THE OHIO STATE UNIVERSITY EXTENSION

FACT SHEET

Agriculture and Natural Resources

Using Cover Crops to Improve Soil and Water Quality

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This is a literature review of cover crop benefits from Dabney et al. 2001 and Dabney 1996. Cover crop benefits include: soil erosion protection, reduced nutrient leaching, carbon sequestration, weed suppression, and integrated pest management. Cover crops protect water quality by reducing losses of nutrients, pesticides, and sediment. Only a small percentage of farmers actually plant cover crops because most farmers believe the disadvantages outweigh the advantages. This fact sheet attempts to highlight the physical, chemical, biological, and economic benefits of using cover crops in a sustainable cropping system.

Cover Crops and Water Quality

Sediment

Sediment is agriculture's number one pollutant. Water erosion occurs even on flat soils and is especially a problem on hilly soils. Cover crops produce more vegetative biomass than volunteer plants; transpire water, increase water infiltration, and decrease surface runoff and runoff velocity. If the velocity of runoff water is doubled in a stream, the carrying capacity of water or the stream competence to transport soil sediment and nutrients increases by a factor of 2^6 or 64 times. *So 64 times more sediment and nutrients are lost with moving water when the velocity is doubled* (Walker et al. 2006). Cover crops protect soil aggregates from the impact of rain drops by reducing soil aggregate breakdown. By slowing down wind speeds at ground level and decreasing the velocity of water in runoff, cover crops greatly reduce wind and water erosion.

Nutrients

Cover crops can increase nutrient efficiency through reduced soil erosion (less soil organic matter and soil nutrients losses in the topsoil). Cover crops are scavengers of residual nitrogen (N), converting N to proteins (enzymes,

Table 1. Advantages and Disadvantages of Using Cover Crops

Advantages	Disadvantages
Reduce soil erosion, increase residue cover	Planted when time and labor is limited
Increased water infiltration	Addition costs (planting and killing)
Increased soil organic carbon	Reduced or increased soil moisture effects depending on weather or management
Improved soil physical properties/reduced soil compaction and improved field trafficability	Difficult to incorporate cover crops with tillage
Recycle nutrients, fix nitrogen with legumes	May increase disease risks
Improve weed control, beneficial insects, disease suppression	May increase insect pests
Wildlife habitat and landscape aesthetics	Allelopathic effects

hormones, amino acids). Nitrogen uptake depends on soil N, climate, cover crop species, seeding rate, planting and killing date. Winter grass cover crops (cereal rye, annual ryegrass) accumulate N in the fall and winter due to fast root growth. After the boot stage, there is not much additional nitrogen uptake with grasses. Legumes accumulate nitrogen longer in the spring but with high soil N, legume N fixation decreases. *Use grass or brassica species to absorb and recycle N if excess N occurs from manure or fertilizer. Use legumes to supplement N for the next crop if more N is needed for fertilization.*

Pesticide Usage

Pesticide usage can either increase or decrease with cover crops. If cover crops are difficult to control, pesticide use may increase. In South America, 95% of some areas use cover crops with no-till to promote weed suppression through dense plantings and competition with weeds for sunlight, water, and nutrients. Cereal rye has been shown to have an allelopathic affect on weeds for up to 6 weeks. Living mulches are better at suppressing weeds than dead mulches. In soybeans, Pythium disease (damping off) decreases because the delaying planting (5 to 14 days) warms the soil. In long-term studies, cover crops reduced the populations of some soil-borne pathogens. Soybean cyst nematodes are significantly reduced by annual ryegrass and cereal rye cover crops. Some green cover crops attract army worm, cutworms, and slugs so the cover crop needs to be killed 3 to 4 weeks before corn planting. *Cover crops can be used as a trap crop for corn earworm, tarnish bug, and other insects if the cover crop is killed early.* Letting cover crops grow and mature may allow populations of beneficial insects to increase. Cover crops complement no-till more than conventionally tilled soils because cover crops may be difficult to incorporate into the soil. There is a need to understand insect cycles and pest interactions with cover crops.

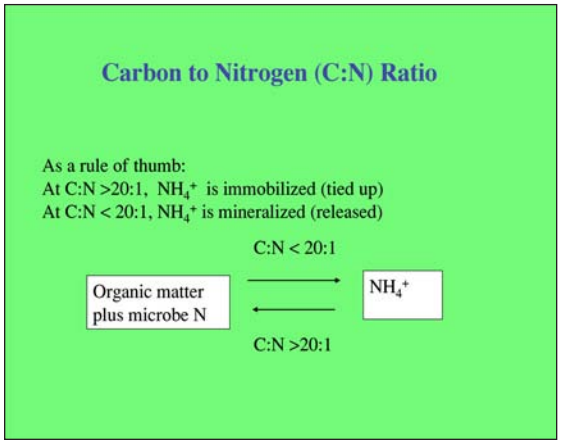
Cover Crops and Soil Quality

Soil Carbon

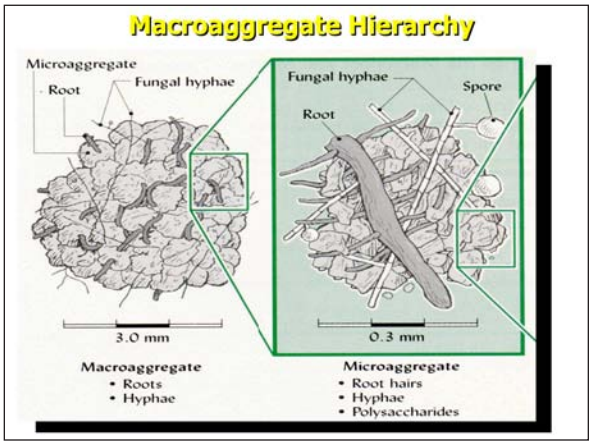
Cover crops can greatly increase carbon inputs into the soil. Reduced tillage plus carbon (C) inputs from residues increase soil organic carbon. Both C and N are needed to form soil organic matter. Grass cover crops may contribute N as scavengers or legumes may fix additional N. Grasses contributes more carbon than legumes due to a higher C:N ration. At C:N ratios less than 20, N is released. The average C:N ratio in the soil is around 10–12:1 indicating that N is available. The soil microbial biomass and enzymatic activity increases with cover crop usage. *Cover crops increase SOM, macroporosity, soil permeability, mean aggregate size, and aggregate stability (macroaggregates vs. micro-aggregates).* Deep rooted cover crops increase subsoil water holding capacity. A bare soil holds 1.7 inches water while a continuous living cover holds 4.2 inches of soil water (USDA-NRCS Engineering handbook). Increased soil structure and stability may improve the soil's capacity to carry machines and improve field accessibility and decrease soil compaction.

Nitrogen Fertility

The release of N from cover crops for the following crop at the right time is an issue. If nutrients are tied up or immobilized from the soil, crop yields can decrease especially in no-till corn. *The release of N depends on cover crop species, growth stage, management, and climate.* An early spring kill of grasses promotes a lower C:N ratio and a faster release of N. Legumes tend to have a lower C:N ratio but if either grasses or legumes are allowed to reach full maturity, N release is delayed. Slower N release occurs more in dry weather than in wet years due to decreased microbial activity needed to decompose residues and release N. N volatilization of cover crops left on the soil surface



Carbon to nitrogen (C:N) ratio



Macroaggregate hierarchy
(from Tisdall & Oades, 1982)

has been suggested but only small loses of NH_3 have been shown to occur with no-till. Leaching (37%) of nitrates into the soil had a bigger effect than volatilization (4–6%) losses. N uptake of cover crops varied from 51 to 270 lbs/acre (57 to 296 kg N/ha) to the next crop. *If 50% of N is recycled, cover crops may supply 22 to 120 lbs/acre (25 to 132 kg N/ha) to the next crop.* Late planted cover crops may not have as much vegetative growth but may impact soil and water quality through reduced soil erosion.

Mycorrhizal Fungus

Cover crops increase mycorrhizal fungus activity promoting a symbiotic relationship with the plants' roots for water and nutrient uptake. *Plants provide the polysaccharides and the mycorrhizal fungus provided the protein to form a glycoprotein called glomalin which promotes soil aggregate stability (more macro-aggregates) and improved soil structure.* Mycorrhizal fungus grows better in undisturbed soils. No-till and actively growing roots promote this reaction to occur. The majority of soil microbes are located next to growing roots with 10,000 times more microbes located in the rhizosphere next to the root than in bare soil.

Soil Water

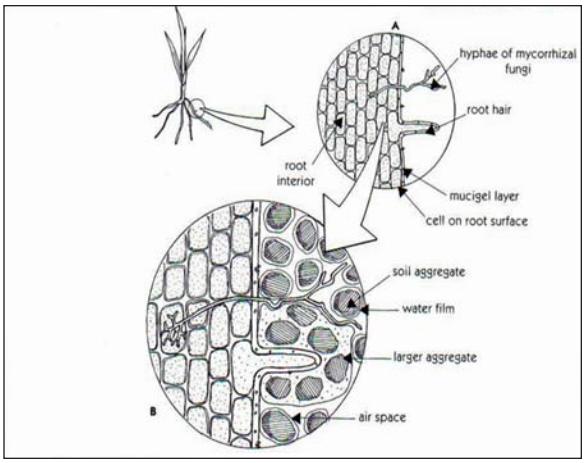
Cover crops may benefit or hurt crop yields due to changes in soil moisture. While cover crops increase water infiltration, they also transpire soil water and dry out fields, possibly affecting yields. In Ohio, fields are wet 7 out of 10 years in the spring so transpiration from living covers may be beneficial to dry out the soil. However, if a cover crop is killed late after considerable cover crop growth and then it turns wet, the cover crop may trap soil moisture and delay planting. If an early spring drought occurs, cover crops may hurt crop yields from reduced soil moisture. However, deep rooted cover crops improve corn rooting depth to attain subsoil moisture and moisture is conserved by mulching the topsoil in a dry year. A pound of soil organic matter has the ability to absorb 18–20 pounds of water, which is beneficial in a dry year. Some of the negative soil moisture effects from using cover crops can be negated as soil compaction decreases and soil quality improves with time. Cover crops may be utilized to improve soil physical, chemical, and biological properties that improve soil drainage but it takes time to make these changes if soil compaction is high and soil quality is low.

Soil Temperature

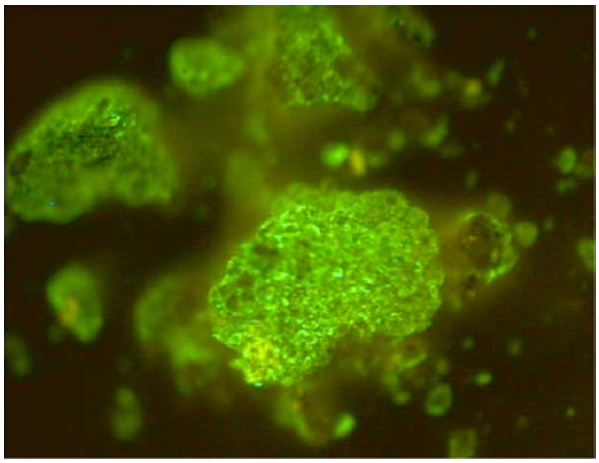
Living cover crops can significantly alter soil temperatures. *Cover crops decreased the amplitude of day and night temperatures more than average temperatures resulting in less variability*. Cover crop mulches protect the soil from cold nights and slow cooling. This may be a benefit in hot regions, but may slow growth in cooler regions. Winter cover crops moderate temperatures in the winter. Standing crops have higher soil temperatures than flat crops. Row cleaners can be used to manage residues to improve soil temperatures in no-till fields. *Temperature and rainfall are the primary climatic variables affecting cover crop selection and establishment.* Broadcasting cover crop seed is faster and cheaper but stand establishment depends on rainfall and good seed to soil contact. Most winter cover crops need to be planted in late summer or early fall (by September) to survive the winter (except cereal rye which can be planted later).

Summary of Cover Crop Effects on Soil and Water

- Cover crops are grown when the soil is fallow.
- Increase the solar energy harvest and increase carbon in the soil.
- Provide food for macro- and micro-organisms and other wildlife.



Mycorrhizal fungus and plant roots
(Photo from *Building Soils for Better Crops 2nd Ed.* by Fred Magdoff and Harold van Es)



Glomalin surrounding soil particles
(Photo from Dr. Sara Wright, USDA-ARS)

Soil erosion, sediment, and nutrient losses from cropland (NRCS photo)

Soybeans no-tilled into a cover crop (photo from Dr. J. Morales Sa)

- Increase evapotranspiration, increase water infiltration, and decrease soil bulk density.
- Reduce sediment production, decrease impacts of raindrops, decrease runoff velocity.
- Increase soil quality by improving the biological, chemical, and physical soil properties.
- Increase organic carbon, cation exchange capacity, aggregate stability and water infiltration.
- Grass and brassica species are great nitrogen scavengers and increase carbon inputs.
- Legumes increase soil nitrogen through nitrogen fixation.
- Cover crops grow best in warm moist areas but may hurt yields in semi-arid regions.
- Soil temperatures may impact yields.
- Systems are needed that reduce the cost of cover crop establishment and killing.
- Cover crops improve soil and water quality. May reduce nutrient and pesticide runoff by 50% or more, decrease soil erosion by 90%, reduce sediment loading by 75%, reduce pathogen loading by 60%.

Acknowledgments

This fact sheet was produced in conjunction with the Midwest Cover Crops Council (MCCC). Outside reviewer: Mark Fritz, Ohio Department of Agriculture.

References

1) Dabney, S.M. 1996. Cover crop impacts on watershed hydrology. *Soil and Water Conservation, 53* (3), 207–213.
2) Dabney, S.M., J.A. Delgado, and D.W. Reeves. 2001. Using winter cover crops to improve soil and water quality. *Community of Soil Science Plant Analysis, 32* (7&8), 1221–1250.
3) Tisdall, J.M., and J.M. Oades. 1982. Organic matter and water-stable aggregates in soils. *Journal of Soil Science, 33*, 141–163.
4) Walker, D., D. Baumgartner, K. Fitzsimmons, and C.P. Gerber. 2006. Chapter 18: Surface Water Pollution, In *Environment & Pollution Science*. Eds. I.L. Pepper, C.P. Gerber, and M.L. Brusseau. p. 283.
5) *USDA-NRCS Engineering Field Handbook*. Chapter 2, Hydrology.

Related Fact Sheet Publications

Crop Rotations with Cover Crops
Understanding Soil Ecology and Nutrient Recycling
Homegrown Nitrogen
The Biology of Soil Compaction
Using Cover Crops to Convert to No-till