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Recent Perspectives in Using Goats for Vegetation Management in the USA[1]

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ABSTRACT

Although an ever-increasing body of research data has documented the usefulness of goats for controlling brushy and weedy species such as shinnery oak, blackjack, and post oak, leafy spurge, sericea lespedeza, and many other species, this technique remains severely underutilized. Environmental concerns and the increased costs of chemical and mechanical control methods provide greater opportunities to utilize biological control methods such as goats for removal of brush and weeds. Goats have an advantage over other biological control methods in that they can profitably convert brush and weeds into a saleable product and they can graze concurrently with cattle. In addition, goats improve the cycling of plant nutrients sequestered in brush and weeds, enabling the reestablishment of grassy species. The foremost limitation to using goats for brush and weed control is the social stigma cattlemen attached to goats. The lack of an infrastructure (animal markets, source of large numbers of adapted animals, producer experience and knowledge base) to support goat enterprises is a serious constraint which is gradually being overcome as the goat industry expands. Suitable goat production systems need to be developed for specific environments. This involves the modification of existing knowledge, especially in regard to kidding date, parasite management, predator control, fencing, and marketing strategy. The lack of economic data and enterprise budgets also are constraints. Further research is needed to collect economic data and to develop stocking rate criteria and production systems to support the use of goats for biological weed and brush control in a diversity of environments.
(**Key words:** goat, weed control, brush control, weed utilization)

INTRODUCTION

Overview of Vegetation Management

Goats have been used for vegetation management in the United States for over a hundred years (Taylor, 1992), and their use for this purpose is expected to expand dramatically in the near future. This is because vegetation management problems will continue to increase in the near future as a consequence of environment degradation created by past systems of farming and grazing, and the increased expense of using conventional methods of vegetation control. Goats have a unique ability to convert unwanted vegetation into a saleable product at a profit while providing control. Although it is a challenge to get life-long cattlemen to accept goats, the economic pressures and visual successes from field demonstrations provide considerable motivation. The unprecedented changes underway in the goat world during the last two decades have paved the way for goat production to become widespread. The Angora goat boom in the mid and late 1980s moved goats from Texas into adjacent states. The dramatic influx of the Boer goat further increased the number of states with significant numbers of goats and goat producers, especially in the South. Because these animals were expensive, more veterinarians became familiar with goats and more equipment and technical knowledge about goats became available. While it is exciting to see the spread of goats throughout the United States, these changes have created a need for more technology that is specifically applicable to these new goat environments. Now that goats have become more widely distributed in the United States, producers are beginning to discover their usefulness for vegetation management in many different ecosystems. There is a need to further develop the technology of using goats to manage vegetation in these many different ecosystems. To summarize, goats, and the technology to use goats for vegetation management is no longer confined to Texas.

Why do we want to manage vegetation? The most common reason given by producers is to grow more grass to produce more beef. And often we can enhance the productivity of degraded range sites. The Army Corps of Engineers may want to improve the wildlife habitat for deer or other species. A ranch manager desires to increase biodiversity and stability of his native range. Government agencies have an obligation to reduce the fire hazard associated with the accumulation of woody biomass especially in and adjacent to residential areas. Utility companies need to control woody species along their right of ways before they grow into large trees which are expensive to remove. Additionally, some form of vegetation management may be used as a pretreatment for chemical treatment or burning. There are a number of invasive plant species that have been introduced without their natural control media, such as insects or disease, that it is in public interest to prevent their spread.

Unfortunately, vegetation management is not as simple as taking a plant out of the wrong place. Often, underlying problems or conditions have encouraged that plant to grow in the wrong place. One of the greatest factors is erosion—in Oklahoma, much of the grassland is go-back land—land that was once cultivated, but has productivity that is too low to be cultivated profitably, usually due to the loss of over half of the topsoil while it was cultivated (Mark Moseley, Natural Re-

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sources Conservation Service). Most of the soil's plant nutrients and OM that were contained in the top several inches of the topsoil were lost, severely diminishing productivity of the soil and the vigor of grasses growing on it. Water infiltration rate is reduced and a greater proportion of infiltrated water is in the subsoil. Because woody species have deeper roots to obtain water and are good at sequestering plant nutrients, they are much more competitive against the grass in eroded areas than in the former uneroded state. This change is basically a permanent one. This phenomena was modeled by Walker et al. (1981) who showed that reduced water infiltration resulted in a shift to woody vegetation that was permanent, i.e., reducing grazing intensity would never restore the grass component of the system. The loss of productivity potential of the soil limits the expenditures that can be made for managing vegetation. The second factor is overgrazing, which causes erosion, reduced water infiltration, and reduced the vigor of grass species enabling undesirable plant species to better compete with native grasses. A third factor has been grazing by one species, usually cattle, which graze only a few plant species. Grazed plants, especially overgrazed plants, are at a competitive disadvantage to ungrazed species because of the loss of significant photosynthate from the plant. The exclusion of fire by man has also exacerbated vegetation problems, especially from woody species (Scifres, 1980).

Producers have only a few options available for vegetation management. These include fire, mechanical, chemical and animal impact. Fire is an economical and effective tool for controlling many types of vegetation (Powell, et al., 1979). However, many woody species sprout from the roots or come back from seed. Fire may be an effective pretreatment for goats, especially where trees are over 3 m tall. Fire can be dangerous physically and politically when it escapes, as occurred recently in the Cerro Grande fire in New Mexico at Bandolier National Monument, burning 45,000 acres, destroying 235 homes and many other structures, and causing the evacuation of 18,000 people. Mechanical methods of vegetation management include rollerchopping, root plowing, bulldozing, chaining or cabling, and mowing. Most of these methods are too expensive; although dramatic results are quickly achieved, the benefits are usually short lived. Chemical control of weeds has been effective in the past, but increased expense for getting chemicals registered has significantly increased the cost of chemicals. The cost of chemicals and application requires that land have high productivity potential to recoup costs. In addition, chemicals may kill desirable plants (Allan and Holst, 1996). J. Mayo (personal communication) observed that when forbs in native range were killed, such as may happen with chemical treatment, productivity the next 2 yr reduced by 20 to 30%, presumably due to the loss of nitrogen fixing forbs. Animal impact involves control of grazing animal species, time of year of grazing, duration of grazing, and length of rest period of the paddock. The problem of overgrazing has been addressed previously. Grazing management can be an effective factor in control of vegetation, but the required level of management is often unavailable.

Overview of Goats for Vegetation Management

What are characteristics of goats that make them especially suitable as vegetation management tools? The first characteristic is their diet diversity. Fraps and Corey (1940) observed that goats consumed a wide variety of plants and selected higher quality plants than cattle and sheep. Goats are resistant to many plant toxins and antinutritive factors This means that goats are capable of defoliating most plants species, many of which cattle will not utilize. Goats consumed a predominance of browse (73%) and lesser amounts of grasses (23%) and forbs (4%), although the proportion varied with availability, (McMahan, 1964). It is common for goats to eat the bark of some tree species, effectively killing the trees by girdling. The second characteristic is that while goats are eating these undesirable plants they are producing a saleable product. Goat meat prices are strong and expected to remain strong since domestic slaughter supplies only about 55% of the domestic demand for goat meat (USDA, 1999). Goats can produce meat at a profit as shown by Hart (2000), who estimated a $5.00 profit per head of stocker goats, while controlling sericea lespedeza. Thirdly, goats also help restore cycling of plant nutrients, which are sequestered by woody species. Escobar et al. (1998) observed that when shinnery oak (*Quercus havardii*) was grazed for 3 yr with goats, available N in the topsoil increased from 1.1 to 23.3 kg/ha. Available P increased from 5.5 to 25.5 kg/ha, and available K increased from 133 to 348 kg/ha. During this time, the cover of Oak species was reduced from 95 to 50% of the area and grass and forbs increased from 5 to 50% of the area. This is important in that N and P are critical for the establishment of native tallgrass species (Rice et al., 1960). Fourth, goats preferentially consume seeding stems, reducing the spread and perpetuation of weeds by seed. Even though mature seeds sometimes survive passage through the digestive tract of most animals and germinate, goats usually consume the seeds in an immature stage, which would not be expected to survive the digestive tract. Allan and Holst (1996) observed that goats reduced the seed bank of thistles when used to control thistles. Mayo (2000) observed a reduction in seed production when goats were used to control sericea lespedeza, as discussed later. Goats can be grazed with other species including cattle, sheep, or horses in a cospecies grazing system. Another advantage of using goats is that ticks and snakes are reduced due to reduction of their habitat. Goats are a low-input animal, requiring a minimum investment for start-up, low expenditure for maintenance, require a moderate level of labor due to need for parasite control, but require a high level of management to avoid serious problems.

It is assumed that goats must consume some portion of the plant to control it. Therefore, the question "what vegetation species will goats control?" is "what plant species do goats consume?" The answer depends on a number of factors. Some factors include the species goats were exposed to as a juvenile, since Provenza and Balph (1988) found that the young learn from their mothers what to eat, but they can also learn from peers. Time of year can be a factor in that some species such as red cedar are most palatable during the winter. Animals may have to physically adapt to antinutritive factors such as high levels of tannin or mimosine to be able to consume significant quantities of those plant species. The presence of other grazing species (sheep and/or cattle) has been observed by Rector (1983) to slightly modify diets. Goats often have a preference to select species that are in minority. Preference of a species is affected by the availability of other plant species. Goats will probably consume, at least to a minor extent, a majority of herbaceous and woody species available in North America. This includes highly preferred species such as

blackberry, green briar, sumac, winged elm, poison ivy, ironweed, kudzu, moderately preferred species such as post oak, multiflora rose, sunflower, ragweed, hickory, hawthorne, tall thistle and eastern red cedar, (Bauni, 1993). Lesser-preferred species include Osage orange, Illinois bundleflower, hackberry, buckbrush, and giant ragweed. Goats will not effectively control less-preferred plant species unless they are minor species. Preference, and hence, degree of control can be improved in some cases by burning or roller-chopping, causing production of sprouts that are generally more palatable (Taylor, 1992.; Davis et al., 1975). Mowing strips through tall dense stands of vegetation will facilitate penetration and control by goats (Allan et al., 1999).

Goats are considered browsers; however, Coblentz (1977) classified them as opportunistic generalists because they tend to consume the most palatable vegetation available. Goats are very flexible in their dietary habits, able to adjust to a diet change from 80% browse to 80% grass precipitated by a drastic change in species availability (Malechek and Leinweber, 1972). Goats have very nimble lips, which enables them to select the most nutritious components of biomass available, regardless of type. Goats also tolerate higher levels of tannins than cattle or sheep. In addition, they have fewer problems from plant toxicity because they consume a large number of different plant species within the day. Goats also are resistant to bloating.

Goats can graze in combination with cattle, horses, or sheep. The main benefit would be that the goats utilize and thereby suppress plant species that are not utilized by cattle (Taylor, 1985). Rector (1983) observed that in a native range situation in Texas, cattle consumed predominantly grass (70%) with lesser amounts of forbs, (5%) browse (24%), and sedge (1%) that varied with season. Sheep consumed predominantly grasses (52%), but severalfold more forbs (15%) than cattle and lesser amounts of browse (31%) and sedges (2%) depending on season. Goats preferred browse (70%), grass (20%), and some forbs (10%). The difference in diet preference not only makes these classes of livestock compatible, but complimentary. A review of Texas studies (Merrill and Taylor, 1981) showed that pasture utilization and carrying capacity were improved 10 to 25% by grazing with a combination of cattle, sheep, and goats. Grass, forbs and browse were utilized uniformly, and no class was over utilized to reduce that species. Additional benefits include a reduction in internal parasite problems when cattle or horses graze with goats. Taylor and Ralphs (1992) observed that livestock losses from poisonous plants were reduced by cospecies grazing. Economic diversification is also a benefit of cospecies grazing. Cospecies grazing requires substantial changes from a cattle only enterprise. Fences and water sources must be modified to accommodate the small ruminants. However, the biggest benefit is that the cattlemen can still run their cattle while the goats reduce weed and brush problems, enabling more grass to grow for the cattle.

CASE STUDIES OF THE USE OF GOATS FOR VEGETATION MANAGEMENT

There has been an accumulation of literature over the years on the use of goats for controlling various plant species in the United States and New Zealand (Thompson, 1988). The Australians also have a large body of literature and have developed some quality bulletins on the use of goats for vegetation management (Allen et al., 1999; May et al., 1995; Turner and May, 1992).

Leafy spurge infests 2.5 million acres in the northwest and west United States and causes severe irritation of the mouth and digestive tract in cows. Of the 297 references in Agricola to leafy spurge, 217 are associated with control. This attests to the magnitude of the problem. Only three of these references are associated with goats. Goats have been shown to have a greater preference for the weed than sheep (Walker et al., 1994), which may be a consequence of the ability of goat rumen microorganisms to detoxify the plant (Kronberg and Walker, 1993). However, it appears that sheep can adapt to the plant over time. Only about 18% of leafy spurge seeds fed to goats and sheep were recovered in the feces, and germination and viability of the seed was reduced, more so for sheep than for goats (Lacey et al., 1992). Goats are able to control the weed, but are more difficult to contain than sheep (Fay, 1991). Sheep are more widely used in Montana because of a historical familiarity with sheep production. The problem with control of leafy spurge is that producers are not responding to the problem until the infestation is extensive and well established. Early intervention with goats or sheep would curtail the spread of the weed and development of a seedbank and prevent the destruction of the native range. Goats have also been used to augment chemical control of leafy spurge with good results (Lym et al., 1997). Goats have been incorporated into control programs for leafy spurge with such good success that no more scientific studies on goats eating leafy spurge are needed (Rod Lym, personal communication). However, based on published literature, there is a deficiency of knowledge. This illustrates a big problem with the literature for vegetation management with goats: much of the knowledge is not documented in the literature.

A land resource area common to both Texas and Oklahoma is characterized by the presence of post oak (*Quercus stellata*), blackjack oak (*Quercus marilandica*) and eastern red cedar (*Juniperus virginiana*) as the dominant woody species. Bauni (1993) observed that at least four goats per acre were required for goats to defoliate the oak species because of the abundance of other more palatable browse. Briggs and Beall (1940) advocated the use of 2-5 Angora goats per acre to clear the brush. They questioned the need to kill off the brush, as it was highly profitable to manage the brush as a renewable resource and have a profitable goat enterprise. Darrow and McCully (1959) advocated the use of goats to prevent resprouting of blackjack-post oak after it had been mechanically or chemical controlled. Magee (1957) found that on ranches that did not use goats keep sprouts and regrowth under control, the regrowth had become a serious problem within 5 yr of clearing. Angora goats were very profitable, and the goat enterprise alone paid for clearing the land within 5 yr. Roller-chopping shinnery oak and gambel oak appeared to be beneficial to control of the plant and nutrition of the goat (Wiedemann et al., 1980, Davis et al., 1975; Merrill and Taylor, 1976). This can be attributed to the sprouts being more palatable and more nutritious than more mature plant parts.

Goats have been successfully used to control sericea lespedeza in Kansas, where it now infests 400,000 acres of native range (Ohlenbusch, 2000). It is particularly destructive in that it completely chokes out large areas of native tallgrasses and is not eaten by the stocker cattle that graze in southeast Kansas.

The seed appear to be spread by birds and rats. It is a prolific producer of hard seed (950 seeds/ramete), which may lie dormant for years. The chemicals required to control it are expensive because it is difficult to kill and the degree of control given by chemicals is sometimes variable for unexplained reasons (Fick and Kilgore, 2000). Chemical application must be repeated in 3 to 4 yr because of reinfestation by new seedlings from the hard seed. Economic analysis has shown that chemical weed control is not very cost effective (May and Jones, 2000). However, goats relish sericea lespedeza, leaving the grass for cattle production. It takes 3 yr of hard grazing by goats (60 to 80% utilization) to kill most of the established perennial sericea lespedeza plants (Escobar et al., 1998). One of the big benefits of goats is the tremendous reduction in seed production from 950 to 3 seeds per ramet (Mayo, 2000), which is important in halting the spread and persistence of the weed. In addition, goats graze the seedlings and prevent them from becoming established. Stocker goat, grazed at 10 hd/ha, gained 10 kg/hd over the summer grazing season and returned a net profit of $5.00/hd (Hart, 2000). Profit/ha for goats was greater than for cattle grazing this area due to the severe infestation by sericea lespedeza reducing carrying capacity. One of the greatest benefits of using goats in controlling sericea lespedeza is the prevention of seed production during early stages of infestation, halting the spread of sericea. Unfortunately, producers wait until the infestation is extensive and large patches of native range have been killed before implementing control measures.

In this study, goats first consumed browse, including honey locust, sumac, eastern red cedar, plum, blackberry, elm, buckbrush, wild rose, dogwood, and Osage orange. The goats appeared to consume little of the sericea lespedeza until later in the summer. Once they started consuming it, they seemed to develop a preference for the plant. Many of the brushy species were killed by the end of the second year of grazing, including most of the eastern red cedar. Goats were dewormed only once at the beginning of the study, and monthly fecal egg counts showed acceptable levels of parasitism. The 40-acre pasture was fenced with sheep and goat net wire, and a small pond provided water. No animals were lost to diseases or predators. With good planning and preparation, goats have minimal management problems.

Goats have been used effectively to reduce fire hazards in public lands. This is particularly important as residential housing has encroached many areas of native vegetation, which have accumulated significant fuel loads due to being protected from utilization and fire. Most of this work has been done in California because of the magnitude of this problem, with nearly 10 million acres being susceptible to wildfire. One method of protection from wildfires is the reduction of fuel load on wide areas, especially around communities. After mechanical removal of mature plants, the fuel breaks are often maintained with herbicide. Green and Newell (1982) showed that goats were an effective alternative to herbicides for clearing and maintaining firebreaks. Tsiouvaras et al. (1989) described the use of goats to reduce brush cover in a Monterey pine understory by 50%, reducing fuel loads by a similar amount. High stocking densities for short periods of time were used in these studies (600 hd/ha for 1 d and 280 hd/ha for 3 d). This opened up the stand to where prescribed fire could be used safely in residential areas. It is not known whether less intense grazing treatment would have achieved similar results. Resource managers need to realize that even though they need the services of goats for only a small period of time, goats must be kept someplace 365 d of the year unless they are stocker goats. Resource managers could make concessions by allowing the producer to keep goats on an alternative area for a large part of the year. Also, fencing expenses must be recouped in this short time.

INNOVATIVE APPLICATIONS OF GOATS FOR VEGETATION MANAGEMENT

There are several innovative uses of goats for vegetation management. Goats were found to be useful to suppress brush that is too overgrown for wildlife (whitetail deer). One season of grazing with goats was adequate to open up dense brush motts and restore desirable wildlife habitat (personal communication, Don Patton Kansas Department of Wildlife and Parks,). An electric company in the New Hampshire is using goats to clear under the powerline right of way in an ecologically friendly manner. Goats are herded by day and penned during the night in electrified net wire pens.

There is great potential to operate a rent-a-goat business enterprise for vegetation management where landowners could rent the services of goats to control their vegetation such as proposed by Frank Pinkerton (retired Goat Extension Specialist). Many landowners who have a need of goats for vegetation management may not want to get into the goat business due to lack of expertise, capital, time or other resources. This provides potential for goat producers to capitalize on free grazing and in a few cases, get paid for grazing. One producer gets paid for grazing fuel breaks in California. The US Forest Service allows another producer in North Dakota to graze goats during the summer. Initially, the Forest Service paid them to graze, but due to budget constraints, grazing is free. The Army Corps of Engineers is ready to allow goats to graze on their land around lakes due to the brush becoming too thick for wildlife and the lack of funds for vegetation management. Constraints to the rent-a-goat business include fencing, water, and a place for the animals when not being used for vegetation management. Other considerations include time required to look after the animals, animal theft problems, working facilities, and moving animals. Benefactors of the rent a goat activities need to be willing to make provision for some of these resources if the services of goats are to be acquired.

One must question the wisdom of controlling brush if it is such good feed for goats and the goats are generating a profit. In fact, it may be practical to plant woody species for goats, and especially on degraded lands that are more suited for brush production than for grasses. In a previous discussion of oak species, the ranchers did not want to eradicate brush because of the profit they made on goats. In South Africa, the brush veldt is managed for the regeneration of woody species for sheep and goats since woody species are more drought tolerant than herbaceous species (Aucamp, 1983). Some species that could be planted include mimosa and black locust. It is also possible that pasturelands could be managed to favor regeneration of woody or weedy species.

Goat Management

Goats have moved from dry south and west Texas to more humid areas, which are conducive to parasitic infestation and the consequent morbidity and mortality. Dewormers are being

used as the sole solution to internal parasites, resulting in the development of dewormer resistance. Fecal egg counts of goats must be monitored at regular intervals. Management practices to reduce the need for deworming should be utilized. This includes deworming during the winter to remove dormant worms, avoid grazing close to the ground, move to new pastures, graze with other species of animals, culling the most susceptible animals. In most cases, survival of the goat enterprise is dependent on controlling internal parasites.

Predators are often a problem with goats. Kid goats appear to be more susceptible to predation than lambs (Merrill and Taylor, 1981), probably a consequence of the goat's planting behavior with their newborn kids. Fortunately predators can be controlled with guard animals and (or) other management practices that reduce predation under semi-intensive conditions. However guard animals in themselves are another management assignment. Predators can be discouraged by electric fencing. Late kidding and confining animals at night inside predator proof fences can also help. Predator control is more difficult under extensive conditions and is likely to be the most important management factor in a goat enterprise under extensive conditions. There is a good reference on predator avoidance strategies by Green (1987).

Goats require better fences than sheep or cattle to ensure their containment. They can be easily contained by sheep and goat net wire, which has a wider space between the vertical stays than field fence so that goats do not get their heads hung by the horns when they put their heads through the fence. Such fence is usually topped with barbed wire and may have a strand of barbed wire at the bottom to discourage predators. A barbed wire fence with 11 strands of wire and fence stays every 2 m is also effective. Electric fence works well with goats, but it is necessary to maintain a minimum of 4500 V to effectively contain goats. Four strands of electrified wire to a height of 75 cm can contain goats, although producers have used as few as two strands. A five-strand barbed wire fence can be easily modified for goats by adding one strand of electric fence 38 cm high and 25 cm out from the existing fence. Some producers use two strands between the lower two barbed wires and the ground. Because goats are more likely to escape under a fence rather than over, care should be taken that there are no gaps greater than 20 cm under the fence.

Challenges to be Overcome for Effective Use of Goats in the Future

Both research and extension activities are needed to develop and transfer the technology for improving the effectiveness and profitability of goats for vegetation management. The biggest factor to be overcome is the mental recalcitrance of cattle producers to using goats for vegetation management. However, this problem may be reduced over time by economic realities. A better understanding of the values and factors that motivate producer management decisions is needed to facilitate transfer of this technology. Field demonstrations provide valuable visual information that has great impact with producers but requires long-term activities of 3- to 5-yr duration. It is difficult to obtain funding for these activities, but with collaboration between federal, state, and local government agencies, educational institutions, nonprofit organizations, local businesses and producers, these activities can be carried out. Although coordination can be a challenge, having more entities involved also facilitates transfer of the knowledge. One agency can supply the land, a producer the goats, another agency monitor animal performance, and another agency quantitate the effect on vegetation. Field demonstrations in concert with field days with the support of local extension specialists can be a valuable tool for transfer of goat technology for vegetation management. Economic data should be collected to provide financial data for producers and bankers.

Research is needed to further develop technology for control of invasive weedy species with goats. What stocking rate is needed to control unwanted vegetation and yet maintain productivity of goats at a profitable level? How many years will it take to kill perennial plants? How long will seed survive in the soil? Specific questions must be answered about stocking rate, timing, and duration of grazing with goats for control of a specific weedy species. Investigations with cospecies grazing of goats with cattle need to be conducted because, for the most part, this is how the technology will be implemented by most producers.

Research is being conducted on the chemical control of weeds that have been weakened by defoliation with goats. This may enable producers to use cheaper chemicals, apply a reduced rate, and (or) improve the degree of control. Goats may also be a useful alternative to fire for weed control in native range, reducing and maybe eliminating the necessity of routine burning of native range. Can fire be a useful pretreatment where woody species are too large to be effectively controlled by goats? Can goats be a good pretreatment for burning in thick understory by clearing enough brush to allow grass growth and accumulation of fuel?

Internal parasite monitoring, management, and control must be improved, especially in the face of developing dewormer resistance. Internal parasites are the most important problem in the goat industry where animals are raised in humid environments. Texas and Oklahoma Extension programs are teaching producers to do their own fecal egg counts. This is a valuable tool, but a tool that was easier to use would be most welcome. It may be possible to develop a cheap handheld spectrophotometer device that could be clamped on the ear to measure hematocrit in situ. Such technology has been developed in the medical field. Further research is needed to develop a model for parasite management strategies. Recent work in New Zealand has demonstrated the beneficial effects of plants containing condensed tannins on internal parasites (Butter et al., 2000; Niezen et al., 1998). The effect of common browse and weedy species on internal parasites infestation needs to be investigated.

Because goats have been moved out of their natural dry tropical environment to more humid environments, especially in the Southeast United States, there is a need to develop goats that are better adapted to humidity and cool weather. In a recent study (Hart, 2000) during a monthly period when humidity was greater than 90%, goats appeared to spend less time grazing and gained less weight (99 vs 42 g/d). Goats should be selected for adaptation to these environments. Goat breeds such as the Kiko goat, which originated in humid areas, may contribute genes for this trait. Eastern Kansas producers that kidded on pasture in early spring had a very high kid mortality due to the cool-wet weather. Production systems and animals that are adapted to these environments should be developed.

Because returns on goats are not high and the cost of permanent fence to contain goats is expensive ($2500/mile for materials and $2500 for labor), fencing costs are a substantial

limitation to the use of goats for vegetation management. Electric fencing is cheaper ($600/mile for materials), can be portable, and greatly improves the economic feasibility of using goats for vegetation management. However, a portable animal containment system requiring a minimum of labor to set up would be useful for small patches that need special attention or high density grazing. One possibility of such system is the "invisible fence" system such as used by Fay et al. (1989). Goats were fitted with dog collars that emit a warning tone if the animal gets near the wire followed by a mild shock if the animal fails to retreat. The wire is insulated and hooked to a portable radio transmitter powered by an automotive battery. The wire can be strung on the surface of the ground and readily retrieved when goats finish grazing. This system needs further investigation with goats. which would make it economic to use with goats grazing smaller patches that are not fenced, especially in a rent-a-goat situation. This would enable the intervention with goats at an earlier stage of infestation of invasive weedy species.

IMPLICATIONS

In conclusion, goats can be effectively used to manage most types of vegetation, but greater knowledge is required before the full potential of using goats for vegetation management can be realized. To effectively transfer the technology of goats for vegetation management, field demonstrations will have to be conducted and economic data collected, and considerable producer interaction is required. The technology is more complex than putting a goat out to eat a plant. Producers must also be educated on fencing and predator and internal parasite control, and the technologies need to be further developed and adapted for specific environments. A holistic animal management system must be offered to producers. There is a bright future in the use of goats for vegetation management because environmental conditions have become more conducive to the proliferation of weedy species and, in most cases, goats are the most cost-effective, nontoxic, nonpolluting solution available.

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