2001; Arriaga and Lowery 2005).

Future Options for Application of Soil Physics to Soil and Water Conservation

Observations from drones, low-flying aircraft, and space are currently available for every corner of the globe and can help assess everything from crop growth and pest management to soil erosion (Wüpper et al. 2020). These detailed methods of data collection were not available 75 years ago, so in the future we anticipate that these sophisticated techniques will only be improved upon. An applied example is the use of remotely sensed data from satellites to estimate soil water content for agricultural fields without the use of sensors installed in the soil (Huang et al. 2019; Siegfried et al. 2019). Not too far in the future, one will be able to view, in real time, data that relates to man-made and natural disasters, such as mudslides, or for soil and water conservation management. Hourly, daily, and monthly changes to soil resources via space and drone crafts can be tracked. Improvements to these technologies focusing on the earth's surface will allow for rapid response to environmental problems including those associated with climate change. For example, scientists currently track changes to polar ice using remote sensed data from satellites (Strozzi et al. 2017). Space observations are also valuable for wildfire monitoring and evaluating natural recovery following these disasters. Algae growth and harmful algal blooms on surface freshwater bodies can also be monitored in real time using remote sensing platforms (Urquhart et al. 2017; Lekki eta al. 2019). Monitoring of cover crop use can be done via satellites (Hively et al. 2015). These real-time technologies are a contrast to simple hot-air balloon and low-flying aircraft monitoring of 75 years ago, and in the future there will be even more advances. The development of remotely sensed soil carbon with satellites provides a window of what the future will hold for soil physics in the context of soil and water conservation.

Conclusion

Soil erosion was a significant concern of soil physics as a discipline 75 years ago. During the decades that followed, advancements in soil physics theory and measurement techniques were quickly recognized as useful for soil and water conservation efforts. Needs for soil and water conservation have changed somewhat, while soil physicists have continued to improve methods and modeling approaches. Over the next 75 years we can expect that the disciplines of soil and water conservation and soil physics will continue to depend upon and work with each other.

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