soil health

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The United Nations (UN) has declared 2015 as the International Year of Soils (IYS) in an effort to raise awareness and promote the sustainability of our limited soil resources (www.fao.org/globalsoilpartnership/iys-2015). A major focus of this effort is soil health: greater understanding and use of the concept, threats to soil health, and practices to maintain and restore soil health. Many soils organizations from around the world (including the Soil Science Society of America: www.soils.org/iys) have been developing and disseminating information on soils and soil health, targeted at scientists, technologists, land managers, policymakers, educators, and the public. One of the key documents that will be coming out later this year is the "State of the World's Soil Resources" report published by the UN's Food and Agriculture Organization (FAO) and the Global Soil Partnership. This report is expected to provide the most comprehensive, global assessment of soil health since the UN-funded

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Fig. 1. A severely eroded field in Minnesota illustrating the dominance of tillage erosion and its impact on soil health.

GLASOD project to assess soil degradation published in 1997 (www.isric.org/projects); it is expected to guide soil conservation programs and policies around the world for many years.

All of the information that I have seen on soil health leading up to the IYS would lead one to believe that we have a complete and sound understanding of the threats to soil health and the practices required to achieve healthy soils. This is not the case. There are some notable exceptions to such a simplistic representation of the situation, and these exceptions bear some consideration.

If farmers adopt conservation tillage, the health of the soil may not be protected

Conservation tillage, by reducing soil disturbance and increasing crop residue cover on the soil surface, can effectively control soil degradation by wind and water erosion. But, there is another erosion process, tillage erosion, which complicates the conventional understanding of how to conserve soil through tillage practices.

Tillage erosion is the net loss and accumulation of soil that occurs within a field due to variability in soil movement during tillage, in how much and/or how far soil moves. Soil movement and its variability are affected by several factors: type of tillage tool, speed and depth of tillage, operator's manipulation of speed and depth during tillage, and soil conditions, including the amount of plant residues. Over time, tillage progressively moves soil downslope from upper slope to lower slope landscape positions within a field. The most widespread evidence of severe soil loss by tillage erosion is eroded hilltops (Fig. 1) and undercut field borders on sloping land. Tillage erosion is often found to be the major cause of soil loss where cultivated soils are most severely degraded by soil erosion (Li et al., 2008; Tiessen et al., 2009; Lobb, 2011).

One commonly used practice in conservation tillage is the use of a chisel plow for primary rather than a moldboard plow. The chisel plow leaves more crop residue on the soil surface. Although the chisel plow reduces the risk of wind and water erosion, it can result in greater tillage erosion. This is because the chisel plow can move as much soil as the moldboard plow and it can move it further distances, and the further the distance soil is moved, the more variability there typically is in soil movement (Lobb, 2011). High-residue levels cause soil to be dragged further during tillage, and this may contribute to the greater erosion by chisel plowing (Liu et al., 2007).

Another commonly used conservation tillage practice is the reduction in number of passes of discs and field cultivators used in secondary tillage operations. This can be an effective means of reducing soil erosion by wind, water and tillage. However, in some forms of crop production, such as potato production, tertiary tillage operations such as seeding, hilling, and harvesting may result in more tillage erosion than primary and secondary tillage operations combined (Tiessen et al., 2007a, 2007b). Consequently, some crop production systems would need to go well beyond conventional conservation tillage to maintain or restore a healthy soil.

The most strongly promoted form of conservation tillage is the use of no-till (or zero-till) systems. In these systems, both primary and secondary tillage operations are eliminated, and the crop is seeded directly into the untilled soil. This eliminates tillage erosion from primary and secondary tillage operations and reduces the susceptibility of the soil to wind and water erosion by leaving crop residue on the soil surface and maintaining soil structure. However, no-till systems can still result in significant soil movement and tillage erosion during seeding. High-disturbance seeders can cause as much tillage erosion as the moldboard plow (Lobb 2008, 2011). Although the amount of soil moved is not great, the variability in how far soil is moved is great, a situation that is exacerbated by the use of high speeds on hilly land. On hilltops where soil losses are often most severe and soil regeneration is slowest, it may be that some no-till systems will not allow soil health to be restored through conservation tillage alone.

There may be a practice that is more effective than conservation tillage in restoring soil health

In fields where tillage erosion is the major form of soil erosion, there is an opportunity to restore severely eroded areas by removing soil that has accumulated at the base of slopes and applying it on the severely eroded hilltops. This practice, known as soil-landscape restoration or rehabilitation, may be the most effective means of restoring soil health on the areas of fields in greatest need. In studies of this practice, the benefits in crop production have shown to be immediate and the costs recovered within four to six years (Lobb, 2008; Smith, 2008; Johnson et al., 2009; Papiernik et al., 2009; Lobb, 2011).

If farmers are successful in protecting soil health, they may not protect water quality

In cold regions where runoff occurs over frozen soils, crop residue left on the surface can be a significant and sometimes the major source of phosphorus contaminating surface waters. Crop residues left on the soil surface have been found to result in substantial amounts of dissolved phosphorus in runoff from cropland (Tiessen et al., 2010). This is the case for any form of plant residue, including perennial crops, weeds, riparian vegetation, etc. (Liu et al., 2014a). Where wind and water erosion are not significant threats to soil health and where eroded sediments are not a significant threat to water quality, it may be appropriate to incorporate crop residues to reduce phosphorus loading to surface waters (Liu et al., 2014b). There is a need to discuss and study the most effective management of plant residue cover for the protection of both soil health and water quality.

The information I have presented in this very short article is intended to encourage a more full and constructive dialog on how to best achieve healthy soils. Unfortunately, none of this information is expected to make it into the UN's upcoming State of the World's Soil Resources report, with the exception of Canada's contribution to the North American regional report.

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Note: Lobb (2008) and Lobb (2011) are good summary documents intended for practitioners as well as scientists. Follow Dr. Lobb on ResearchGate (http://www.researchgate.net) to track/download extension-oriented information.