Agricultural Innovations Fact Sheet

SARE Sustainable Agriculture Research & Education

Sheep Grazing to Manage Crop Residues, Insects and Weeds in Northern Plains Grain and Alfalfa Systems

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SARE *Agricultural Innovations* are based on knowledge gained from SARE-funded projects. Written for farmers, ranchers, and agricultural educators, these peer-reviewed fact sheets provide practical, hands-on information to integrate well-researched sustainable strategies into farming and ranching systems. The articles are written by project coordinators and published by SARE.

Geographic Applicability:

Northern Great Plains and other semi-arid regions with small grain and alfalfa production.

Wheat and alfalfa growers in the Northern Plains face a number of challenges in managing their farms. With the implementation of stricter environmental regulations that ban burning in many locations, wheat residue management has become particularly difficult; large amounts of residue after harvest can hamper no-till or low-till field operations, and wheat residue also provides a habitat for wheat stem sawfly, a major pest in the Northern Plains. Weed management and moisture conservation in summer fallow rotations also present challenges for dryland wheat farmers.

In a SARE-funded project consisting of three separate studies coordinated by Montana State University (see SARE-Funded Research Synopsis at end of article), researchers have demonstrated that using sheep to graze crop residue and summer fallow can address these challenges. Researchers also found that sheep were effective in controlling alfalfa weevil. Grazing also:

- provides an environmentally friendly alternative to herbicides and pesticides;
- increases soil nutrient cycling and soil carbon from sheep waste deposited across the field;
- provides an important tool for erosion control by allowing the grower to control the amount of remaining residue, whereas herbicides and cultivation can leave the soil completely exposed;
- lowers equipment and fossil fuel costs through reduced tillage.

Using sheep as a management tool in cropping systems also benefits the sheep producer. Sheep are traditionally grazed on rangelands or pasture forages and supplemented dur-

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ing winter with harvested feeds. Using sheep to graze hay and grain residue not only provides a new and valuable feed source, it can also reduce costs, and offer new business opportunities.

Because targeted grazing is gaining prominence as a land management tool, crop producers can usually find sheep producers in their area who provide this service. Thus, grain farmers do not have to become sheep producers to take advantage of the strategies described in this fact sheet.

Grazing in Summer Fallow to Control Weeds

A fallow rotation (sometimes called summer fallow) is an integral practice for many Northern Plains farmers in non-irrigated areas where soil water content is insufficient or rainfall too sporadic to produce a profitable cereal crop every year.[1] In traditional summer fallow rotations, fields are left to rest for an entire growing season. In spring wheat systems, for example, after wheat harvest in September, the field would not be planted until April or May, a full year and a half later. During the 18- or 19-month interval, farmers must manage the land to conserve soil moisture and nutrients for the next crop. Typically, this involves the use of tillage and/or herbicides to control weeds.

Targeted grazing of sheep can be a viable alternative for managing weeds on fallow land since many weeds found in summer fallow rotations (e.g., volunteer grain, kochia, Russian thistle, wild oats, and cheatgrass) are highly palatable to ruminants, particularly when in the young vegetative phase. However, not all weeds are palatable and so it is important to know which weeds are predominant in fields to be grazed. In one study from the 1970s, researchers found that six of 12 species of annual weeds in the young, vegetative growth phase were as palatable as oats to grazing sheep: yellow foxtail, barnyardgrass, green foxtail, redroot pigweed, Pennsylvania smartweed, and common lambsquarters.[2] Four other weed species were unpalatable to sheep and two were identified as "interacters," i.e., some sheep found them palatable, whereas other sheep refused to graze them. Other research at Montana State University has shown that volunteer wheat is also highly palatable for any class of ruminant. Some weeds growing in summer fallow,

Figure 1. Sheep grazing successfully controlled weeds in a summer fallow field at Montana State University.
Photo courtesy Hayes Goosey, Montana State University

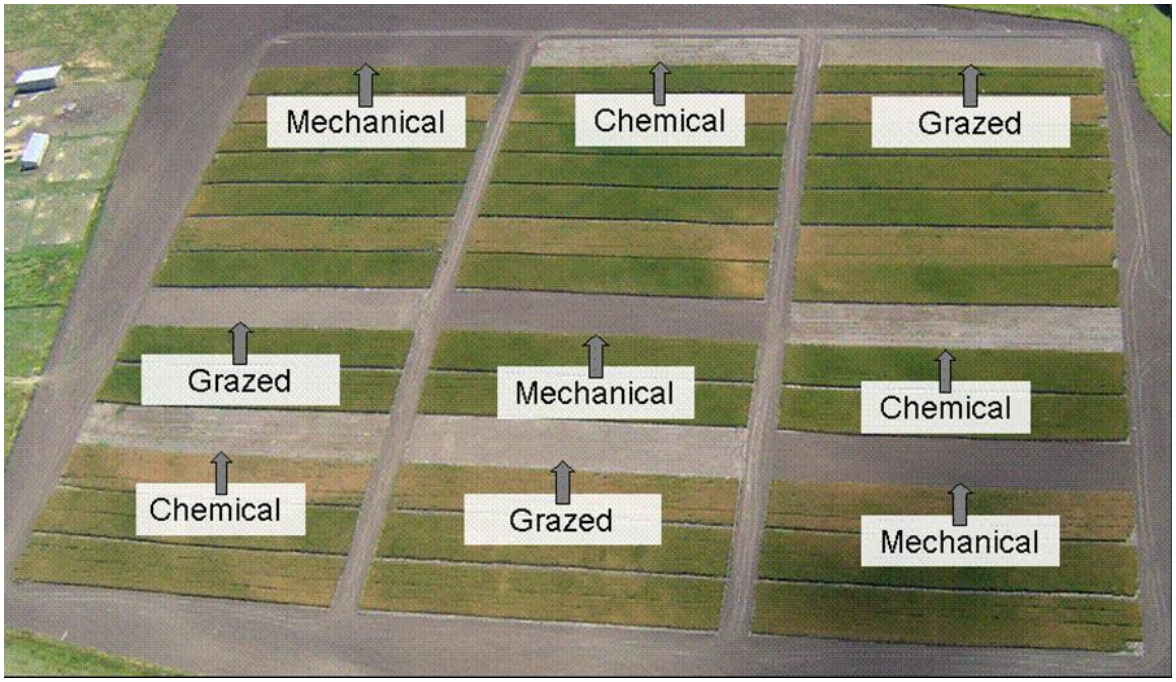

Figure 2. Aerial view of summer fallow treatments at Montana State University. Plots compared mechanical, chemical and grazed fallow in three rotations:

Top: spring wheat / summer fallow

Middle: winter wheat / summer fallow

Bottom: spring wheat / spring wheat

Photo courtesy Hayes Goosey, Montana State University

such as common mallow, have a fairly short period when they will be aggressively consumed by sheep. However, when the target weed is the only green forage available, consumption is generally high, regardless of palatability factors.

Selecting Animals

Any breed, age or background of sheep will work for a summer fallow grazing program if weeds are at an immature stage or the predominant weed is volunteer small grain. In one of the SARE-funded Montana State studies, sheep of various classes (black and white face ewes and rams), and ages (1-5 years), successfully removed volunteer wheat and other annual broadleaf and grass weeds, at stocking rates ranging from 50-150 sheep days/acre. Results showed that even lactating ewes with their higher nutritional demands can be used for fallow management if weeds are in the early vegetative phase and there is an abundance of volunteer wheat.

When weeds become scarce or mature beyond the stage that sheep find them palatable, the animals may require supplementation (particularly protein) to meet nutrient demands. Alternatively, animals with lower nutritional requirements, such as dry or open ewes, could be used for grazing under such circumstances. Wethers may be a good choice when forage quality is lower, particularly if the sheep producer's primary business is land and vegetation management. Wethers from certain fine-wooled breeds on a low, but consistent, nutrient program have the potential for producing fine, high-quality wool, which may provide additional income.

Stocking Rates

Stocking rates are an important factor for grain growers and sheep producers to evaluate in grazing summer fallow. They vary widely depending on the amount and type of forage available (proportion of volunteer wheat vs. weeds) and the kind of sheep being used. For example, in the spring, when conditions lead to rapid weed growth, a high stocking rate will be required to keep weeds under control. On the other hand, when the primary weed is volunteer grain and sheep with a high nutritional requirement are being used, a lower stocking rate might be more appropriate to maintain the sheep in good condition for the grazing period. As indicated above, stocking rates in the study ranged from 50-150 sheep days/acre. In general, managing the stocking rate at the upper limit is preferred in order to limit weed selectivity by the sheep, resulting in more uniform removal of weeds on the fallow ground.

Timing of Grazing

Another critical factor in summer fallow systems is timing. The crop producer needs weeds and volunteer crops controlled before they deplete soil water and nutrients. On the other hand, the sheep producer needs the right quantity and quality of vegetative material to meet their animals' nutritional requirements. Fortunately, timing of grazing for optimum fallow management generally coincides with the time when plants are most nutritious and palatable—typically in May and June (Figure 1). In the early vegetative phases of growth, many weeds have relatively low fiber content and crude protein values in the 15-25 percent range, providing excellent feed. As they mature and initiate flowering and seed production, the plants become less desirable

to grazing animals and some also accumulate unpalatable compounds (i.e., tannins, oxalates or terpenes).

As with mechanically and chemically managed fallow, the number and timing of grazing applications per season will vary with weed type, soil moisture and weather conditions. In the study, five grazing applications were needed to properly control weeds, equivalent to or slightly greater than the typical number of herbicide applications and tillage operations used in fallow management. Grazing followed roughly the same schedule each year, with sheep placed in the fields on or around May 7, June 4, June 20, July 15, and August 5.[3]

Impacts on Crop Yield, Soil Nutrients, Moisture Conservation, and Other Benefits

Figure 2 shows an aerial view of the experimental site of the three summer fallow treatments. During the study's first two years, researchers found that sheep grazing winter and spring wheat summer fallow all conserved the same amounts of soil NO3 and gravimetric moisture as the chemical treatment and mechanical treatment.[3] By the end of the four-year study period, however, this effect was not maintained. Grazing treatments resulted in less soil nitrogen compared to chemical and mechanical control. Under such circumstances soil nitrogen levels would need to be monitored in order to determine fertilizer needs for the subsequent crop. In the long run, the lower levels of soil nitrogen could be considered a positive effect since there would be less nitrogen to leach into groundwater. Despite these differences, grain yields did not differ among the three treatments when the grazed treatments were fertilized with adequate nitrogen. The project did not include an economic assessment, but ongoing research in this area at Montana State will address the profitability of the three fallow management strategies. With rising costs of fuel and pesticides, sheep-grazed summer fallow treatment should prove to be a viable option for many grain producers.

Grazing to Manage Crop Residues

Crop residue management can be a significant challenge for grain producers, particularly in high-production areas. Burning has been a common practice, but is being phased out in many areas due to stricter environmental regulations. Cultivation is effective, but can be costly, particularly if residue levels are high. Spreading and leaving residue on the surface can work well under certain conditions, however, in high-rainfall and irrigated environments, cereal residues can become so dense that they prevent no-till planting of the next crop. Removal of residue by windrowing and baling is another common practice, but income from straw depends on market conditions and may not always cover costs.

Sheep grazing of crop residues offers growers a viable alternative. It is responsive to environmental goals and restrictions and can be adapted to a variety of residue handling practices. For example, sheep can graze either spread or windrowed straw: Windrowing the straw may increase the amount available for consumption by sheep, because less is lost to trampling, whereas spreading provides a more uniform residue cover, which can help prevent erosion along with the grain stubble still rooted in place.

Figure 3. Adult female Wheat Stem sawfly. Photo courtesy Department of Entomology, University of Nebraska-Lincoln

Grazing for residue management can also provide a number of other benefits to growers. First, grazing can improve soil tilth through the addition of ruminant-processed organic matter to the soil. Grazing also allows the manager to determine the amount of residue left in the field by controlling the duration and intensity of grazing to achieve the desired amount of soil cover. Finally, windrowed straw may expand grazing seasons for sheep producers, although protein supplements may be needed if volunteer grain or other palatable green plant materials are not available. Grazing can improve the bottom line for growers, particularly if the benefits of insect control (see next section on wheat stem sawfly) and added soil organic matter are considered.

An Added Benefit of Grazing Crop Residue: Control of Wheat Stem Sawfly

Wheat stem sawfly is one of the most damaging insects in the semiarid Northern Great Plains. Originally a pest of spring wheat, the sawfly's adult emergence and egg depositing period has gradually changed, making it a significant pest of winter wheat.[4] Adults emerge in early summer, and females deposit single eggs within an elongating wheat stem (Figure 3). Eggs hatch and larvae feed inside the stem. As wheat matures, the larva completes its feeding and travels to the base of the stem, where it cuts and plugs the stem behind it, forming a sheltered stub for overwintering. Larval cutting weakens the wheat stem, resulting in lodging. The wheat stem sawfly passes most of its life (egg through pupae) within a single wheat stem, protected from environmental influences and control practices.

Figure 4. Sheep grazing wheat stubble in Montana, reducing excess crop residue and incorporating organic matter into the soil. Photo courtesy Hayes Goosey, Montana State University

Control of this pest has proven quite difficult. Insecticides have minimal impact because the insect population emerges over a 4- to 6-week period and is difficult to target with a single application. Tillage and burning also have not been very effective. Plant breeders are working on this problem, but the solid-stem varieties of spring and winter wheat developed so far have only variable resistance to the insect. In addition, the yield with the resistant varieties can be lower than susceptible varieties when sawflies are not present. Breeders are developing newer varieties with improved yield, sawfly resistance, and forage value, but so far results are inconsistent.

In the residue management part of the SARE funded study, results from work conducted on four Montana farms showed that grazing was more effective at controlling wheat stem sawfly than either tillage or burning.[5] Sheep grazing wheat stubble in the fall and spring killed 75 percent of wheat stem sawfly compared with a no-treatment control (42 percent sawfly killed), tillage (40 percent killed), and burning (45 percent killed).[5] Wheat-fallow production systems, particularly those managed with zero tillage, leave wheat stem sawfly overwintering sites undisturbed. Researchers hypothesized that grazing sheep disrupted the overwintering environment, exposing sawflies to extreme winter conditions that can kill the larvae. Consumption of wheat stem sawfly and hoof action across the field were also likely factors in reducing the number of insects.

Selecting Animals

When selecting animals for grazing crop residue it is important to consider the herd's history. Sheep that are used to grazing dormant forage during the winter are likely to graze cereal grain residue without any problems. Sheep that have been fed hay, on the other hand, can have a difficult time adapting to crop residue as a new feed source. Mature range ewes, for example, can dramatically reduce both cut residue and standing stubble, especially when nitrogen supplementation or adequate levels of green weeds and volunteer cereal plants are available. In a situation where weeds are present and the grower's aim is to maintain some residue cover, research suggests that younger sheep (e.g. replacement ewe lambs) may be the best choice since they will prefer the weeds.

Stocking Rates

Stocking rates for grazing crop residue without supplemental feed will vary depending on the quantity of biomass present in the field and the level of soil cover the producer wishes to maintain. In this case, 182 sheep days/acre was adequate for complete removal of standing crop residues—equivalent to levels in plots treated with tillage (Figure 4).

Timing of Grazing

For most effective control of wheat stem sawfly, it is best to extend the length of time sheep are on the stubble field. This may require supplemental feeding, so producers should initially offer sheep a protein or energy supplement and eventually feed hay to sheep that are grazing sawfly infested stubble.

Economic Considerations

Many producers view burning grain stubble as an inexpensive, labor-efficient method for removing crop residue. However, as previously stated, stricter environmental

regulations have led to phasing out burning in many areas of the country, as the practice impairs air quality through the release of particulate matter and gases, including carbon dioxide, methane, carbon monoxide, and nitrous oxide. In addition to air quality issues, long-term burning can decrease cereal grain yields over time[6], thus increasing fertilizer costs. The downsides to burning are helping to make grazing an increasingly desirable alternative for residue management. Although the project did not include a detailed economic analysis, Montana State University Extension offers several web-based tools that will help producers determine the economic feasibility given their own inputs and projected returns. See Livestock and Forage Production, Finance, and Economics Software Downloads (http://www.montana.edu/softwaredownloads/livestock-downloads.html) and look for the links titled Ewe Cost and Sheep Grazing Crops Partial Budgeting.

Grazing to Control Insects in Alfalfa

Alfalfa Weevil

The alfalfa weevil is alfalfa's most economically damaging insect pest in the United States. In Montana, alfalfa weevil adults go into a dormant phase during summer, emerge in fall, and overwinter in leaf litter and around plant crowns. The overwintering generation of adult female weevils deposits its eggs (oviposit) in spring prior to first cutting for hay, which reduces yield and hay quality. Larvae that survive the harvest process can damage subsequent crown buds, retarding green-up and yield of subsequent cuttings.

Several cultural management practices have been tried for control of alfalfa weevil larval infestations, but results vary widely. Conventional biological control agents introduced to reduce weevil populations below economic thresholds are generally ineffective in the western United States. Insecticides for alfalfa weevil larvae control are used on one-third of U.S. alfalfa acreage, but are costly and require intensive field monitoring to determine when a treatment is economically justified.

In the third Montana State study, conducted on a commercial sheep operation in southwestern Montana, adult weevils were reduced in grazed plots by 35-100 percent, and larvae were reduced by 40-70 percent, depending on sampling date and study year.[7] The grazed plots generally had reduced biomass, lower relative humidity and higher temperatures—all factors making the grazed areas less attractive for ovipositing adults moving into the fields after hibernation. Also, any alfalfa weevil eggs successfully laid in grazed areas were probably quickly consumed by grazing sheep, further reducing weevil densities (Figure 5).

Grazing did not negatively impact subsequent crop yields or quality. Hay yields at harvest were not different between grazed and ungrazed areas, even though forage biomass was reduced by 73-98 percent by grazing sheep.[8] In addition, crude protein, acid detergent fiber and neutral detergent fiber did not differ between grazed and ungrazed alfalfa. Canadian scientists suggest that after the stand has been exposed to three days of 20°F lows, grazing or cutting will not impact stand longevity.

Selecting Animals and Stocking Rates

Alfalfa residues have high nutritive value and any class of sheep will likely be effective grazers. Adapting animals and breeds suited to low-nutrient, high-fiber diets is not necessary. Timing grazing to maintain stand longevity, minimize risk of bloat and limit soil compaction are likely more important than animal selection. Stocking duration and intensity are also more important than breed or class of animal for grazing alfalfa residues to control insect pests. In this study, stocking rates ranged from 145-190 sheep days/acre.

Timing of Grazing

Sheep grazing can decrease larval infestations in the first hay cutting when insects are depositing eggs. Timing of grazing should take into account the weevil life cycle and level of activity. Producers should also keep in mind the condition and growth stage of the alfalfa stand, and the need to avoid bloat in grazing animals. In this project, grazing from early winter until early May provided effective control (sheep were in the field 80 percent of the time during this grazing period). Other operators may find stocking rate and duration of grazing will vary depending upon individual stand characteristics, weather patterns and other factors affecting plant growth and weevil populations.

Additional Management Factors

Soil Compaction Concerns

Producers might be concerned about soil compaction when integrating sheep into cropping systems. While grazing of wheat fields by cattle may compact the soil to some degree, it appears that sheep have less impact.[8] The shape and small size of the sheep hoof might churn and till up the soil rather than compress it, and plants have been shown to grow more vigorously in the sheep-grazed fields. Even if sheep grazing does cause some compaction, freezing and thawing over winter and pre-planting tillage will most likely alleviate the impact in northern environments.

Animal Production Considerations

The following list summarizes some of the key considerations for managing animals in targeted grazing systems:

- A mix of volunteer grain and weeds provides an excellent feed resource for sheep, particularly where fall rains or irrigation have stimulated plant growth.

- Watch for bloat and acidosis in sheep that eat spilled grain.
- Sheep can be placed in fields when snow is present as it may help meet the herd's water requirements while grazing stubble and residue.
- As the duration and intensity of sheep grazing on a particular field increases, so does the potential for higher pest insect mortality.
- Feeding supplemental feed to sheep while they graze crop residue expands the period during which grazing and hoof action reduce numbers of insect pests.

Lastly, it is important to note that a ewe's cycle can be used to advantage in grazing to manage resources. The period of high nutrient demand runs from the last six weeks of a five-month gestation through the first six weeks of lactation. Outside this period, the ewe is at or near maintenance requirements, and she can be used to manipulate low-quality forage without hindering animal performance.

Targeted Grazing: A Long-term View

The Montana State studies showed that targeted grazing in grain and alfalfa production is a viable alternative to tillage, burning and herbicides. When managed correctly, it has the potential to enhance environmental quality and conserve soil and nutrient resources. From a broader perspective, integrating sheep into farming systems can also enhance rural development by presenting new low-capital entrepreneurial opportunities based on the concept of landscape management in addition to traditional meat and wool production. The largest constraint to entering a land-based animal agricultural industry is often the purchase cost of land: Targeted grazing for residue, weed and insect control can help alleviate this constraint, resulting in mutually profitable economic activities that strengthen agricultural competitiveness in the region. Success requires a high level of cooperation between the crop and animal producer as they integrate their two diverse agricultural enterprises. This research shows that shared business and production benefits can form a strong basis for that cooperation.

SARE Research Synopsis

This fact sheet reports results from three distinct studies:

Grazing Sheep in Summer Fallow. This study, conducted during four years at Montana State University's Fort Ellis Experiment Station, compared the effect of three fallow treatments—sheep grazing, chemical application and mechanical cultivation—on crop production and soil nutrient profiles in a spring or winter wheat/summer fallow two-year rotation. Treatments were imposed during the seedling to vegetative growth stages of the weeds in the field (weeds included volunteer grain and other grass and broadleaf weeds). During the four years of the study, chemical and mechanical treatments were applied 3-4 times per fallow period while the grazing treatment was implemented 4-5 times per fallow period. Chemical fallow plots were treated with Gly Star Plus® (glyphosphate, N-[phosphonomethyl] glycin). Mechanical fallow was completed with cultivators tilling soil to an approximate depth of 15 cm. Graze fallow was implemented using a variety of classes and ages of western white-faced sheep. Within a given fallow period, these sheep were randomly assigned to fenced plots at the beginning of each grazing session. Stocking rates ranged from 120–370 sheep days/ha. Each grazing session ended when approximately 6.5 kg/plot or fewer green weeds and volunteer cereal plants remained.

Figure 5. The aftermath of sheep grazing alfalfa in Montana. Grazing reduced harmful insect infestations without impacting hay production. Photo courtesy Hayes Goosey, Montana State University

Sheep Grazing for Residue Management and Control of Wheat Stem Sawfly. Studies were conducted at eight sites on four Montana farms with high wheat stem sawfly infesta-

tions to evaluate the effects of grazing on overwinter sawfly larval mortality. In a series of experiments, treatments included fall-tilled, fall-grazed, spring-grazed, fall- and spring-grazed, burned, trampled, and untreated control. Plots were sampled to determine sawfly larval numbers prior to treatment imposition in the fall (September and October) and following completion of treatment in the spring (May), but before adult sawfly emergence. Sampling was conducted by removing all stubble material, including plant crowns, from a 0.46 m length of a single stubble row. Sawfly-cut stems were identified and dissected in the laboratory to search for live sawfly larvae.

Grazing to Control Insects in Alfalfa. Research was conducted over a two-year period on a commercial sheep operation in southwestern Montana to assess the impact of grazing on insect pest control in alfalfa. During each study year, six non-grazed plots were randomly located within a two-year-old field of Geneva alfalfa. Grazed plots were established in the same field and paired with non-grazed plots. Pre- and post-graze biomass samples were taken from each plot by removing all plant material from three 0.11 m^2 quadrats per plot, drying at 48°C for 72 hours, and weighing to determine dry matter. Plant height and weevil count samples were taken weekly at four sampling dates during both study years.

References

[1]Hirnyck, Ronda, and others. 2004. Pest Management Strategic Plan for PNW Small Grains (Wheat and Barley). *Available at:* http://www.ipmcenters.org/pmsp/pdf/WestSmallGrain.pdf

[2]Marten, G.C. and R.N. Andersen. 1975. Forage nutritive value and palatability of 12 common annual weeds. *Crop Science* 15:821-827.

[3]Snyder, E.E., H.B. Goosey, P.G. Hatfield, and A W. Lenssen. 2007. Sheep grazing wheat summer fallow and the impact on soil nitrogen, moisture, and crop yield. *West. Sec. Amer. Soc. Anim. Sci.* 58: 221-224.

[4]Morrill, W.L. and G.D. Kushnak. 1996. Wheat stem sawfly (Hymenoptera: Cephidae) adaptation to winter wheat. *Environ. Entom.* 25:1128-1132.

[5]Hatfield, P.G., S.L. Blodgett, T.M. Spezzano, H.B. Goosey, A.W. Lenssen, R.W. Kott, and C.B. Marlow. 2007. Incorporating sheep into dryland grain production systems: I. Wheat stem Sawfly; II. Weed control; and III. Soil characteristics. *Small Rum. Res.* 67:209-15; 216-21; and 222-31.

[6]Dormaar, J.F., U.J. Pittman, and E.D. Spratt. 1979. Burning crop residues: Effect on selected soil characteristics and long term wheat yields. *Canada Journal of Soil Science* 59:79.

[7]Goosey, H.B., P.G. Hatfield, S.L. Blodgett, and S.D. Cash. 2004. Evaluation of alfalfa weevil (Coleoptera: Curculionidae) densities and regrowth characteristics of alfalfa grazed by sheep in winter and spring. *J. Entom. Sci.* 39:598-610.

[8]Murphy, W.M., A.D. Mena Barreto, J.P. Silman, and D.L. Dindal. 1995. Cattle and sheep grazing effects on soil organisms, fertility, and compaction in a smooth-stalked meadowgrass-dominate white clover sward. *Grass and Forage Science* 50:183-190

Further Resources

Targeted Grazing: A Natural Approach to Vegetation Management and Landscape Enhancement. Available at http://www.cnr.uidaho.edu/rx-grazing/Handbook.htm. See Chapter 14: Incorporating Targeted Grazing Into Farming Systems.

Enterprise Budget Decision Support Program to Evaluate the Incorporation of Sheep into Farm Systems. A free on-line Excel-based enterprise budget decision tool. http://www.montana.edu/softwaredownloads/livestockdownloads.html
Click on the address then scroll down to Sheep Grazing Crops Partial Budgeting

This publication was developed by the Sustainable Agriculture Research and Education (SARE) program with funding from National Institute of Food and Agriculture, USDA. Any opinions, findings, conclusions or recommendations expressed here do not necessarily reflect the view of the U.S. Department of Agriculture.

SARE Outreach operates under cooperative agreements with the University of Maryland and the University of Vermont to develop and disseminate information about sustainable agriculture.

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SARE Publication #11AGI2011