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For Better Soil, Get Better Data

If you were buying a house, would you expect the value of the property to be based on its current condition, or its condition 50 years ago? When it comes to farmland in the United States, buyers are often forced to make decisions based on data rooted in the past. In most states, farmland value is heavily influenced by the practice of scoring soil quality, which has become a proxy measurement for estimating a farm's expected crop yield and productivity capacity—major drivers of potential farm income. Systems for scoring soil quality differ between states (like the Iowa Corn Suitability Rating or the Illinois Soil Productivity Index), but it is common for scoring to rely in large part on historical state or national soil composition surveys, which can date as far back as the 1950s. These static metrics are vestiges of efforts by states to tax farmland based on its use value, but they are now widely used by farmers, appraisers, and financers to estimate the value of farmland in real estate transactions across the country.

Relying on historical data to value cropland distorts the market and creates a disincentive for farmers to invest in preserving an important nonrenewable resource that is vital for agricultural productivity: topsoil. Topsoil is the nutrient-rich, five- to ten-inch layer of abundant minerals and organic matter that supports biological activity and water and air retention within soil. Topsoil erosion occurs naturally from wind and rain, but another significant driver is cropland tillage, which is entirely preventable with minor adjustments to farming practices. Until relatively recently, measuring the quality of topsoil—its depth, nutrient composition, acidity, organic matter content, and other elements—required a combination of manual labor, machinery, and laboratory analysis for each sample. But new techniques using remote sensing, robotics, and artificial intelligence are lowering the barriers to gathering data on the real-time characteristics of topsoil, and by extension, managing it for increased productivity.

As an undervalued agricultural input, topsoil is being lost at an unsustainable rate. We think getting better soil quality data in the hands of farmers and land assessors can fix this market distortion. One of us (Mitchell) is a fifth-generation Iowa farmer and the managing director of a private equity firm focused on investments in US farmland and agricultural technology. In a dozen years of buying and selling farmland, he has never been provided with or asked to provide up-to-date soil test measurements at the point of sale, despite the current boom in advanced technologies that can be used to cheaply and effectively measure and monitor soil health. More comprehensive and dynamic soil surveys, improved farmland retail data, and increased circulation of easy methods for preventing tillage erosion can reorient incentives so that landowners take actions to conserve soil.

Digging for data

A key factor in the undervaluation of soil quality is a dearth of data. Without active and comprehensive soil quality monitoring, topsoil loss has gone largely unobserved at the commercial scale. The US Department of Agriculture's Soil Survey Geographic Database (SSURGO) is the most comprehensive national soil survey available. Over the course of the last century, SSURGO data have been collected through field observations and soil core analysis, but only around 10% of the map is updated annually. In fact, one study using Iowa SSURGO soil maps found that 80% of counties in the study area relied on data from fieldwork completed around 1979, and the remaining 20% relied on fieldwork completed around 2003. Since soil quality can vary greatly even within a single parcel of farmland over a much shorter period of time, continued reliance on these historic assessments can seriously skew the picture of modern soil quality.

New techniques such as remote sensing and machine learning offer the promise of faster and more accurate monitoring of soil conditions at a lower cost. Bradley Miller, the leader of the Geospatial Laboratory for Soil Informatics at Iowa State University, has used locally enhanced digital mapping to generate soil maps that more accurately predict true soil properties, such as soil class and soil organic matter content, than SSURGO. Using fine-grained data from statewide soil core samples in combination with broader environmental data (such as satellite imagery for detecting vegetation patterns) and local knowledge, Miller's team then trains a model capable of predicting soil quality data across the entire state. In contrast to static metrics like state productivity indices, Miller's data can depict the current quality of the soil for an entire area. Updating soil maps using this method would cost an estimated two cents per acre (including labor costs of soil sampling and data processing), making an annual update fiscally feasible.

However, updating national soil maps annually would require a different kind of survey operation—one that prioritizes partnerships between federal agencies standardizing soil map elements and regional organizations implementing the sampling and training surveyors. The US Department of Agriculture's National Resources Conservation Service (NRCS) recently began a Dynamic Soil Properties program to modernize sampling standards, encouraging partnerships between universities, K–12 institutions, conservation groups, and other organizations for gathering samples from hundreds of sites across the United States. But more guidance on data sharing and integration at the federal level is needed to effectively coordinate stakeholders.

Farming is an evermore data-intensive industry, and the availability of more accurate soil quality metrics could begin to influence real estate transactions and markets. For buyers or tenants doing precision agriculture, for example, real-time soil quality assessments could offer valuable transparency and predictive data. But even though comprehensive soil quality tests can be commercially ordered for less than $10 per acre—trivial compared to the 2024 average cropland price of $5,570 per acre—few appraisers, lenders, and investors request them.

What is needed is a more explicit valuation of soil, which would begin with asking farmland sellers to report up-to-date soil composition results when putting farmland up for sale. Dynamic soil maps showing changes in soil quality (e.g., loss of topsoil) across US farmlands would also help farmers and farmland real estate agents nationwide to normalize this practice, thus prompting change without regulatory action. This shift would more strongly incentivize soil conservation by strengthening the link between farm resale value, management history, and actual soil quality.

Cultivating soil conservation best practices

With a more accessible, granular, and dynamic picture of soil conditions, farmers, researchers, and policymakers can make better decisions about how to manage this important—and on a human timescale, nonrenewable—natural resource. It is theoretically possible to run out of usable soil; indeed, a recent survey of 255 farms in 38 countries found that, without changes in management practices, 16% had soil lifespans of less than a century. However, among farms managed with conservation strategies, nearly half had lifespans estimated to exceed 5,000 years. If soil is appropriately managed, it can be preserved—which differentiates it from other farming inputs like fuel and fertilizer that are strictly consumable.

The most effective way to preserve soil is to prevent erosion arising directly from cultivation, also known as tillage or digging. Tilling disturbs the microbiome, lowers water and nutrient holding capacity, and leads to higher rates of wind and water erosion. However, a less recognized factor is that tilling directly causes sediment movement. In some landscapes, tillage erosion contributes to sustained annual topsoil losses exceeding 50 tons per hectare per year, which is greater than erosion from wind and water. And unlike water and wind erosion, direct tillage erosion is typically not observable with the naked eye.

Methods for combating tillage erosion are generally simple and inexpensive to implement. In addition to common erosion management techniques such as cover cropping, even easier adjustments can be made. For example, adding a mere 10-foot swath of grass where water exits a field can reduce sediment loss by over 90%. Since tillage erosion is largely caused by topsoil displacement from downhill tillage, driving the tractor back uphill has an ameliorating effect. Tillage erosion is a function of travel speed at the time of damage, so it is entirely preventable if tractors are driven at an appropriate speed, which can be calculated based on the slope of the field. Modern technology makes it easy to map tillage erosion over time: Topography is a standard base layer in farm management software, and machine speed and type can be recorded with high spatial resolution. Consequently, most farm machinery can already accurately capture the forces behind tillage erosion to help prevent it, but this information is usually treated as a byproduct rather than a cost-effective tool for enhancing soil productivity.

These simple strategies are more likely to be adopted on commercial farms if farmers see the economic significance of managing and preserving soil health as a valuable farm input. Greater awareness of tillage erosion and other opportunities to improve or apply precision soil management practices should be disseminated through local services, such as NRCS's regional field offices and land grant universities' extension programs, which already have an established relationship with farmers. The Iowa Nitrogen Initiative, which uses advanced computing to help farmers identify optimal nitrogen application rates, is an important example of how to connect researchers working with advanced modeling and forecasting techniques with farmers to advance soil health, productivity, and conservation.

Information is key to pricing and treating healthy soil like the integral farm input it is. With so many opportunities to leverage new innovations in agricultural data collection and analysis, the benefits of harnessing data to improve soil quality, crop yields, and agricultural sustainability far outweigh the costs. We can preserve US soil for generations to come, but such an effort won't be possible if farmers and land assessors stick to outdated ways of monitoring and valuing soil quality. By building the data infrastructure to support this market correction, federal and state governments, universities, industry, and nonprofits in collaboration can set US agriculture on a more productive path for the future.

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