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BUFFELGRASS ON SOUTH TEXAS RANGELANDS: EXPLORING THE RANGE OF MANAGEMENT OPTIONS

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Buffelgrass (*Pennisetum ciliare*) is a non-native, invasive grass that is found in most of South Texas and some West Texas counties. The first step in managing any rangeland plant is the ability to identify it. Buffelgrass is a warm-season, perennial bunchgrass. Perennials are present on the landscape year-round. Buffelgrass leaves are lime green to darker green during growing seasons and turn golden-brown when dormant in winter. The bunchgrass can look messy because the stems branch excessively at the nodes (Fig. 1). Nodes are bulbous areas on a grass stem that may have a little bend, similar to our elbows. The seed head, or inflorescence, is compact and linear. Seedheads look like long feather dusters and are reddish-purple when young but turn tan when older. If the seeds are removed from the seed head stem, or rachis, the seed head stem is rough and zigzagged (Fig. 1).

Figure 1. Buffelgrass images. From left to right: A. Buffelgrass seed head with seeds attached, B. Buffelgrass seed head with most seeds detached showing the zigzagged seed head stem, and C. Buffelgrass bunchgrass growing on South Texas rangeland.

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The second step in managing any rangeland plant is to collect background information to make well-informed management decisions. We begin with a brief history of buffelgrass to provide insight into how and why this grass was introduced to Texas. Next, we explore the pros and cons of buffelgrass to provide insight into both the benefits and the consequences to better guide management actions. Finally, we provide research-based management recommendations so landowners can select the management plan that works best for them based on their available time to invest and access to resources.

A LOOK BACK IN TIME: A BRIEF HISTORY OF BUFFELGRASS IN SOUTH TEXAS

During the 1930s and 1950s, South Texas experienced extreme droughts that resulted in severe soil erosion and threatened the livelihood of many livestock producers. In response to these extreme conditions, professionals with government agencies and researchers set out to find drought-resilient plants that could reduce soil erosion and provide forage for livestock. Buffelgrass (*Pennisetum ciliare*) was one of the plant species that met these criteria, and it was introduced into South Texas in the 1940s. Buffelgrass gained wide popularity across South Texas as livestock forage because of its nutritional value and resistance to heavy grazing, even under drought conditions (Perramond, 2000). Commercial production of buffelgrass seeds began in the 1950s (Wied et al., 2020). In the 1970s, research was conducted to determine the optimal seeding depth for buffelgrass across soil types, revealing that a depth of 0 to ¼ of an inch resulted in the greatest seedling production across many soil types (Mutz & Scifres, 1975). By 1985, buffelgrass had been established on approximately 10 million acres of improved pasture, which accounted for 90 percent of the improved pastures south of San Antonio (Wied et al., 2020).

TWO SIDES TO EVERY STORY: THE PROS AND CONS OF BUFFELGRASS

As with most plants that inhabit Texas rangelands, its story has two sides. To make well-informed management decisions, it is crucial to understand the pros and cons of the plants that landowners intend to manage. Thus, this publication explores the pros and cons of buffelgrass before discussing management options.

Pros of Buffelgrass

Buffelgrass gained extensive popularity as a forage species for livestock because of its nutritional value and resistance to grazing. Buffelgrass' nutritional quality, especially percent crude protein (CP) and phosphorous, is equal to or slightly higher than native grasses that cattle select for on South Texas rangelands (Table 1). Buffelgrass' typical percent CP range meets the nutritional requirements of mature, dry, and lactating beef cows, except during dry winter and summer months. CP values of buffelgrass substantially increase above the maximum nutritional requirements of lactating beef cows following winter prescribed burns and seasonal rain events (Hanselka, 1989). Percent CP on a dry matter basis is an important nutritional measure of forages because CP and forage digestibility affect forage intake. Without an efficient amount of digestible CP, microbial activity in cattle rumens decreases, leading to a reduction in forage intake and a decrease in overall nutrient availability (Hanselka, 1989). In Texas, phosphorus is the primary mineral deficiency because of the low availability in forages. Buffelgrass' typical amount of phosphorous on a dry matter basis exceeds that of many native grass species and is within the requirements of mature, dry beef cows, except during dry winter and summer months (Table 1). With management and rain, buffelgrass' percentage of phosphorus can meet and exceed the nutritional requirements for mature, lactating beef cows. Its phosphorous content increased for a few months during the late winter to early spring following a winter prescribed burn and increased after seasonal rain events. At other times of the year, buffelgrass' phosphorous content was below the minimum nutritional requirements. Therefore, its phosphorous content throughout the year is too erratic to serve as a reliable source to always meet minimal beef cattle requirements (Hanselka, 1989).

Buffelgrass is also tolerant to heavy grazing (Williams & Baruch, 2000). Grazing stimulates growth, leading to a bunchgrass with several branching stems. Each branching stem has multiple sites that can give rise to seeds quickly. In fact, buffelgrass can mature and produce flowers, which develop into seeds within 3 to 6 weeks following ¾ to 1 inch of rain. Because of the multiple seed-production sites per plant, 1 pound of buffelgrass can produce 260,000 seeds. Buffelgrass easily reseeds itself, and seeds can germinate, or develop into a new plant, across many soil types, at shallow depths, and with little water. Because of these characteristics, a stand of buffelgrass is persistent and recovers quickly following heavy grazing and other disturbances, such as droughts and fire (Tinoco-Ojanguren et al., 2016).

Table 1. Comparison of nutritional value (on % dry matter or DM basis) for buffelgrass and two native grass species widespread in South Texas and selected for by cattle. In conjunction with forage digestibility, CP affects forage intake. Phosphorous is the main mineral deficiency in South Texas. Livestock requirements are based on mature beef cattle requirements (Hanselka, 1989; Lalman & Richards, 2017). The nutritional value ranges are based on research conducted in South Texas in the 1980s (Hanselka, 1989; Gonzales & Everitt, 1982).

Grass Species	Native Status	Crude Protein (% DM) Livestock Requirements: Dry cow ~ 6–8% Lactating cow ~ 8.5–10.5%	Phosphorous (% DM) Livestock Requirements: Dry cow ~ 0.20% Lactating cow ~ 0.31%
Buffelgrass (*Cenchrus ciliaris*)	Non-native, introduced invasive	7–10.5% (typical), 4–6% (dry months), Peak 11–19% following prescribed fire and/or rain	0.13–0.23 % (typical), 0.05–0.15% (dry months), Peak 0.3–0.5% following prescribed fire and/or rain
Thin or Fringeleaf Paspalum (*Paspalum setaceum*)	Native	7–10.4% (typical)	0.10–0.19% (typical)
Red lovegrass (*Eragrostis secundiflora*)	Native	5.9–8.0% (typical)	0.10–0.16% (typical)

Cons of Buffelgrass

Given the benefits of this drought-tolerant grass, it is easy to understand why buffelgrass accounted for 90 percent of the seeded range south of San Antonio after the extreme droughts in the 1930s and 1950s (Wied et al., 2020). It was assumed that buffelgrass could be used in conjunction with native rangeland forage (Multz & Scifres, 1975). However, buffelgrass outcompetes native plants and forms monocultures. Monocultures reduce rangeland health because the rangeland becomes dominated by a single plant. The decrease in plant diversity decreases the ability of the rangeland to recover following unforeseen events. The competitive nature of buffelgrass and the formation of buffelgrass monocultures was not realized until after it had been seeded on millions of acres of South Texas rangelands.

Buffelgrass has several competitive advantages over native plants and often becomes the dominant plant on a site. First, as stated in the previous section, it has reproductive advantages over native plants. Buffelgrass produces a large number of seeds that germinate into seedlings at shallow planting depths (0 to ¼ inches) across a variety of soil types and requires less water to germinate compared to many native plants (Mutz & Scifres, 1975; Tinoco-Ojanguren et al., 2016). Second, it rebounds quickly after disturbance events such as heavy grazing or prescribed fire. One eye-witness account in LaSalle County, Texas, observed buffelgrass grow and produce seed quicker after multiple discing treatments; it matured into a flowering plant in as little as 3 weeks following ¾ to 1 inch of rain (personal communication, Dr. Eric Grahmann, Habitat Consultant, El Coyote Ranches). Third, even though buffelgrass is highly nutritious, it is a moderately palatable forage for cattle (Cooperative Research Centres [CRC], 2008). Thus, on lands where buffelgrass has just started to establish among a variety of native plants, cattle may select for and graze more heavily on native grasses over buffelgrass. This creates a negative feedback loop that results in the overgrazed, native grasses dying, creating more space for the prolific buffelgrass seeds to take hold and spread. Today, the rapid spread of this non-native, invasive species is well documented—buffelgrass has the potential to double in the percentage of area covered every 2 to 3 years (United States Forest Service [USFS], 2014).

Buffelgrass monocultures diminish rangeland health by reducing the diversity of species, from plants to insects to wildlife. The snowball effect of diversity reduction starts when buffelgrass outcompetes native plant species and becomes the dominant plant in the area. When the diversity of native plants decreases, so does the diversity of other species. Insects in the orders Araneae, Coleoptera, and Hymenoptera are less abundant in buffelgrass monocultures (Flanders et al., 2006). These insects are an important food source for many brooding birds, such as bobwhite quail (*Colinus virginianus*). During brooding, bobwhite quail need additional protein provided by these insects to ensure the health and survival of their young. It is not surprising that bobwhite quail abundance also decreases in buffelgrass monocultures. In fact, researchers determined that quail use decreases on rangelands when there is more than 20 percent cover of buffelgrass (Hernandez & Guthery, 2012). Therefore, as buffelgrass increases, the diversity of native plants decreases, leading to a decrease in insects, leading to a decrease in wildlife. This may be an issue for Texas landowners interested in diversifying the management options on their rangelands and/or applying for the Tax Valuation for Wildlife Management.

Buffelgrass monocultures also reduce rangeland health because rangelands dominated by a single plant are more susceptible to loss and have a harder time recovering from unforeseen changes. If something changes tomorrow that negatively impacts buffelgrass monocultures, there may not be another grass on the rangeland to persist. The future may bring with it unpredictable and changing weather patterns. For instance, South Texas has experienced several freezes recently, and buffelgrass is not frost tolerant (Perramond, 2000). Also, buffelgrass dies in areas where rainfall exceeds 24 inches, and years with above-average rainfall are not uncommon in Texas (CRC, 2008). Finally, diseases and pests can wipe out plant species in an area. Relying on a single grass species for economic security is like putting all the eggs into one basket—it may work for a while until something causes the basket to fall, resulting in a complete loss. Change does happen; there is just no way to predict when it will happen.

IT'S HERE, NOW WHAT? MANAGEMENT OPTIONS FOR BUFFELGRASS MONOCULTURES

Now that buffelgrass monocultures have been established on millions of acres of South Texas rangelands, what are the management options? Well, it depends. Answering these three simple questions will help you decide:

1. What is your end goal?
2. How much time do you have to invest?
3. What resources do you have available to you?

Have Livestock? Graze It.

Buffelgrass is recommended as forage for livestock in South Texas, such as cattle, horses, and sheep (Hanselka, 1989; Wied et al., 2020; Dorsett & Householder, 2012). During our research, we discovered some reports of oxalate poisoning in horses and sheep and a reduction in calcium absorbency in cattle that consumed cultivars of buffelgrass grown in Australia and South Africa (Blaney et al., 1982; McKenzie et al., 1988). However, this has not been an issue reported with livestock consuming the cultivars of buffelgrass grown in North America (Burrows & Tyrl, 2013; personal communication, Dr. E. Murl Bailey, Jr. DVM, Ph.D., Professor of Toxicology and Emergency Medicine, Texas A&M University; Dr. Walter Cook, Clinical Associate Professor, Veterinary Pathobiology, School of Veterinary Medicine and Biomedical Sciences, Texas A&M University; & Dr. Christine Mesecher DVM, Animal Medical Clinic Kingsville, Texas).

For livestock species with higher nutritional requirements, buffelgrass can be managed and grazed to provide an optimum return on investment. For example, a late winter burn in February increases the palatability, quantity, and quality of buffelgrass the following spring. The regrowth in the spring can be used by first-calf heifers to meet their higher nutritional needs. If engaging in this practice, it is recommended to provide phosphorous supplements free choice, as the phosphorous levels in buffelgrass may or may not meet minimal beef cattle requirements. The increased palatability and nutritional quality of buffelgrass following winter prescribed burns are short-lived, typically lasting 3 to 4 months after the prescribed burn. However, the quality of buffelgrass will increase again that year if adequate rainfall is received during the growing season. The increase in buffelgrass quality following growing season rain events was similar in pastures that had a winter prescribed burn and in pastures that were not burned (Hanselka, 1989).

Want Improved Rangeland Health or Wildlife? Restore It.

If the end goal is to increase diversity on the rangeland, then restoring a buffelgrass monoculture to a native grassland may be an option. However, it depends on how much time can be invested and the resources that are available. In general, there are three management approaches to consider: passive management, diversity management, and eradication (Clayton et al., 2017b).

Passive Management

Passive management is the best option when time or resources do not allow for the application of multiple treatments to reduce the abundance of invasive grasses (Clayton et al., 2017b). However, passive management does not mean that no action is taken at all. The goals of passive management are two-fold: (1) to prevent the spread of the invasive grasses to non-invaded areas and (2) to take quick action to remove them if an invasive grass plant escapes into a new area.

Start by mapping locations of buffelgrass monocultures on the property. Do not engage in disturbance practices, such as heavy grazing or discing, that will create bare soil near buffelgrass plants, as buffelgrass easily seeds on bare soils. Also, identify areas where potential buffelgrass seed spread is the highest, such as animal travel corridors, near roadsides, and in ditches (USFS, 2014). Buffelgrass seeds are spread by wind, water, animals, humans, vehicles, and equipment (CRC, 2008; USFS, 2014). Early detection of new invasions is key in decreasing the spread of buffelgrass. Plan to monitor these areas within a couple of weeks following ¾ to 1 inch of rain during the summer and autumn months. Monitoring should also be conducted following rain events during warm winter and spring months, as buffelgrass seeds have germinated when soil temperatures were as low as 50 degrees Fahrenheit, albeit the most successful germination of buffelgrass seeds occurs when soil temperatures are 77 degrees Fahrenheit for 3 to 6 days (Tinoco-Ojanguren et al., 2016). Once a new buffelgrass plant (Fig. 2) has been identified in a new area, remove it by hand-pulling or treating the plant with herbicide (see the *Eradication* section for more details).

Figure 2. Young buffelgrass plant.

In addition to monitoring programs following rain events, the spread of buffelgrass seeds can be reduced by inspecting and removing seeds from animals, clothing, equipment, and vehicles. Wash the undersides of vehicles and equipment that may be carrying seeds and request the same for any vehicles or equipment brought onto the property (USFS, 2014). If hay is purchased, ensure the producer is taking precautions to prevent the presence of invasive seeds in their product. If these steps are followed but buffelgrass is still actively spreading into new, uninvaded areas, a barrier between the buffelgrass monoculture and the area where new and reoccurring invasions may be needed. The spread of buffelgrass seeds by wind and animals can be reduced by a natural barrier, such as allowing native shrubby vegetation to grow around the buffelgrass monocultures.

Lastly, most passive management strategies recommend leaving the monoculture alone completely. However, buffelgrass monocultures that are completely left alone can produce a large amount of dead leaf material, increasing the fuel load. Buffelgrass fires burn hot enough to melt aluminum, and fires can spread 2 to 3 miles per hour in mild conditions (National Park Service [NPS], 2011). Buffelgrass can burn even when it is green because of the fuel-load buildup and heat intensity of the fires (CRC, 2008). Thus, the inclusion of a management plan to remove dead growth, such as prescribed fire or mowing and bailing, may be needed to reduce any potential damage from an intense wildfire. This disturbance will promote new growth and buffelgrass seed production within the monoculture but may be necessary to protect the property against an intense wildfire.

Diversity Management

Diversity management includes a year of intense combination treatments to reduce the abundance of invasive grasses, typically followed by reseeding with native grasses and forbs (Clayton et al., 2017b). Diversity management will not eradicate the invasive grass, but the goal is to reduce the abundance of the invasive grass while increasing the diversity and abundance of native grasses and forbs. In one observational study in Arizona, researchers determined buffelgrass abundance was reduced in areas repeatedly grazed by free-roaming horses but provided no information on the diversity of plants in the areas where buffelgrass abundance had been reduced (Krebs, 2018). Buffelgrass is highly competitive with native grasses and forbs, as seeds can remain viable in the soil for over 5 years, and it can double in the percentage of area covered every 2 to 3 years (USFS, 2014; Gowdy et al., 2022). Thus, there is the potential for diversity management treatment in buffelgrass monocultures to fail. Because of this potential relapse and the lack of research, we cannot prescribe a diversity management treatment for buffelgrass at this time.

Eradication

The goal of eradication is the complete removal of the invasive grass and restoration of the monoculture back to native grasses and forbs. Eradication is, at minimum, a 5-year process that requires: (1) an initial winter treatment (prescribed burn or mowing/bailing) to prepare the area for follow-up treatments, (2) at least 2 to 3 years of maintaining bare soil while engaging in intensive combination treatments (discing, herbicide) following rain events to knock back buffelgrass before it can produce new seed, (3) reseeding with native grasses and forbs following treatments, and (4) several years of monitoring and quick action to treat individual invasive grass plants by hand-pulling or spot-spraying with herbicides (Table 2; Gowdy et al., 2022; USFS, 2014; NPS, 2011). It is a labor-intensive process that requires flexibility, commitment, and perseverance.

The conversion of a non-native invasive grass rangeland back to a native grassland is at least a 5-year process. Typically, it requires 2 years to remove the invasive grasses and exhaust their seed bank, 1 year to prep the seedbed and wait for the correct environmental conditions for seeding, and another 2 years of intense maintenance. Table 2 provides a suggested timeline based on the successful conversion of a rangeland dominated by buffelgrass and old world bluestem back to a native grassland in LaSalle County, Texas, from 2014 to 2018 (Gowdy et al., 2022). Discing or applying herbicides to buffelgrass must occur following rain events and buffelgrass regrowth. Buffelgrass must be treated before it produces new seeds. Otherwise, the 2-year process of maintaining bare soil while exhausting the buffelgrass seed bank must be restarted. Flexibility is necessary. For example, during year one, the rangeland was not treated after April due to no new buffelgrass growth. However, it was treated multiple times during years two and three after rain events that led to new growth of buffelgrass.

Buffelgrass Eradication Success Stories

Buffelgrass is being eradicated in Saguaro National Park in Arizona (NPS, 2011). Park staff and volunteers first began to remove buffelgrass by hand and using backpack sprayers to chemically treat individual plants with herbicides in 1993. However, their initial efforts failed because buffelgrass was spreading faster than they could remove it. Park staff reevaluated their efforts and began an integrated pest management plan in 2004. They have been successful at eradicating buffelgrass with year-round treatments that occurred for a 3- to 5-year period. During the 3- to 5-year treatment

Table 2. Suggested timeline for the conversion of non-native invasive grass rangeland back to native grassland based on the successful conversion of a rangeland dominated by buffelgrass and old world bluestem back to a native grassland in LaSalle County, Texas, from 2014 to 2018 (Gowdy et al., 2022).

Year one	
February	Prescribed burn
April	Disc field
Year two	
January	Disc field
May	Disc field
June	Disc field
July	Disc field
Year three	
March	Top-spray herbicide*
June	Top-spray herbicide*
August	Top-spray herbicide*
September	Top-spray herbicide*
October/November	Plant native mix by drill seeding *(see next page for more information on seed mixes)*
Year four	
Summer/Autumn	Post-rain events: Monitor and hand-spray and/or hand-pull invasive grasses
October/November	Reseed patches that failed to establish, if needed
Year five	
Summer/Autumn	Post-rain events: Monitor and hand-spray and/or hand-pull invasive grasses

*Glyphosate was applied at a rate in accordance with label directions and manufacturer recommendations.

period, they applied the herbicide, glyphosate, multiple times to individual buffelgrass plants when they were green (mostly in summer, but also sometimes during late winter or early spring) and removed some of the buffelgrass plants by hand-pulling during winter when the plants were dormant and golden-yellow in color. They continuously monitored previously treated areas and acted when new buffelgrass plants emerged. Following 3 years of intensive, year-round treatments in the buffelgrass monocultures, only a few individual buffelgrass plants remained (NPS, 2011).

Another successful restoration of native plants in an area dominated by buffelgrass occurred on the Hixon Ranch in La Salle County, Texas, from 2014 to 2018 (Gowdy et al., 2022). The 292-acre monoculture had greater than 85 percent cover of non-native invasive grasses that mostly consisted of buffelgrass, although some old world bluestem were present. In February 2014, a prescribed burn was conducted to consume aboveground biomass and prepare the area for discing. From April 2014 to July 2015, several discing treatments were completed after each rain event that stimulated buffelgrass regrowth. The area was disced within a couple of weeks after buffelgrass first emerged so that it did not have time to produce seed. During the third year in 2016, the researchers transitioned from discing to glyphosate herbicide treatments to allow the soil to firm before drilling in native plant seed. All herbicide applications were conducted according to manufacturer label directions. Applications were made several times throughout March, June, August, and September following rain events when buffelgrass regrowth occurred but before it produced new seed. From October to November of 2016, when almost no buffelgrass regrowth was seen after rain events, the site was seeded with a mix of 26 to 27 native grasses and 37 to 43 native forbs and subshrubs. After planting, the area was monitored for new buffelgrass plants following rain events. Once found, they were destroyed via individual plant treatment by hand-pulling or spraying with glyphosate. During the fourth year, from October to November of 2017, patches that failed to establish with the native grass and forb mix were reseeded. During the fifth year in 2018, they monitored for and treated any new individual buffelgrass plants following rain events during the summer and autumn (Table 2). The 5-year process cost $611 per acre (Gowdy et al., 2022).

It is not necessary to apply all discing treatments or all herbicide treatments in the same year, but the combination of these two treatments during the first 3 years will increase the success of the restoration. Therefore, be ready to apply one of the treatments within a couple of weeks following rain events when green leaves are present but before the seeds produce (personal communication, Dr. Eric Grahmann, Habitat Consultant, El Coyote Ranches).

We contacted Mike Hehman in December 2022 to get an update on the restored native grassland on the Hixon Ranch in La Salle County, Texas. We asked Mike what management actions had been taken in the last 4 years since the restoration project was completed. Mike told us, "We are taking a hands-off approach to the restoration site and not treating any invasive grasses because one of the research goals following this project was to see how fast the invasives may expand with competition from the natives. We have not grazed the native grassland yet, but we plan to implement some grazing for a month or so next summer." Dr. Hines visited the restored native grassland in LaSalle County in March of 2023 along with Dr. Eric Grahmann (Habitat Consultant, El Coyote Ranches). We estimated that only about 5 percent of the entire 292 acres had non-native invasive buffelgrass and old world bluestem present. The native grasses and forbs planted 5½ to 6½ years ago predominate in the restored site (Fig. 3).

Figure 3. Images of the restored grassland on the Hixon Ranch in La Salle County, Texas. The photos were taken in October of 2022, 4 years after the end of the 5-year restoration cycle. *Photos taken and provided by Mike Hehman.*

Buffelgrass Eradication Follow-up Management

After the initial 5-year restoration process is complete, monitor and treat individual invasive grass plants or they will return. This is especially true if there is bare ground nearby, such as a caliche road. Annual monitoring and treatment after rain events in summer and autumn will need to continue beyond 5 years. Although an exact duration cannot be determined due to a lack of data, we suggest regularly monitoring until no new invasive grasses come up in the native restored grassland.

NATIVE SEED MIXES: HOW TO FIND AND WHERE TO BUY

Selecting the correct native seed mix is vital to restoring native grasslands. A proper seed mix for the area will increase plant diversity and improve health and economic returns from livestock and wildlife operations on Texas rangelands. The proper seed mix does depend on the location. The Texas Native Seeds (TNS) program has a tool to help landowners select the best mix based on the area and soil type (if dealing with sandy or clay soils). The native seed mix list provided through this tool will also list the contact information of reputable commercial dealers and experts for some additional advice. Most of the seed mixes provided by the TNS program are a base mix that could be enhanced by collecting or including a variety of native grasses and forbs. For example, in La Salle County, Texas, the native grassland mixes for the varying soil types included anywhere from 26 to 27 native grasses and 37 to 43 native forbs and subshrubs (Gowdy et al., 2022). Diversity increases successful establishment. A mix of various annual and perennial native seeds of plants that grow in wet and dry conditions will maximize the bottom dollar and provide cover of native plants in the grassland during the highly variable weather conditions of South Texas.

To access the Native Seed Selection Tool, visit *https://www.ckwri.tamuk.edu/research-programs/texas-native-seeds-program-tns/native-seed-selection-tool.*

ROADMAP TO AN ECONOMIC DECISION REGARDING BUFFELGRASS AND NATIVE GRASSLAND

To make the economic decision between buffelgrass and native grassland, the rancher may reflect on the five steps elaborated by Horngren et al. (2015). First, identify the problem and uncertainties. Weather, prices, and demand are among agriculture's primary sources of uncertainty. Diversification—not putting all the eggs into one basket—mitigates the risk. Therefore, embarking on different activities that are not directly related contributes to managing the adverse effects. In addition, there are problems and risks inherent to each specific rancher. For instance, an engaged son may leave the property, leading to a labor shortage.

Second, obtain information. The rancher needs to gather data to understand the uncertainties of the problem better. Both qualitative and quantitative insights shed light on pressuring issues. For example, price time-series data may suggest revenue patterns and cycles. Weather data indicating drought suggests the possibility of extreme events. The knowledge of neighboring ranchers and specialists brings new perspectives on cause-and-effect relationships. Market analysis can reveal an increasing demand for wildlife. This information surrounds the rancher in a specific way in each case.

The third step requires making predictions. Given the information collected, the rancher should forecast the possible scenarios for the enterprise. To assist with this task, budgets and cash flows are tools that express the business outlook in financial terms. The budget focuses on the short-term, such as the upcoming crop season. The Texas A&M AgriLife Extension Service provides budgets for a variety of agricultural activities (*https://agecoext.tamu.edu/*). Cash flow, on the other hand, captures the long-term behavior of money coming in and out of a business. However, an important caveat is to recognize that making projections demands judgments and assumptions. Therefore, the rancher needs to look for thinking biases during the process.

In the fourth step, the rancher decides by choosing among alternatives. Two standard tools to assist in this task are the cost-volume-profit (CVP) and the net present value (NPV). The CVP evaluates the operating income—the difference between revenue and cost (fixed and variable)—as quantities and prices vary. Thus, it is possible to determine the amount produced that implies zero profit, or the break-even point. Complementing the analysis, the safety margin, or the distance between budgeted and break-even sales, may indicate the better alternative. The CVP drawbacks include ignoring the money's time value and assuming coefficients as constant.

Net present value (NPV) shows the current value of all the incoming and outcoming cash flow streams. To estimate the current value, the cash flow needs to be discounted by a rate that reflects the cost of the capital or the return available for alternative projects with similar risks. If the NPV is positive, the rancher should execute the project. The higher the NPV, the better.

Luz (2021) developed a bibliometric study to summarize the literature on the economics of restoration, noticing that most studies do not go beyond estimating costs. Although costs are crucial in the analysis, the lack of understanding of the benefits restricts the rancher's analysis. Furthermore, not incorporating public goods concepts into these investigations prevents the design of better public policies.

Knight and Overbeck (2021) surveyed the literature on grassland restoration costs. The sparse investigations on the topic show a wide range of values. The authors presented activity costs from $0.40/acre to $1,689,256/acre and project costs from $5.25/acre to $32,087/acre. Meanwhile, when investigating South Texas, Clayton et al. (2017a) noted the exact field preparation costs for native plants and buffelgrass at $63.40/acre. They pointed out slightly more establishment costs for native plants ($107/acre) than for buffelgrass ($89/acre). However, the maintenance for buffelgrass ($97.78/acre) nearly triples the native plants' costs ($33.78/acre).

The data range highlights the need to understand the peculiarities of each project. In addition, contrasting the benefits (value) against the costs (expenses) grants better decisions and policies. Cost-share programs are available that ranchers can apply for to help offset some of the expense of native grassland restoration. Contact the local National Resources Conservation Service office or visit their website at *nrcs.usda.gov* for more information.

The last steps are to implement the decision, evaluate performance, and learn. Then, after adopting one possible course of action, the rancher can compare the actual with the planned (budget) outcome. Accordingly, a control system allows for result evaluation and feedback to improve ranch operations.

Besides being economically feasible, the decision should be aligned with the overall strategy of the ranch. After these five steps, the rancher is expected to be more enlightened to strategically decide between buffelgrass and native grassland.

THE FINAL WORD: TAKE-HOME MESSAGE

The effective management of any rangeland plant first requires the ability to identify the plant. Once the plant has been identified and confirmed on the property, consider the pros and cons of the plant species while investigating all research-based management options. Then, weigh the pros and cons of the plant against the potential management options. Consider the time that must be invested and the resources required. Determine which decision works best for the rangeland operation economically. Following these steps will help to select the best management option that will be attainable and sustainable.

Buffelgrass is a non-native grass that provided a potential solution for soil stability and livestock forage following historical droughts. The unintended consequence—the formation of buffelgrass monocultures—was not realized until after buffelgrass had already been seeded on millions of acres of South Texas rangelands. We cannot change history—buffelgrass is here now, so landowners must decide what management option works best for them. It can be managed to provide forage for livestock, or landowners can engage in passive management options to prevent spread. Alternatively, landowners can commit to eradication and return the rangeland to a native grassland. Each of these options is detailed in this publication, and now it is up to each landowner. The short-term and long-term rangeland management goals will help to determine which management option or combination of management options to pursue.

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