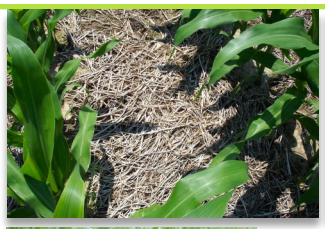
MICHAEL FIELDS
AGRICULTURAL INSTITUTE

Cover Crops and Water Quality

Dr. Jim Stute, MFAI Research Director, March 2016



Cover Crops for Water Quality

Although great strides have been made, agriculture continues to be a major contributor to water quality degradation world-wide as well as here in the upper mid-west. This contribution results from off-farm movement of soil, nutrients and pesticides and affects both surface and groundwater. Cover crops, certain to be a component of sustainable agricultural systems of the future, are widely demonstrated to improve water quality and in this context will be of increasing importance as climate change increases the frequency and intensity of rainfall events and the potential for water degradation.

What are cover crops?

Cover crops are adapted species grown when other crops are not present. They are used for their impact on the agroecosystem and not intended for harvest. In the strictest sense they provide soil cover and protection (hence the name) but impart other benefits including increased soil organic matter, biological nitrogen fixation, nutrient scav-enging, increased infiltration and pest suppression. They also interact with soil flora improving soil quality. In the short-term they also tie-up atmospheric carbon dioxide partially mitigating its effect on climate change although the extent of this contribution is not well understood. Many of these benefits work in concert to improve water quality, mostly by reducing off-farm soil movement.

The erosion process and surface water quality

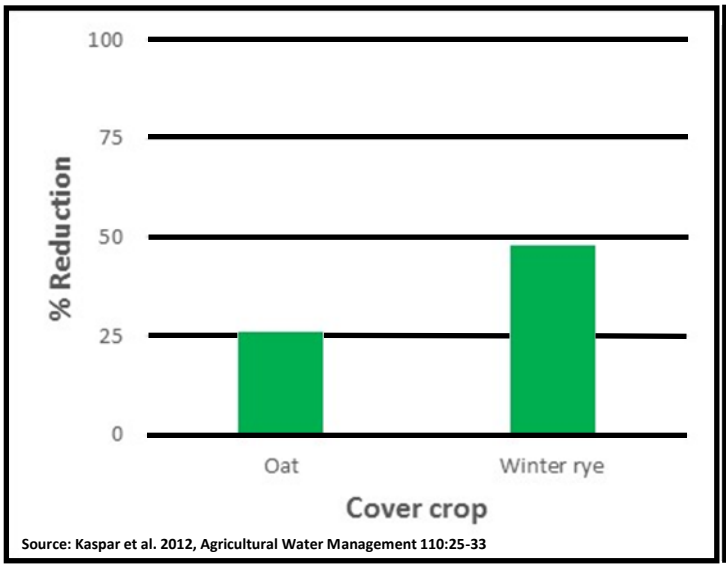
Soil erosion is a simple process which starts with a raindrop striking a soil particle causing detachment. The force of this collision is determined by raindrop size, velocity and shape and the resistance to detachment is influenced by soil strength. If the surface is sloped and infiltration rates are low, water travels down-slope taking soil particles (clay and silt) as well as nutrients and pesticides with it. Most nutrients and pesticides are attached to clay particles but soluble forms also exist. In the absence of resistance caused by standing crops, residue or a rough surface, and with sufficient slope-length, this run-off gains velocity and often has sufficient energy to cut into the profile causing channels, moving more soil in the process. If the run-off water encounters resistance such as a fencerow or riparian buffer it slows and soil is deposited. If not, it can enter surface water with the resulting decline in water quality. Because most of the phosphorus (P) in soil is bound to soil particles, it is the primary agricultural pollutant of surface water.

Tile drainage also contributes to surface water degradation. Subsurface drainage is used on poorly-drained soils to remove excess water and facilitate soil drying and warming. Excess water exits tile-lines through outlets that drain into ditches which are a direct conduit for soluble nutrients to enter surface water.

Groundwater contamination

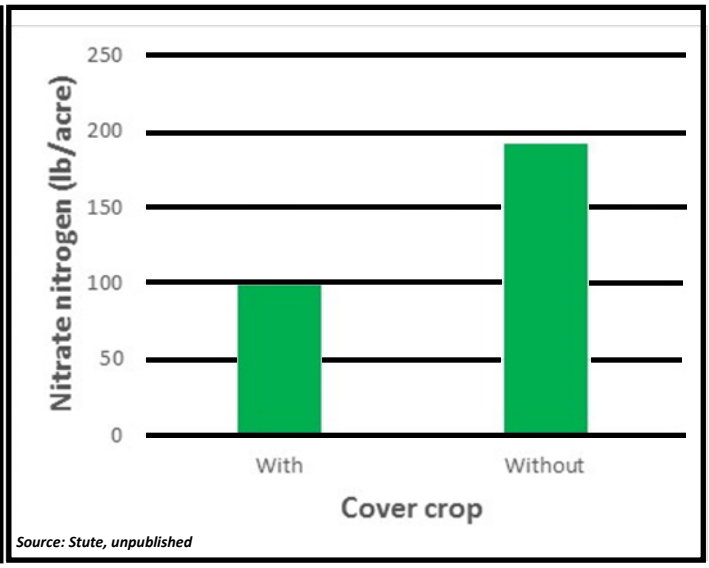
In agricultural systems, water moves downward when a soils storage capacity is exceeded and the crops water requirement for transpiration is met. Soluble nutrients move through the soil profile accompanying water pulled by gravity, most notably during groundwater recharge. In the upper Midwest this typically occurs during the non-frozen periods between growing seasons, but can occur early in the growing season when crops are small and water requirements are low. Often nutrients have been applied at this point in advance of the period of rapid crop uptake so they can be at-risk for leaching.

Nitrate-nitrogen is the major contaminant of groundwater. Regardless of applied form (organic or inorganic) nitrogen is ultimately converted to the nitrate form and that which isn't taken up by crops leaches due to its solubility. Atrazine and its metabolites are the major pesticide contaminant of groundwater in Wisconsin caused by historic widespread use and solubility.



Source: Kaspar et al. 2012, Agricultural Water Management 110:25-33

Reduction of tile-drain nitrate concentration by cover crops over 5 years in Iowa.



Source: Stute, unpublished

Over winter soil nutrient reduction caused by cover crops.

The Role of Cover Crops

Breaking the erosion cycle

Cover crops reduce erosion directly by intercepting raindrop energy, increasing infiltration and slowing surface water movement as well as indirectly by increasing soil strength.

Cover crops are grown mostly when other crops are not present so they effectively extend the proportion of the growing season when living canopy is present and can intercept rainfall, preventing the particle detachment which initiates erosion. This is particularly true of winter annuals which survive winter and resume growth in early spring, prolonging the period when canopy is present. Even if terminated early or the cover winterkills, its residues provide the same service, but the degree to which it's effective depends on the percent soil cover.

Increased infiltration results from a combination factors. By preventing detachment, crusting is reduced allowing water to enter soil more freely. Cover crop growth, especially that of tap-rooted species tends to cause surface loosening and cracking, providing a conduit for direct entry of water into the profile. Finally, many soil invertebrates, especially night crawlers (*Lumbricus terrestris*) feed on cover crop tissue and their feeding habits create macro pores which allow direct entry.

Indirectly, covers increase soil aggregation which impacts porosity, improving both infiltration and gas exchange. Microbial gums, a waste product of plant tissue decomposition glue soil particles together helping form aggregates. This is true of all species used a cover crops, however, a select group of species, most notably the forage legumes, red clover (*Trifolium pretense*) for example, support populations of mycorrhizal fungi which produce glomalin, a waste product which also binds particles together. This glycoprotein, which gives soil its characteristic earthy smell is water insoluble, so aggregates are stronger and able to withstand wetting without disintegrating.

Reducing leaching and tile-drain losses

Adapted cover crop species can reduce nutrient losses through uptake of unused nutrients in a process commonly referred to as "scavenging". Theses covers are grown in late fall, may overwinter into spring and remove nutrients from the profile during periods when crops are not growing and actively taking-up nutrients. Effective species such as winter rye (*Secale cereale*) are deep-rooted, have high nutrient uptake rates and sequester nutrients at the soil surface where they are released through decomposition to the subsequent crop.

Conservation of water for agriculture

Water is frequently the yield-limiting resource for agricultural crops. In addition to increasing infiltration, cover crops alone or in conjunction with no-till methods can increase soil water holding capacity. The return of additional residue may increase soil organic matter. Organic matter increases water holding capacity and certain types of organic matter hold up to 10 times its weight in water. In no-till systems where residue remains on the surface, evaporation rates are reduced, infiltration increased and fluctuations of soil temperature buffered, keeping soils cooler and more conducive for crop root growth and biological activity.