Cover Crops for Soil and Water Quality

Tom Kaspar
USDA-ARS, National Laboratory for Agriculture and the Environment
Ames, IA

Abstract:

Cover crops have many potential benefits for both soil and water quality in an annual grain cropping system, like the corn-soybean rotation. Cover crops provide these benefits by growing during the fallow periods between harvest and planting of main crops. Studies in Iowa have shown that rye and oat winter cover crops can reduce erosion and nitrate leaching in corn-soybean rotations, which improves both water and soil quality.

Introduction:

Cover crops have been used to manage soils for many different reasons and are known by many different names. Cover crops are literally “crops that cover the soil” and they were originally used during fallow periods in annual grain systems to reduce soil erosion. Cover crops are also known as “green manures” or “catch crops.” Green manure cover crops are usually legumes that fix nitrogen (N) and are grown to provide N to the following grain crop. Catch crops are cover crops that are grown during fallow periods in cropping systems to take up nutrients, especially N or phosphorus (P), that would be lost if plants are not present to take them up and recycle them. Winter cover crops are planted shortly before or soon after harvest of the main grain crop in the fall and are killed before or soon after planting of the next grain crop the following spring. Small grains, such as oat, winter wheat, barley, triticale, and winter rye, are excellent winter cover crops because they grow rapidly in cool weather, withstand moderate frost, and their seed is relatively inexpensive. Many winter-hardy cultivars of rye, triticale, and wheat can overwinter in the Upper Midwest basin and continue growing in the spring. These winter-hardy cover crops must be killed with herbicides, tillage, or mechanical rolling prior to planting corn or soybean. Oat, barley, spring wheat, and some varieties of winter wheat and winter triticale are not winter-hardy in this region. Because the non-winter-hardy small grain varieties do not survive the winter, they do not need to be killed prior to planting the main crop, but they also do not produce as much shoot or root growth as winter-hardy varieties planted after full-season grain crops (Johnson et al., 1998). When the non-winter-hardy small grains are seeded in August after short-season crops or by overseeding into standing crops, they can produce substantial biomass. Winter-hardy legumes, such as alfalfa, hairy vetch, red clover, white clover, and sweet clover are also excellent cover crops, and they fix nitrogen as an added benefit. Legumes usually do not grow as well as the small grains during the fall and winter months and survive the winter much better and produce more biomass if they are interseeded into wheat or planted in late July or August following a short-season crop. Grasses (such as annual ryegrass) and brassicas (such as oilseed radish, oriental mustard, and forage radish) are also potential cover crops. Annual ryegrass grows well in cool weather and will overwinter in many parts of Illinois and Indiana. In Iowa and northern parts of Illinois and Indiana, winter hardiness of ryegrass is cultivar- and location-dependent. The brassicas also grow well in cool weather, but many species do not overwinter in the Upper Midwest. Brassicas have been shown to suppress nematodes, some diseases, and winter annual weeds. Some varieties of oilseed radish, which produce large roots, have been used to alleviate compaction. My work in Iowa, however, has been mostly with oats or winter rye.

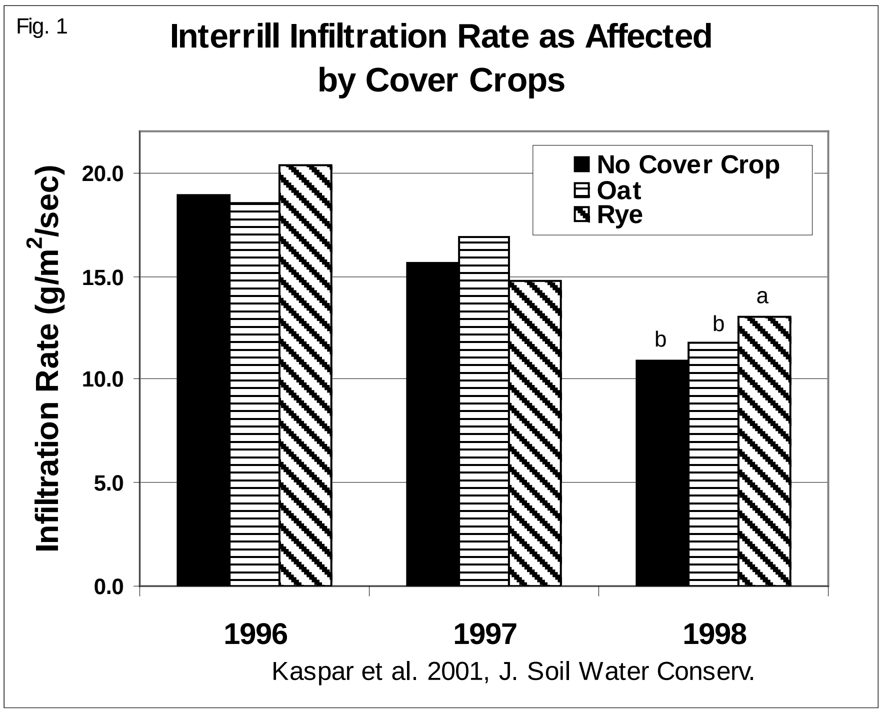
The basic premise for using cover crops is to reduce fallow periods in cropping systems. Natural ecosystems typically have some plants growing, covering the soil, transpiring water, taking up nutrients, fixing carbon, and supporting soil fauna for most of the year the ground is not frozen. Agricultural cropping systems producing grain and oilseed crops in temperate regions typically only have living plants for four to six months of the year and are fallow for the remaining six to eight months. For example, corn or soybean planted in Iowa on May 1 would be mature by Oct 1, a period of only 5 months, and during part of that time the plants are very small or are nearing maturity. Additionally, many tillage and fertilizer application practices bury residues and leave soil bare and exposed during fall, winter, and early spring. As a result of these fallow periods in annual cropping systems, soil is left unprotected from erosive forces, nutrients and organic matter are lost or not replenished, runoff increases, soil fauna are stressed or die out, and soil productivity diminishes. Thus, inserting cover crops into fallow periods in cropping systems can improve or maintain soil productivity and protect water quality. Although cover crops can have multiple benefits, I am going to present information on the effect of winter rye and oat cover crops on soil erosion and nitrate leaching.

Erosion:

Erosion continues to be one of the primary causes of reduced productivity or soil quality. In many cases, highly productive topsoil moves from upland soils with shallow topsoils to lowland areas with deep topsoils and never leaves the field. Over time, yields decrease on the upland soils and often stay the same or decrease on the lowland soils. In cases where runoff and sediment reach surface waters, water quality also is degraded. Sediment continues to be the number one contaminant of surface waters in the Midwest. Additionally, sediment and runoff carry phosphorus, nitrogen, organic matter, fecal bacteria from manure, and agricultural chemicals to surface waters.

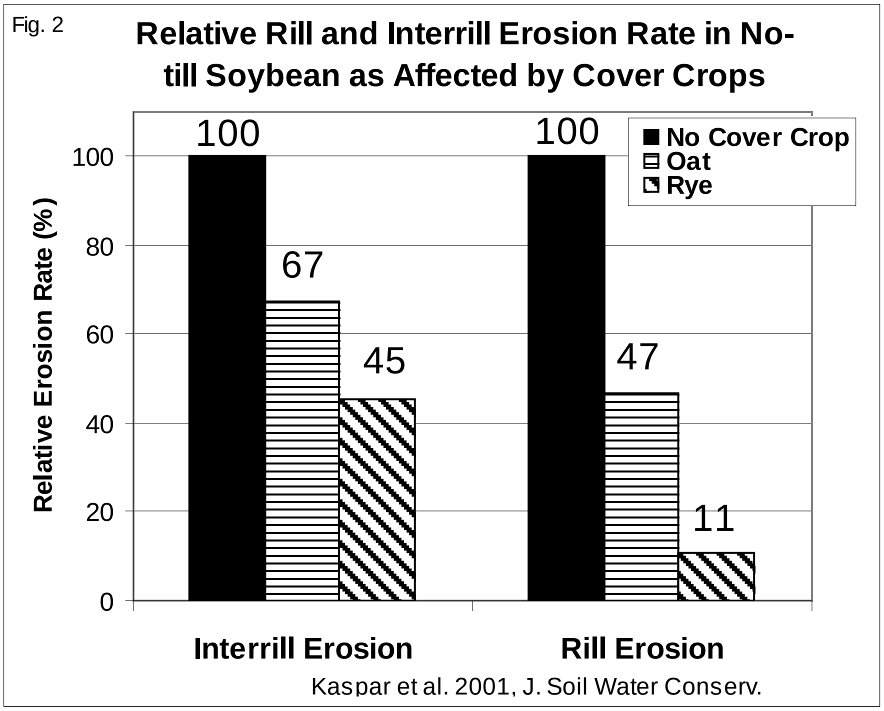
Reducing erosion is one of the main reasons for growing cover crops. Cover crops provide living canopy cover during the fallow months of grain cropping systems and they replenish surface residues and organic matter left by the preceding crop. The use of cover crops for erosion control is based on maintaining continuous ground cover to protect the soil against raindrop impact, increasing infiltration to reduce runoff volume, reducing the flow rate of runoff across the soil surface, and binding of soil particles with plant roots. Obviously, the erosion reduction caused by cover crops is more pronounced following crops that do not produce large amounts of residue or in situations where the residue is harvested, is incorporated with field operations, or decomposes rapidly. Thus, cover crops have the potential to substantially reduce erosion in the Upper Midwest when they follow manure incorporation, soybean, corn harvested for silage, seed corn production, and vegetable crops.

We conducted a study in central Iowa over 3 years where we measured erosion, runoff, and infiltration with and without rye and oat cover crops using simulated rainfall in April following no-till soybean on a 4.4% slope (Kaspar et al., 2001). Because the cropping system was no-till with a corn-soybean rotation, residue cover without a cover crop averaged 78% and was not increased by the cover crop. The rye cover-crop treatment increased infiltration and reduced runoff in only one of the three years (Fig 1). Both oat



and rye cover crops, however, decreased interrill and rill erosion (Fig. 2). Interrill erosion, also known as sheet erosion, is the detachment of soil by raindrop impact and subsequent movement by diffuse water flow across the surface. Rill erosion, on the other hand, is the detachment and movement of soil caused by concentrated water flow across the soil surface. Both oat and rye cover crops reduced both interrill and rill erosion even though neither cover crop measurably increased residue cover or infiltration in all years. We attributed the reductions in erosion in this system to a reduced water flow rate across the soil surface, anchoring of residues, and increased binding of soil by roots. In particular, in plots without cover crops, water flowing across the soil surface dislodged and moved residue, which exposed the surface and made it more susceptible to erosion. Thus, cover crops can significantly reduce erosion even in cropping systems with high levels of residue cover.

Fig. 2



Using cover-crop growth data from central Iowa, we prepared cover crop vegetation files for RUSLE2, which is a model used by NRCS to estimate erosion potential of cropping systems for conservation planning. Then, using the slope, soils, and climate data for our erosion experiment site, we estimated potential erosion for the system we had in place and for a continuous corn silage system (Table 1). The estimated erosion for the no-till corn-soybean rotation was reduced 0.9 t/ac/yr or 43% by a rye cover crop, which is similar to the substantial reduction measured in the field experiments. For the continuous corn silage system, which leaves much less surface residue after harvest, the predicted erosion was considerably greater without a cover crop (4.8 t/ac/yr) and a rye cover crop reduced predicted erosion by 2.9 t/ac/yr. This preliminary modeling exercise demonstrates that a rye winter cover crop has the potential to reduce erosion even more in low residue systems like corn silage. At this time, however, NRCS databases do not have tested vegetation files for the various cover crop species, cropping systems and states in the Upper Midwest, because cover crops have not been used extensively.

Table 1. RUSLE2 Erosion Estimates Using Beta Version of Cover Crop Vegetation Files

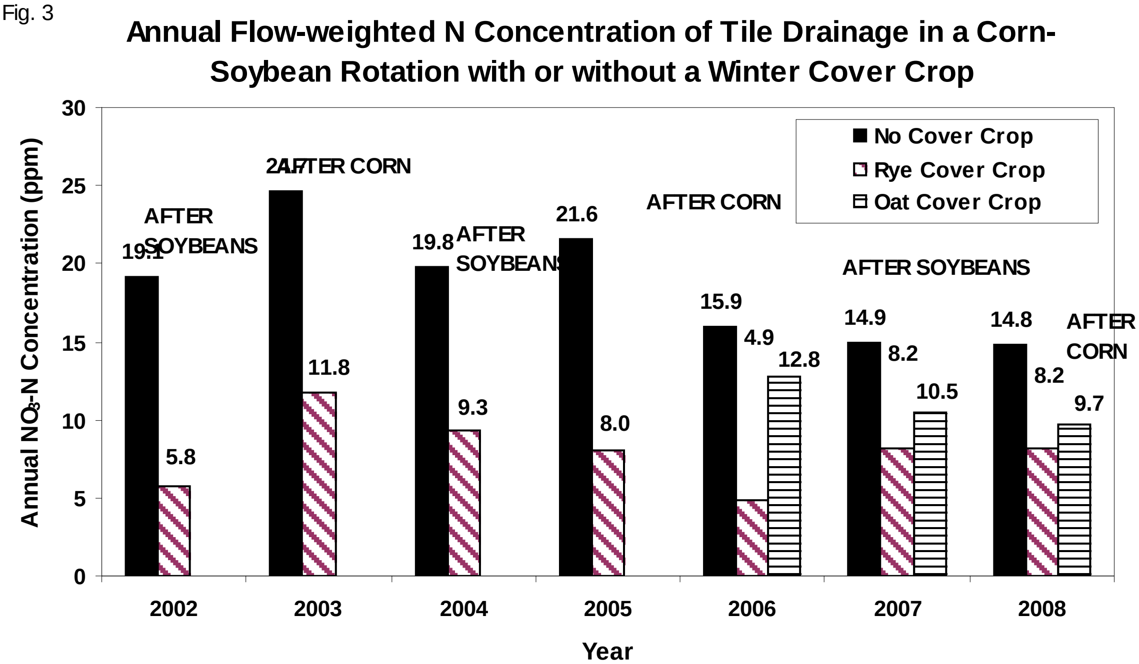
- Corn–Soybean rotation, NT, spring anhydrous, 5% slope, 150 ft slope length, Ames, IA
  - without rye cover crop = 2.1 t/ac/yr
  - with rye cover crop = 1.2 t/ac/yr
- Continuous Corn Silage, NT, spring anhydrous, 5% slope, 150 ft slope length, Ames, IA
  - without rye cover crop = 4.8 t/ac/yr
  - with rye cover crop = 1.9 t/ac/yr

Nitrogen Leaching:

In the Upper Midwest, nitrate concentrations in surface waters often exceed the 10 ppm maximum contaminant level (MCL) for drinking water set by EPA—and a significant proportion of the nitrate in surface waters comes from agricultural land used for corn and soybean production. Attempts to reduce nitrate losses to surface waters in this region have focused on N fertilizer management. Numerous studies, however, have shown that nitrate losses can still be substantial even in the soybean year of the rotation when no N fertilizers are applied or in the corn year even when N fertilizers are applied at less than the economic optimum rate (Jaynes et al., 2001). One of the reasons that fertilizer management alone will not solve the problem is that most of the NO_3 losses to drainage water or deep percolation occur between maturity and emergence of the corn and soybean crops. In other words, most of the losses occur during the fall, winter, and early spring when the ground is fallow and corn and soybean crops are not taking up water and nutrients. Thus, a winter cover crop growing during this fallow period and taking up nitrate has the potential to reduce these losses.

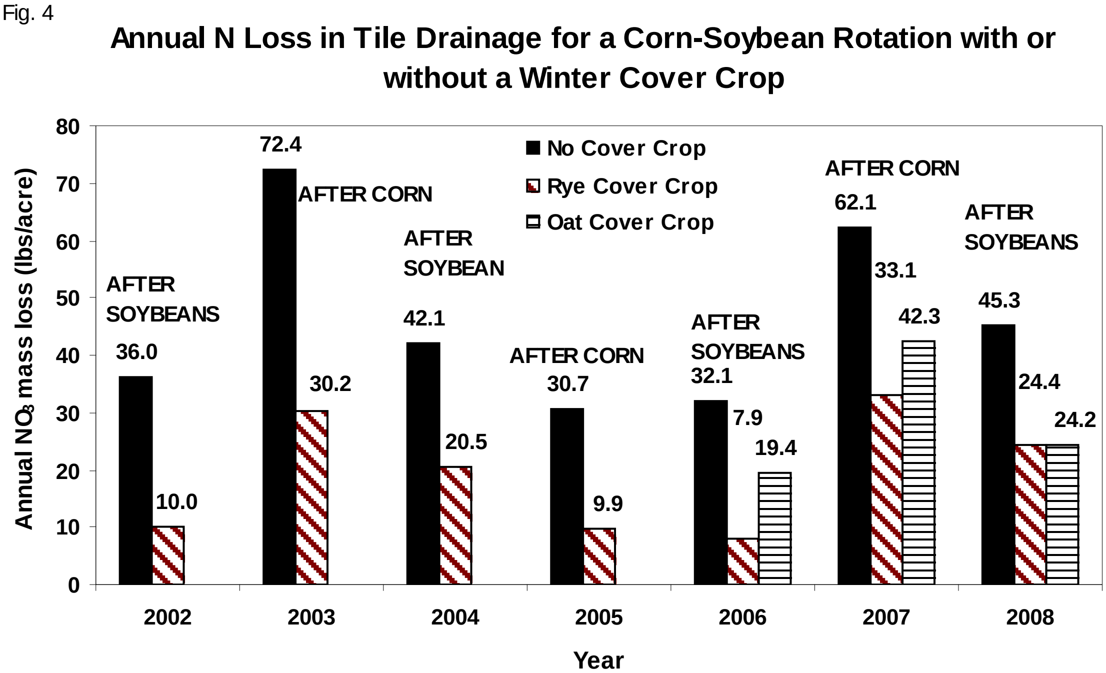
We conducted an experiment near Ames, Iowa, where we monitored the nitrate concentration and load in tile drainage of a no-till corn-soybean rotation with and without cover crops. In the original study (Kaspar et al., 2007) we used a rye cover crop, and in later years we had both rye and oat cover crops. We had expected that the cover crops would reduce the total amount of water passing through the tiles, but that did not prove to be the case. In spite of this, both the rye and oat cover crops reduced the nitrate concentration of drainage water in the tile lines (Fig. 3). In all years except 2003, the rye

Fig. 3



cover crop reduced the nitrate concentration of drainage water to less than 10 ppm. The total amount of N lost in tile drainage each year (Fig. 4) shows several things. First, the rye cover crop treatment reduced the amount lost by at least 47% each year. Second, surprisingly, even the oat cover crop, which only grows in the fall, reduced N loss by at least 32%. Third, substantial losses of N occurred each year, regardless of the crop or whether N fertilizer was applied. Nitrogen fertilizers were applied only in late May or early June of the corn years (2002, 2004, 2006, and 2008) and, because most of the drainage occurred in March, April, and May, fertilizer N probably didn't affect N losses much in the year it was applied. For example, the "no cover crop" treatment had the

Fig. 4



greatest loss N in 2003, but one of the lowest losses in 2005, which both occurred after a corn year. So while some of the losses in 2003, 2005, and 2007 may be coming from residual fertilizer, some of the nitrogen in drainage water is also coming from mineralization of soil organic matter. The corn-soybean rotation without a rye cover crop lost 321 lbs of N/acre (Table 2) in the tile drainage water over 7 years. This was 185 lbs of N/acre more than the rye cover crop treatment. We believe that the N taken up by the cover crops is being stored in soil organic matter, and we are continuing these studies to try and determine that. If this is true, the N stored by the cover crop will be slowly released from the soil organic matter over time and will improve the soil's background level of N availability and overall productivity.

These studies on nitrate leaching and soil erosion demonstrate that winter cover crops can have substantial effects on both soil and water quality by keeping plants growing in corn and soybean fields during the normally fallow months between harvest and planting.

Table 2

Total Nitrate-N Lost 2002-2008

Treatment	Nitrate-N lost	
	7-yr total lbs/acre	7-yr avg lbs/acre
Corn-soybean	321	46
Corn-Soyb w. Rye	136	20
Difference	185	26

2002-2004 from Kaspar et al. J. Environ. Qual. 36:1503-1511.

REFERENCES

Jaynes, D.B., T.S. Colvin, D.L. Karlen, C.A. Cambardella, and D.W. Meek. 2001. "Nitrate loss in subsurface drainage as affected by nitrogen fertilizer rate." *J. Environ. Qual.* 30:1305-1314.

Johnson, T.J., T.C. Kaspar, K.A. Kohler, S.J. Corak, and S.D. Logsdon. 1998. "Oat and rye overseeded into soybean as fall cover crops in the upper Midwest." *J. Soil Water Conserv.* 53:276-279.

Kaspar, T.C., J.K. Radke, and J.M. Laflen. 2001. "Small grain cover crops and wheel traffic effects on infiltration, runoff, and erosion." *J. Soil Water Conserv.* 56:160-164.

Kaspar, T.C., D.B. Jaynes, T.B. Parkin, and T.B. Moorman. 2007. "Rye cover crop and gamagrass strip effects on NO_3 concentration and load in tile drainage." *J. Environ. Qual.* 36:1503-1511.