CHAPTER 20

Benefits of Perennial Forages in Rotations

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Perennial forages are grown on over 23 million ha (57 million ac) in the U.S., and alfalfa, hay and fodder crops are grown on 8 million ha (20 million ac) in Canada, based on the most recent Census of Agriculture (USA 2007; Canada 2006). Alfalfa is the most widely grown perennial forage species in both countries — 8.2 million ha (20 million ac) of pure alfalfa in the U.S. and 5.1 million ha (12.6 million ac) of alfalfa and alfalfa mixtures in Canada. Greatest acreage is in the upper midwestern and western states and the provinces of Ontario, Manitoba, Saskatchewan and Alberta. Alfalfa area has been declining steadily for the past 50 years in the U.S., while the area of soybeans and, more recently, corn has been increasing. In Canada, on the other hand, alfalfa area was increasing (at least until the 2006 census) because of the low profitability of small grain production. But, as we show in this chapter, incorporating perennial forages in the landscape produces great direct and indirect benefits to farmers and the public.

There is heightened public scrutiny of agriculture's environmental 'footprint' (water and air quality, greenhouse gas production, and energy use) so farmers, farm advisors and policy makers need to consider the ***total*** value of having perennial forages in their crop rotations. This includes the direct benefits of perennial forages used in rotation or as a cover crop and the more far-reaching benefits of perennial forages in terms of improved soil and water quality.

One of the reasons for the increase in corn area and decrease in alfalfa area in the U.S. is that the amount of corn silage fed to dairy herds has risen significantly in the last 20 years. The reasons for increased corn are higher yield and dietary energy per hectare from corn silage, improvement of corn silage hybrids, problems with winterkill of alfalfa,

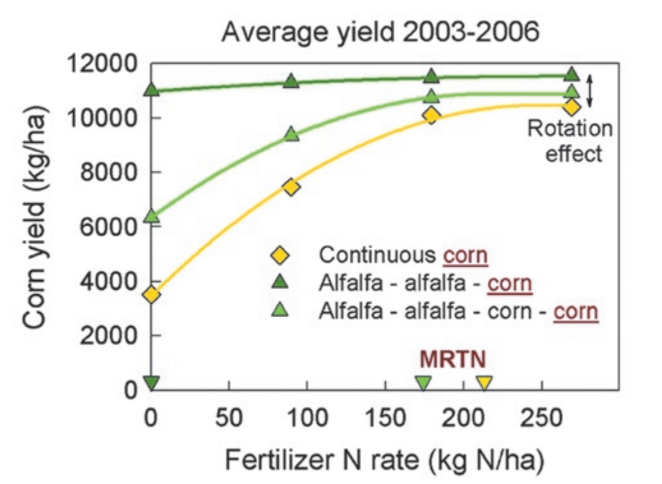

Figure 1. Grain yield response to fertilizer N for continuous corn and corn following alfalfa (first and second year). MRTN, Maximum Return to N, is the economically optimum N rate. (for lb/ac multiply by 0.9) Mallarino and Pecinovsky 2006.

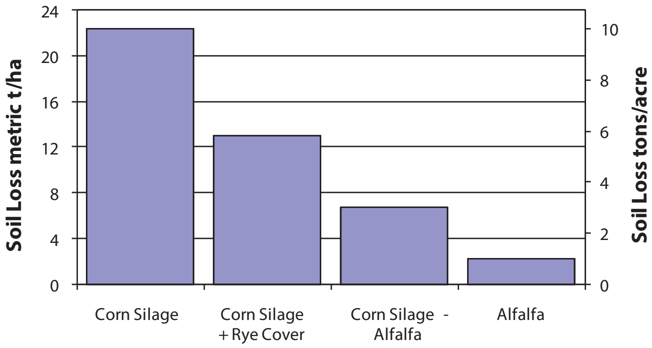

Figure 2. Cropping system effect on soil loss. Rotation is 2-yr corn and 3-yr alfalfa. Estimates by Brian Hillers, USDA-NRCS, were based on the RUSLE2 equation for a Miami silt loam soil in Dodge County, WI.

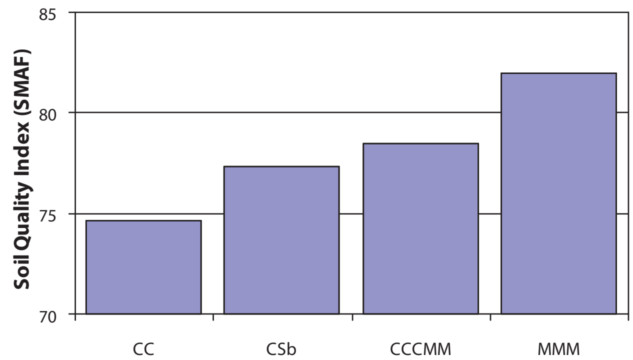

Figure 3. Rotation effects on soil quality index (SMAF). 30-yr average, Lancaster, WI. C=corn, Sb=soybean, M=alfalfa/red clover. (Karlen et al. 2006.)

excessively high rumen degradability of alfalfa protein and better opportunities for manure application with annual crops (Shaver, undated).

There are, however, a number of economic and environmental benefits from production of alfalfa and other perennial forages that are sometimes overlooked when comparing them to silage corn. One of the most important economic reasons to incorporate perennial forages into a rotation is the N credit for the crop following the forage:

- In NY, first-year corn silage yield and quality after perennial forages did not respond to N rates higher than 35 kg/ha (32 lb/ac) banded as a starter, regardless of the legume composition of the previous sod (Lawrence et al. 2008).
- In four separate studies in IA, WI, MN and PA, grain yield of corn following alfalfa responded to added N fertilizer in only seven of 61 sites (Kelling and Schmitt 2003). Optimum N rates for responsive sites were 28 kg/ha (25 lb/ac; 6 sites) or 47 kg/ha (42 lb/ac; 1 site).

Nitrogen released from decomposing forage tissue and from newly accumulated soil organic matter can supply most or all of the N required by the following corn crop, as illustrated in the Iowa study (Fig. 1; Mallarino and Pecinovsky 2006).

Estimates of fertilizer N credit vary depending on the forage species, the quality of the stand (Table 1), and the amount of forage regrowth incorporated. For example, University of Wisconsin recommends an additional first-year N credit of 45 kg/ha (40 lb/ac) when 20 cm (8 in) or more regrowth is incorporated (Laboski and Peters 2012). The N credit can vary with termination method and timing (Mohr et al. 1999; Kelling et al. 2001). The importance of timing is reflected in N credit recommendations in Manitoba, which are 100, 78, 50, and 34 kg/ha (90 to 30 lb/acre) for alfalfa termination before July, July-August, fall, or spring, respectively (MAFRI ref.1). The N contribution from a previous alfalfa crop is lower for a relatively short season crop such as wheat than for longer season corn (Kelling et al. 2002); in Minnesota alfalfa N credit for wheat is half that for corn (Kaiser et al. 2011).

Recommendations also vary depending on soil and climatic conditions. Previous crop N credits can be lower where more extreme (high or low) annual precipitation or soil drainage either limit mineralization rates or increase leaching losses relative to the north central and northeastern U.S. states represented in Table 1 (WI, MN, NY, PA, VT). For example, the credit for a poor (<⅓ alfalfa), fair (⅓ to ⅔), and good (>⅔) stand of alfalfa is 0, 40, and 80 kg N/ha (36 and 72 lb/ac), respectively, in New Brunswick (Zebarth et al. 2006) and 0, 55, and 110 kg N/ha (50 and 100 lb/ac), respectively, in Ontario (OMAFRA 2006). Nitrogen credits in Manitoba range from 34-100 kg/ha (30-90 lb/ac) for good alfalfa stand (see above) with ⅓ or ⅔ credit for poorer stands. Recommended N credits for previous legumes in Wisconsin are reduced by 56 kg/ha (50 lb/ac) on sands and loamy sand soils compared to medium or fine textured soils (Laboski and Peters 2012).

The benefit may be limited or even negative when the legume leaves too little stored soil water for a subsequent crop, especially in dry years (Sahs and Lesoing 1985; Hesterman et al. 1992). However, in a 13-year study in Ontario corn yields in a corn-alfalfa rotation were consistently higher than those in continuous corn despite large variations in moisture deficiency and yields (Bolton et al. 1976).

Net revenue of the first-year crop after a perennial legume, like alfalfa, can be more stable over time than in many other rotations, as was found with potatoes (Kahkbazan et al. 2010). In addition, first-year corn grown after alfalfa may have 10-15% higher yield potential due to factors other than N supply ("rotation effect" in Fig. 1), including improved soil tilth and fewer pest problems. Because of lower insect pressure after a perennial forage, additional savings can be had by purchasing lower cost corn seed or less insecticide. In a long-term experiment in Wisconsin, Stanger and Lauer (2008) found that corn grain yield increased by 1.4% annually when corn was rotated with

Table 1. Fertilizer N credits for corn and other high N demand crops grown after perennial forages as previous crop*.

Crop	Stand Density**	Legume N Credit		Typical Fertilizer N Savings	
		Typical	*Range*	*@$.88/kg or $.40/lb*	*@$1.76/kg or $.80/lb*
		kg/ha***		$/ha****	
Alfalfa	Good	145	123-185	128	257
	Fair	112	78-155	99	198
	Poor	78	45-123	69	138
Red Clover/ Trefoil	Good	100	90-134	89	178
	Fair	78	67-100	69	138
	Poor	56	45-78	49	99
2nd Year		56	0-84	49	99

*Extension recommendations from Minnesota, New York, Pennsylvania, Vermont, and Wisconsin.
MN: http://www.extension.umn.edu/nutrient-management/Docs/BU-06240-S-1.pdf
NY: http://nmsp.cals.cornell.edu/publications/extension/Ndoc2003.pdf
PA: http://extension.psu.edu/agronomy-guide/cm/sec2
VT: http://pss.uvm.edu/vtcrops/articles/VT_Nutrient_Rec_Field_Crops_1390.pdf
WI: http://www.soils.wisc.edu/extension/pubs/A2809.pdf

** Stand density definitions vary somewhat by state but are approximately as follows: Good, >⅔ legume or >43 plants/ m^2 (4/ft^2); Fair, ⅓ - ⅔ legume or 22-43 plants/m^2 (2-4/ ft^2); Poor, <⅓ legume or <22 plants/m^2 (2/ft^2).
*** for lb/ac multiply by 0.9
**** for $/ac divide by 2.5

other crops (including alfalfa). They found that advances in corn genetics over 35 years did not overcome the yield depression in continuous corn and N rates of 56 kg N/ ha (50 lb/ac) or less were sufficient for first-year corn yield after alfalfa. These benefits help reduce the net greenhouse gas emissions from cropping systems that include perennial forages (Meyer-Aurich et al. 2006; Russelle et al. 2010).

A major environmental concern with corn silage production is the increased risk of soil erosion when there is little residue to protect the soil surface over winter. Erosion can be greatly reduced, typically by 70-90%, by incorporating perennial forages into the rotation (Sharp et al. 1995). An example from southern Wisconsin based on RUSLE2 estimates shows that soil erosion can be reduced to 6.7 t/ha (3 T/ac) soil loss in a corn silage-alfalfa rotation, compared to 22 t/ha (10 T/ac) with continuous corn silage (Fig. 2). Erosion also can be reduced with a winter cover crop after corn silage, but not as much as with a perennial crop. Winter cover crops can be difficult to establish after field corn and may not produce enough dry matter before winter in shorter-season climates (Feyereisen et al. 2006) unless planted early (Stute et al. 2007). Climate trends towards longer and warmer growing seasons in agricultural areas of Canada may offer greater potential for cover crops but increasing precipitation also indicates a greater need for preventing erosion (Zhang et al. 2011).

Decreasing soil erosion helps protect surface water from sediment, one of the most frequently cited impairments of water quality. In addition, most phosphorus (P) lost in surface runoff from row crop systems is associated with eroded sediment. Both sediment and P impair habitat for high-value fish species, and excessive P can increase algae growth, leading to water quality degradation and fish kills. Producers should be aware however, that significant soil erosion and associated P loss can occur during establishment of perennial forages, and that dissolved P can be present in runoff from freeze-damaged forage (Roberson et al. 2007). Producers can reduce erosion during establishment by including a companion small grain or forage grass, and can reduce runoff of dissolved P by removing forage regrowth in late fall.

Much of the benefit in controlling erosion is derived from the year-round vegetative cover perennial forages provide, but another important factor is increased accumulation of soil organic matter, or total organic C, compared to annual cropping. Total organic C in the topsoil increased more than 6600 kg/ha (6000 lb/ac) over 15 years in a perennial legume-grain rotation in Pennsylvania compared to no significant change in a corn-soybean system (Drinkwater et al. 1998). Long-term studies in Iowa and Wisconsin reported greater total organic C, as well as higher total and potentially mineralizable N, in rotations with alfalfa than in grain systems (Russell et al. 2006; Jokela et al. 2011). Soil organic matter supports improved soil physical properties such as water infiltration, water holding capacity, aeration and soil aggregate stability.

The composite effects on physical, chemical, and biological soil properties can be estimated by calculation of a soil quality index. One such index, the Soil Management Assessment Framework (SMAF), incorporates several

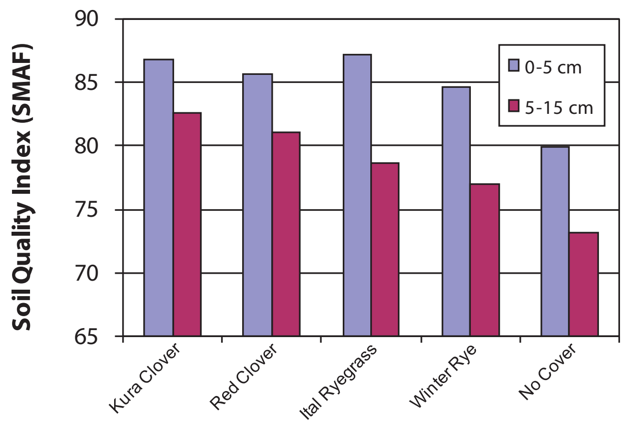

Figure 4. Effects of forage companion/cover crops in silage corn on a soil quality index (SMAF) for soil depths of 0–5 cm (0–2 in) and 5-15 cm (2–6 in). Liquid manure applied annually. Treatments are corn planted into a herbicide-suppressed kura clover living mulch, red clover or Italian ryegrass interseeded into corn, winter rye seeded after silage corn harvest, and silage corn with no cover crop. 4-yr average. Prairie du Sac, WI. (Jokela et al. 2009).

topsoil characteristics, including bulk density, water-stable aggregates, organic matter, extractable P, pH, and microbial biomass. Legume and grass forages improved the SMAF soil quality index, both as rotation crops (Fig. 3; Karlen et al. 2006) and as companion or cover crops (Fig. 4; Jokela et al. 2009), compared to continuous corn without a cover crop.

Another environmental concern is the leaching of nitrate into subsurface tile drains or shallow groundwater. Land seeded with alfalfa or Conservation Reserve Program vegetation (mixed perennial grasses and alfalfa) in Minnesota had lower tile line discharge and negligible nitrate-N loss (less than 6 kg N/ha or 5 lb N/ac) compared to continuous corn or a corn-soybean rotation (35-90 kg N/ha or 31–80 lb/ac) (Fig. 5; Randall et al. 1997). This high capacity for absorbing nitrate contributes to the recommendation that deeply rooted perennial forages, like alfalfa, be used to remove excess subsoil nitrate (MAFRI ref. 2).

While nitrate leaching is greatly reduced under the perennial forage phase of a rotation, conversion back to annual row crops may result in a return to high leaching losses. Conversion from long-term grassland in Iowa (Zhou et al. 2010) or six years of alfalfa or Conservation Reservation Program vegetation in Minnesota (Huggins et al. 2001) to a corn-soybean system resulted in an increase in soil profile nitrate, and within two years nitrate leaching losses were similar to those from the row crop systems. Implementation of perennial vegetative filter strips (Zhou et al. 2010) or a fall-seeded rye cover crop (Feyereisen et al. 2006; Strock et al. 2004) can reduce nitrate leaching but, as noted earlier regarding erosion control, timely establishment of a cover crop can be a challenge in short-season colder climates.

What about manure on perennial forages? Fields in perennial forages provide an opportunity for manure application during mid-season when land in annual crops is not available. Manure can supply needed nutrients for forages – K, P, S, micronutrients and, for non-legumes, N. Large nutrient removal in the harvested forage helps with nutrient balance and minimizes nitrate leaching.

Other benefits from alfalfa and other perennial forages in rotation with corn include better distribution of labor needs and improved wildlife habitat. For grain producers who do not want to purchase a new line of equipment, contract planting and harvesting often is available.

And on top of all these benefits, nearly every economic analysis has concluded that alfalfa production is, on average, more profitable than corn (Olmstead and Brummer 2008). For example, a 2009 survey of farms in southern Minnesota revealed that the average farm reported a net return over labor and management of $250/ha ($100/ac) for corn and $536/ha ($217/ac) for alfalfa (on owned land; Brudelie and Deters 2010). The least profitable farms lost $179/ha ($72/ac) with corn, but lost only $104/ha ($42/ac) with alfalfa. During that year, average price received for corn was $152/t ($3.87/bu) and $128/t ($115/T), and average yields were 12.0 t/ha (192 bu/ac) and 10.2 t/ha (4.6 T/ac), respectively. Clearly, forages bring the greatest return when they are produced, stored, and utilized at the best quality for the livestock involved (Charbonneau et al. 2011). The fact that forages also can produce substantial direct and indirect economic returns should make the decision to include more forages in the rotation an easy one.

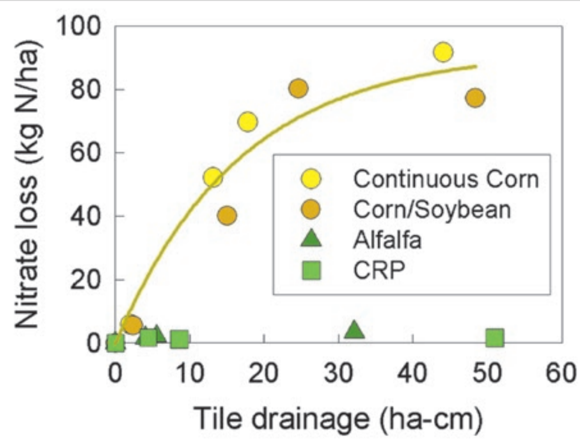

Figure 5. Annual nitrate-N loss into subsurface tile drains under continuous corn, corn-soybean, alfalfa, or Conservation Reservation Program (CRP) vegetation as a function of tile drainage volume. Waseca, MN. (Randall et al. 1997). (for lb/ac multiply by 0.9, 1 ha-cm = 100 m³ or 3500 ft³)

References available online at www.farmwest.com

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