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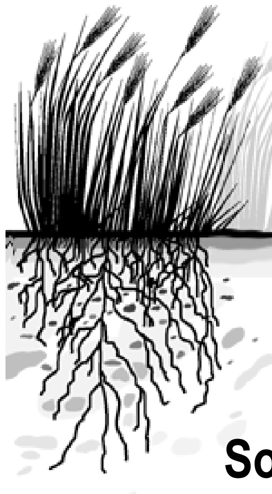

Soil Quality – Agronomy Technical Note No. 18

# Sod-Based Rotations:
## A Proven Old Practice to Improve Soil Productivity

### Historical overview

Sod-based rotations are those that alternate sod-forming grasses and legumes with row crops and cereal grains. The grass and/or legumes should break up the row crop cycle for more than 1 year.

Farmers in many countries, including France and England, have learned over centuries that grass-based systems are essential for maintaining the long-term productivity of soils (Albrecht, 1938). The most important benefits of sod relate to the accumulation of organic matter facilitated by the extensive root systems of perennial grasses. In fact, the productivity of sod-based virgin soils is typically associated with high levels of organic matter. As American settlers spread west, they cleared trees and sod and cultivated the land. The result of this clearing and plowing was the loss of one of our most valuable resources—soil organic matter.

Many long-term studies in the United States have documented trends of organic matter losses on agricultural land (NRCS Soil Quality Institute, 2001). Cultivated cropland typically has only 50% of the organic matter of soils that support native vegetation. These same studies show significant advantages of grass-based systems over continuous cropping for maintaining or increasing the content of organic matter. For example, the Morrow plots in Illinois and the MacGruder plots in Oklahoma showed that fertility, productivity, and organic matter content all declined under continuous cropping systems and then leveled off after approximately 75 years. The organic matter levels of these soils began around 4% and steadily degraded to 1–1.5% under the corn-soybean-wheat rotation. In contrast, the highest organic matter levels were under the long-term rotations with grass (Wright et al., 2002).

Unfortunately, when cultivated crops are grown in rotation with grass, organic matter levels rapidly decline and rise again only when the land is returned to sod. Thus, it is critical to use conservation tillage during the cropping phase of a sod-based rotation to preserve the benefits of grasses and legumes.

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This is the eighteenth in a series of technical notes about the effects of land management on soil quality.

Series written by:
Soil Quality Institute
411 S. Donahue Dr.
Auburn, AL 36832
334-844-4741 x177

soils.usda.gov/sqi

History has shown that the benefits of sod-based rotations may be greatest on soils that have limitations because of erosion hazards, drought stress, or restricted soil depth. In the past, many of these marginal lands were farmed as mixed crop-livestock enterprises. As agriculture became more specialized after World War II, sod became less common on farms. Soil degradation (from loss of organic matter and erosion) coupled with higher costs of inputs forced many farmers to quit farming and to plant trees or a permanent grass cover. These same conditions–soil degradation and high input costs–have created a renewed interest in including sod-based rotations and cattle grazing along with crop production on a variety of lands.

## Benefits of sod-based rotations

Sod-based rotations provide several benefits to commercial agriculture. Perhaps the greatest benefit is improved yields as a result of enhanced soil quality (Reeves, 1997). The fibrous roots from grasses and the taproot systems of legumes help to build organic matter levels and improve soil structure. Including sod in the crop rotations increases diversity and breaks pest cycles, thus reducing pressure from insects, root-feeding nematodes, weeds, and diseases. Adding legumes to sod rotations supplies nitrogen to the soil, reducing the amount that must be applied for the accompanying grasses.

Many farmers agree that crops grown after years of grass sod generate 50–100% higher yields than continuous crops. For example, the average peanut yield in the Southeast U.S. is about 2,500 lbs per acre, but yields after bahiagrass (*Paspalum notatum* L.) are often 3,500–4,500 lbs per acre. Economic modeling showed that profits for cotton and peanuts in a sod-based rotation were about two times greater than those for a peanut-cotton-cotton rotation (Marois et al., 2002). Yield increases can be attributed to soil quality improvements following perennial sod, including increased soil organic matter and water-holding capacity, better soil structure and water infiltration, and decreased erosion compared to continuous cropping or even following green manure cover crops (Wright et al., 2002). Cooper and Morris (1973) referred to soil organic matter and associated improvements in soil properties when they stated that the sod in a wheat-sod rotation put the *heart* back into the soil.

Deep-rooted sods can increase the potential rooting depth for subsequent crops (Marois et al., 2002). Elkins et al. (1977) showed the importance of grass rotations for increasing rooting depths on the Southeast Coastal Plain. They calculated that, given an evaporation rate of 0.17 inches of water per day and available water of 1 inch per foot of soil, plants with a 6-inch rooting depth would experience water stress in 3 days without rainfall or irrigation. Plants with a 5-foot rooting depth would not experience water stress until 30 days after rainfall.

Since 1962, researchers in Uruguay have studied the economics and the soil conservation effects of combining pasture and cropland in rotations. Their interest in sod-based rotations began in response to the risk of erosion on continuously cultivated cropland. Leading farmers began to rehabilitate the land by establishing pastures and then by rotating in crops after the pasture. Initially, these sod-based rotations included conventionally tilled crops. Organic matter levels rose as high as 4% during sod years and decreased as low as approximately 3.3% during the cultivated crop years (Garcia-Préchac et al., 2004). In contrast, continuous cropping resulted in a steady decline in soil organic matter from 3.5% in 1962 down to approximately 2.8% in 1990. Bulk density of these soils began at 1.12 $g/cm^3$, rose to 1.28 $g/cm^3$ after 4 years of crops, and dropped back to 1.2 $g/cm^3$ after 3 years of grass (Garcia-Préchac et al., 2004).

This study showed a significant economic advantage to sod-based rotations because of lower nitrogen fertilizer inputs, higher productivity, and a gross income that was similar to or higher than that of continuous cropping. The mean gross income (profit after variable costs) was $120 per acre for the sod-based rotation and $70 per acre for continuous cropping (Garcia-Préchac et al., 2004).

A characteristic of sod-based rotations using conventional tillage is the roller coaster effect as soil organic matter rises during the grass cycle and declines during the crop cycle. To address this effect, researchers in South America and in the Southeast U.S. have been looking at rotating sod with no-till crops. Under this no-till system, residue decomposition is reduced and soil organic matter levels are maintained during the cropping portion of the rotation (Garcia-Préchac et al., 2004). Table 1 shows the effect of no-till vs. conventional tillage on erosion losses, carbon change, and relative yields from studies in Uruguay.

**Table 1.─Erosion, yield, and soil carbon in sod-crop rotation**
Adapted from Garcia-Préchac et al., 2004

| Cropping system | Soil loss[1] (tons/acre) | Relative yield– 1st cycle (%)[2] | Relative yield– 2nd cycle (%) | Soil organic carbon (tons/acre) |
|---|---|---|---|---|
| Continuous crop (conventional) | 8.5 | NA | NA | 15.2 |
| Continuous crop (no-till) | 1.3 | 96% | 106% | 18.7 |
| Crops-pasture (conventional)[3] | 3.2 | 100% | 100% | 16.5 |
| Crops-pasture (no-till) | 0.7 | 96% | 120% | 18.3 |

[1]Mean soil losses for two sites.
[2]Cycle of rotation included 4 years of crops (1st cycle), 4 years pasture, and 4 years of crops (2nd cycle).
[3]Crops-pasture (conventional) is 100% relative yield.

## Transition from pasture to no-till

The above results show the advantages of using conservation tillage in conjunction with sod-based rotations, but conversion to no-till raises a few concerns that need to be addressed. One area of concern noted by researchers in Uruguay was infestation of bermudagrass (*Cynodon dactylon* [L.] Pers.) into cool-season grass. When the sod was killed chemically (with glyphosate), some of the bermudagrass survived and competed with the crop. This competition explains the relative yield of 96% in the first cycle of crops after grass (table 1). By the second cycle, the bermudagrass was under control and there was more fallow time between killing the sod and planting the crop. The researchers compared 15 days fallow time after killing sod to 70 days fallow time. Wheat yields were 22.3 and 46.3 bushels/acre, respectively, and nitrate levels in the top 6 inches were 10 and 35 ppm, respectively (Garcia-Préchac et al., 2004). When no-till crops are grown after sod, plenty of time is needed for dead sod to mineralize and release nitrogen prior to planting. Applying nitrogen starter fertilizer would lessen this concern.

Another concern associated with converting any cropping system from conventional tillage to no-till is a pre-existing plowpan. The no-till system inherits the problem. The problem can be eliminated eventually by root growth, enhanced biological activity, and increased organic matter from the increased root growth and reduced tillage of sod-based rotation systems.

## Compaction from grazing

In addition to tillage, grazing is another potential source of compaction in sod-based systems. A study in the Georgia Piedmont showed some compaction associated with grazing but less than that produced by machine traffic in haying operations. Compared to hayland, bulk density (BD) was lower in grazed pasture at 0–0.8 inches but higher at 0.8–1.6 inches. In the top 2.4 inches, unharvested grassland had the lowest BD, grazing land was intermediate, and hayland tended to have the highest BD. This study showed that cattle at densities of 2 to 4 head per acre continuously grazing bermudagrass for 4.5 months in the summer did not contribute to excessive soil compaction (Franzluebbers et al., 2001).

**Table 2.─Surface residue and soil organic carbon under grazed and hayed bermuda-grass (Franzluebbers et al., 2000)**

| Property | Grazed | Hayed |
|---|---|---|
| | Carbon (tons/acre) | |
| Surface residue | 0.8 | 0.5 |
| Soil (0-5 cm) | 8.2 | 6.0 |
| Soil (5-12.5 cm) | 5.3 | 4.7 |
| Soil 12.5-20 cm | 3.4 | 3.1 |
| Soil total (0-20 cm) | 17.0 | 13.9 |
| Total carbon (surface residue and soil) | 17.8 | 14.4 |

Franzluebbers and Stuedemann (2003) reported variations in bulk densities for different land uses. At a depth of 0–8 inches, BD was 1.38 g/cm$^3$ under 50-year-old grazed tall fescue pasture, 1.52 g/cm$^3$ under 40-year-old hayed bermudagrass, and 1.57 g/cm$^3$ under 24-year-old conservation tillage cropland. The lower bulk densities in grazing systems compared to haying systems are explained by soil carbon increases from the additions of manure as well as grazing management (table 2).

Other studies show more severe compaction from grazing, especially winter grazing of annual cover crops. Compaction from short-term grazing can inhibit the yield potential of subsequent crops. Touchton et al. (1989) measured soil compaction on a sandy loam down to 20 inches after 7 weeks of grazing winter rye, resulting in an average corn yield reduction of 14 bushels/acre. Yields were much improved by subsoiling or using a paraplow prior to planting corn (table 3).

Similarly, studies of winter grazing of cover crops in southern Alabama showed yield-limiting compaction down to 4–6 inches on a sandy loam. A similar study showed compaction down to 5 inches on a silt loam in northern Alabama (Siri-Prieto et al., 2003). Noninversion, in-row subsoiling can alleviate the effect of compaction on the yield. Before using tillage to reduce compaction in grazing systems, farmers should assess the extent of compaction (NRCS, 2003).

**Table 3.─Corn yield following grazed or ungrazed cover crop (Touchton et al., 1989)**

| | Tillage for corn | | | | | |
|---|---|---|---|---|---|---|
| Rye treatment | No-till | No-till, w/ in-row subsoiling | Disk | Chisel | Turn plow | Paraplow |
| | Corn yield (bu/acre) | | | | | |
| Grazed | 57 | 65 | 46 | 60 | 66 | 77 |
| Not grazed | 82 | 87 | 69 | 72 | 71 | 73 |

## Economics of sod-based rotations

Incorporating short-term grazing into cropping systems has financial benefits. Research in Alabama found that contract grazing of stocker cattle in early spring (up to 140 days) offered returns of $70 to $225 per acre (Bransby et al., 1999). In studies of annual crop production with short-term grazing of winter annuals, researchers found that in-row subsoiling (noninversion subsoiling to 20 inches) with no-till reduced the effects of compaction caused by winter grazing and increased the net return per acre over growing only a cash crop (tables 4 and 5; Siri-Prieto, 2004).

Researchers at the University of Florida used a working business model to predict the potential income of continuous cropping of cotton and peanuts compared to a 4-year rotation consisting of 2 years of grazing cattle on bahiagrass followed by peanuts and cotton. Costs and yields were obtained from interviews with farmers, researchers, and extension specialists. Based on the interviews, the researchers assumed a 50% yield increase from adding grass to the rotation (from 650 to 975 lbs of cotton per acre). The model predicted that a 200-acre farm would yield $5,000 per year growing continuous cotton compared to $22,000 per year under the 4-year rotation if the 2 years of sod were not utilized. When grass was sold in rectangular bales the first year and grazed in a cow/calf operation the second year, the 200-acre farm yielded $31,000 per year (Marois and Wright, 2003).

**Table 4.—Return per acre–peanuts**

Stockers grazed on oat forage. Forage was cropped annually with a peanut-cotton rotation in southern Alabama. Returns are averaged over 3 years. (Siri-Prieto, 2004).

| Tillage | Peanut yield (tons) | Peanut net profit ($) | Animal net gain ($) | Total ($) |
|---|---|---|---|---|
| Chisel | 1.75 | 13 | 75 | 148 |
| Paratill[1] + no-till | 1.71 | 65 | 75 | 160 |
| KMC[2] + no-till | 1.84 | 105 | 75 | 180 |
| No-till[3] | 1.02 | -51 | 75 | 18 |

See footnotes at end of table 5.

**Table 5.—Return per acre–cotton**

Stockers grazed on ryegrass or oat cover crops. Forage was cropped annually with a peanut-cotton rotation in southern Alabama. Returns are averaged over 3 years. (Siri-Prieto, 2004).

| Tillage | Cotton yield (lbs) | Cotton net profit ($) | Animal net gain ($) | Total ($) |
|---|---|---|---|---|
| Chisel | 3,006 | 256 | 75 | 331 |
| Paratill[1] + no-till | 3,120 | 288 | 75 | 363 |
| KMC[2] + no-till | 2,987 | 263 | 75 | 338 |
| No-till[3] | 2,261 | 129 | 75 | 204 |

[1]Paratill is a bent-leg subsoiler.
[2]KMC is a straight-shank subsoiler.
[3]No-till without noninversion is not normally recommended on soils that are compacted on a recurring basis.

## Conclusions

Sod-based rotations help to control erosion, increase soil organic matter, and offer diversity, which helps to control diseases, insects, and weeds. The increased diversity and soil organic matter tend to improve productivity of crops grown in rotation with sod. In addition, the roots of sod improve the rooting depth for annual crops, thus reducing compaction and drought stress. Grazing systems can lead to surface compaction, especially on some soils that are grazed in winter. If no-till is integrated into sod-based rotations, many benefits of sod are preserved through the cropping phase of the rotation. After the grazing component of the rotation, farmers should measure for soil compaction prior to planting the next annual crop. Also, the farmers should provide plenty of time between killing the sod and planting the next cash crop to allow for N mineralization. Short-term grazing can supplement the income of sod-based rotations. These rotations are not for everyone but may be effective on farms that already have livestock or are in areas of marginal soils where annual cropping systems are economically and environmentally risky.

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