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RANGELAND CONSERVATION ANALYSIS #1
CONTROLLING ASHE JUNIPER ENCROACHMENT ON RANGELAND IN THE EDWARDS PLATEAU, TEXAS

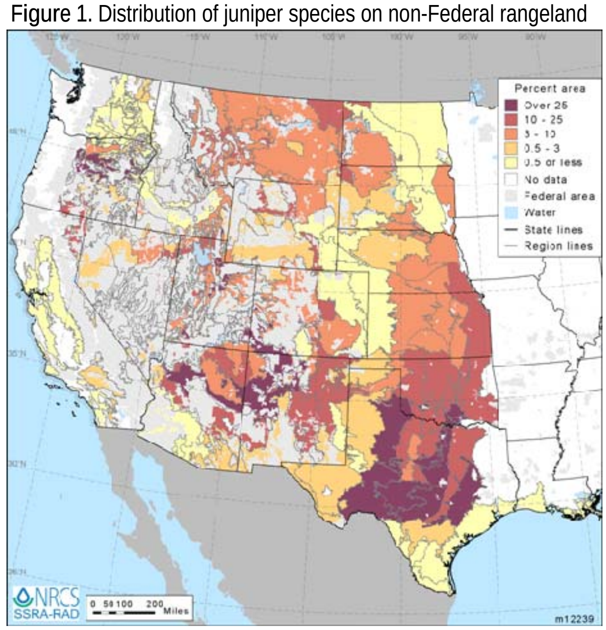
The Issue

Woody plant encroachment into semiarid and arid rangelands is a major problem, with hydrologic and biogeochemical consequences (Madsen et al. 2011). Shrub density and cover have increased dramatically on rangelands, changing former grasslands and savannahs into shrublands or closed canopy woodlands (Romme et al. 2009, Archer et al. 2011). Tree and shrub encroachment often leads to declining productivity, loss of desirable understory and interspace plants, reduced biodiversity, altered hydrology, and increased soil erosion (Mack et al., 2000, Brooks et al. 2004, Pierson et al. 2011).

One of the dominant woody invaders across the Western and Plains States is juniper (Miller et al. 2008). Juniper is native to North America and present on many rangeland ecological sites; however, it can be an invasive species where it did not historically exist or where it has exceeded its historic density and canopy cover. Juniper has expanded its range, degrading the soil health of systems it invades, altering biotic integrity by displacing native species, altering fire frequency and intensities, and accelerating soil erosion and loss of critical wildlife habitat (Dye et al. 1995, Ueckert 1997, Miller et al. 2008, Pierson et al. 2011). Juniper is present on 10 percent (40.7 million acres) of the Nation's non-Federal rangeland (fig. 1, NRI rangeland data 2003–06). Juniper plants are considered invasive on ecological sites where it is not a native component *and* it has the potential to become a dominant or co-dominant species if their future establishment and growth is not actively controlled by management (Pellant et al. 2005).

Expansion of one species of juniper, Ashe juniper, has accelerated in the last 50 years in Texas due to fire suppression and overgrazing (Smeins and Fuhlendorf 1997). Heavy grazing reduces the possibility of fire and facilitates rapid encroachment of Ashe juniper and associated woody species. In 1985, it was estimated that Ashe juniper occupied over 8 million acres of Texas rangelands (USDA 1985). NRI data collected from 2003 to 2006 show that Ashe juniper had increased to 9.3 million acres (out of a total of about 18.7 million acres of Texas rangeland with juniper present). The greatest abundance of Ashe juniper is found in the eastern and southern portions of the Edwards Plateau in south-central Texas, but Ashe juniper also extends into the South Texas Plains and north into the Cross Timbers and Rolling Plains areas of the State. Ashe juniper is a native component on many ecological sites, comprising 5 to 10 percent of plant cover, often on rocky outcrops and rocky, north-facing slopes where they are protected from intense grass fires.

Figure 1. Distribution of juniper species on non-Federal rangeland



SOURCE: USDA-NRCS NATIONAL RESOURCES INVENTORY RANGELAND REGIONAL ASSESSMENT

As Ashe juniper cover increases, the amount of precipitation that reaches the soil surface is significantly reduced. Hester (1996) reported canopy interception losses of 37 percent of gross precipitation for Ashe juniper. By comparison, live oak, a native tree species, intercepts approximately 25 percent of gross precipitation. Rainfall that passes through the canopy is intercepted by the dense litter layer under the plant. Thurow and Hester (1997) estimated that litter mats under Ashe junipers intercept 40 percent of gross precipitation. As a result, less than 25 percent of annual precipitation reaches the mineral soil surface under the canopies of Ashe junipers (compared to 82 to 89 percent under grass cover). With less soil moisture available for plant growth, native grasses and forbs die back and bare soil increases between mature junipers. Increased connectedness of bare soil patches allows the formation of concentrated flow paths which can initiate accelerated soil loss, including rills and gullies (Wilcox et al. 1996, 2003; Pierson et al. 2009; Davenport et al. 1998).

The Edwards Plateau—Eastern Part

The eastern part of the Edwards Plateau[1] covers approximately 8,060 square miles in south-central Texas, is 98 percent rangeland (USDA-NRCS 2006, Hatch et al. 1990), and is composed of 20 rangeland ecological sites. An ecological site has specific soil and physical characteristics that distinguish it from other sites in its ability to produce distinctive kinds and amounts of vegetation, and in its ability to respond similarly to management actions and natural disturbances. Limestone ridges and canyons (karst geology) dominate the landscape with nearly level to gently sloping valley floors. Average annual precipitation is 24 to 30 inches, most of which occurs in spring and fall. The native vegetation is grassland and open savannah plains, with tree or woody species found along rocky slopes and stream bottoms. Tall grasses originally dominated the area, and stocking rates for cattle varied from 3 to 10 acres per animal unit month, depending on the depth of soil and site conditions.

Deep Redlands Ecological Sites

A common ecological site in the eastern part of the Edwards Plateau is the Deep Redlands Ecological Site. The historic plant community of a Deep Redlands Ecological Site is an oak savannah (fig. 2, State I, Community 1), comprised of numerous tallgrasses and forbs, with scattered oaks providing less than 10 percent canopy cover. The dominant native grasses are little bluestem, big bluestem, Indiangrass, switchgrass, sideoats grama, and Eastern gamagrass. During the course of the natural fire interval, Ashe juniper will invade the site (State I, Community 2), but rarely exceeds around 5 percent canopy cover before being removed by fire. The natural fire interval is influenced by grazing intensity: overgrazing can reduce native grasses and the fine litter biomass which facilitates the natural fire cycle necessary to reduce densities of Ashe juniper and associated woody species.

If the fire cycle is interrupted, Ashe juniper densities can expand rapidly and reach 10- to 20-percent cover in a decade (State II, Community 3). In the last several decades, a combination of fire suppression, overgrazing, and no other brush management treatments has resulted in conditions characterized in State II on thousands of acres in Texas. In order to restore the site to State I, implementation of rangeland conservation practices such as prescribed burning, prescribed grazing, brush management, and possibly herbaceous weed control is required. The classification as two distinct states indicates that an ecological threshold has been crossed, meaning that intervention is required to reestablish the historic fire interval and plant communities.

Without brush management, continued fire suppression allows Ashe juniper and other woody species to increase and dominate the site (State III, Community 4). Ashe juniper can reach 20 feet or taller, with canopies exceeding 30 percent, and in time attain full canopy closure. Grasslike vegetation is significantly reduced due to competition for sunlight, moisture, and nutrients. The total grasslike production potential for this community is severely restricted, and may generate only 20 to 40 percent of reference condition forage production. Bare areas often develop in the interspaces between juniper trees and in time expand in size and connect with each other forming a conduit for concentrated runoff and the formation of rills and gullies. Once the site is truly representative of State III, Community 4, especially with significant soil loss from erosion, another threshold has been crossed and transitioning back to States I or II is very unlikely.

One other State, the Open Grassland or Open Savannah type community is represented as State IV. Through the reintroduction of prescribed fire and grazing, and replanting of native forbs and grasses, sites can shift towards a grassland-dominated plant community (State IV, Community 5); however, it will be difficult to regain the original native diversity of the historic plant community. The "Open Grassland Community" may also represent a community of seeded species which are non-native and may occur as monoculture communities, with less habitat or food for wildlife. In many cases, native grasses may be missing entirely, along with dramatic reductions in the native forb and legume diversity. Total production in State IV, Community 5 is usually less than the production potential of the reference historic plant community due to loss of native tallgrass species and replacement by introduced species. With proper resource management, this state can be maintained as an open grassland community. Without proper management, Ashe juniper can invade again, and the site will gradually transition to an "Open Grassland with Juniper Encroachment Community" (State IV, Community 6).

[1] Major Land Resource Area 81C.

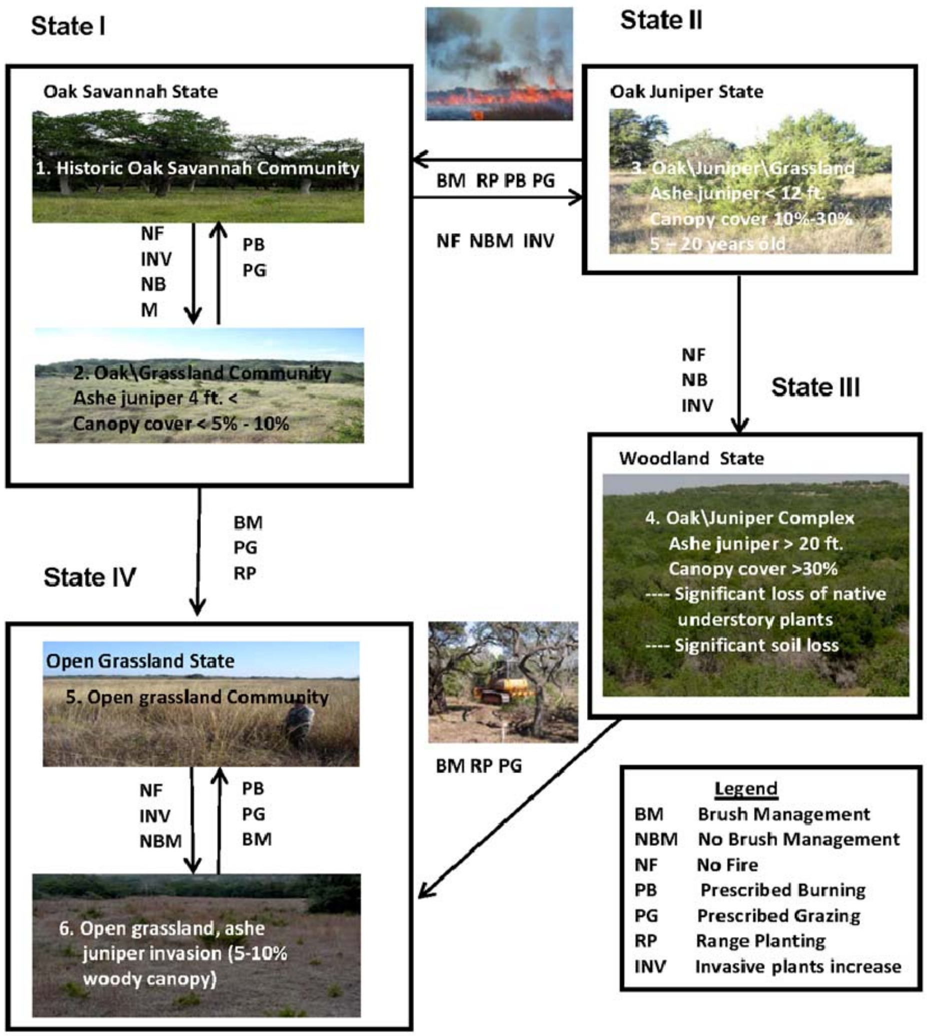


Figure 2. State and Transition Model illustrating the Deep Redlands Ecological Site in eastern Edwards Plateau, TX (Major Land Resource Area 81C)

Impact of Invasive Species on Hydrologic Function in the Edwards Plateau

Plant communities, soil health, site management, and climate determine the dynamics of water cycles and soil erosion. Plant and litter cover are important factors that protect the site from erosion, whereas total biomass and the types of plant species present have greater impact on infiltration capacity and runoff. Soil health also contributes to high hydrologic function, which is affected by the organic matter content of the soil, soil biotic activity, and soil surface structure, including lack of compaction (high porosity) and high soil aggregate stability.

Average annual soil erosion is not an appropriate metric for evaluating vulnerability of rangelands. On arid and semiarid rangelands, soil erosion is primarily episodic in nature, and most soil loss occurs during intense storms that generate large amounts of runoff. Exposed bare soil surface is easily eroded and concentrated flow paths can form; on rangeland these concentrated flow paths are generally not removed once formed. During storm events, runoff is channeled and accelerated soil loss can result in the site crossing a hydrologic threshold and being permanently degraded (Urgeghe et al. 2010). Under current vegetative cover, approximately 12 percent, or 48.2 million acres of non-Federal rangelands, are vulnerable to accelerated soil loss from a 50-year return period runoff event (fig. 3). Accelerated soil loss is defined as soil loss above the expected level for the reference plant community with a similar rainfall event. The Edwards Plateau shows one of the highest potential soil erosion rates in the Nation, in part because of the high Ashe juniper density and corresponding reduction in grass and forb cover (fig. 4).

As ecological sites transition from one state to the next, hydrology and soil erosion change. For Deep Redlands Ecological sites near Johnson City in States I, II, and III, the

Rangeland Hydrology and Erosion model (Nearing et al. 2011) was used to estimate runoff and soil losses for different intensity storms (table 1).

State 1 Hydrology and Erosion

For Reference State conditions with a high composition of native tall-mid grass species and forbs, average annual runoff is typically low, about 1.7 inches per year. Healthy stands of perennial native grasses, forbs, shrubs, and trees provide multiple canopy cover layers, and associated litter layers reduce raindrop impact and buffer soil loss, even during intense storms. High-intensity thunderstorms, however, can produce significant runoff. A 2-year return period runoff event could generate as much runoff as the annual long-term average; a 25-year runoff event, about two times the annual long-term average; and a 50-year runoff event, almost three times the annual long-term average. A 50-year runoff event causes estimated soil erosion of only 1.1 tons per acre in the reference state.

Figure 3. Non-Federal rangeland vulnerable to sheetflow soil loss from a 50-year return period runoff event

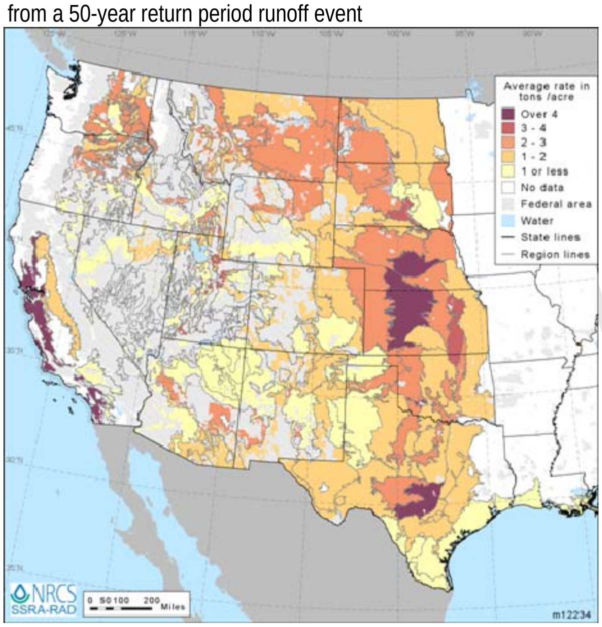


Figure 4. Texas rangeland vulnerable to sheetflow soil loss from a 50-year return period runoff event

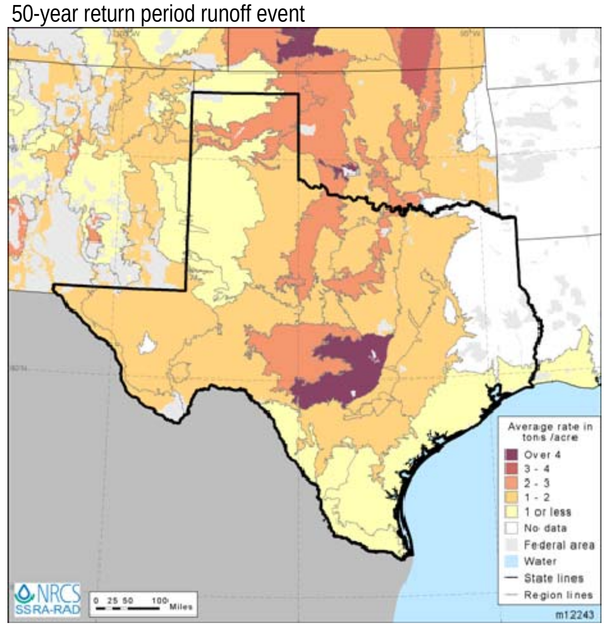


Table 1. Rangeland Hydrology and Erosion model estimates of runoff and soil loss during runoff events for Deep Redlands Ecological Sites in the Edwards Plateau near Johnson City, TX

Return Period Runoff Frequency	Precipitation (inches)	Runoff (inches)	Soil Loss (tons per acre)
State I (Reference state; juniper < 4 feet and < 5% juniper canopy cover)			
2 yr	2.8	2.1	0.2
10 yr	4.3	2.5	0.7
25 yr	5.4	3.6	0.9
50 yr	5.6	4.6	1.1
State II (Juniper > 4 feet and < 12 feet and juniper canopy cover of 10-30%)			
2 yr	2.8	2.2	1.2
10 yr	4.3	4.3	2.8
25 yr	5.4	5.6	3.2
50 yr	5.6	7.9	3.5
State III (Juniper > 20 feet and > 30% juniper canopy cover)			
2 yr	2.8	2.3	2.1
10 yr	4.3	6.8	3.0
25 yr	5.4	8.3	5.3
50 yr	5.6	13.1	6.7

State II Hydrology and Erosion

During the transition phase from State I to II, the decline in tall-mid grasses leads to more bare ground, increased soil compaction and physical crusting, loss of soil organic matter, and deterioration in soil structure. As infiltration decreases and runoff increases, accelerated soil loss may begin. Runoff is about 70 percent higher on State II sites than on State I sites during 10-, 25-, and 50-year runoff events, and estimated soil loss more than triples. Ecological sites in this condition can contribute to an increased frequency and severity of floods during intense rainfall events.

State III Hydrology and Erosion

When Ashe juniper and associated woody species dominate the site, understory species become increasingly sparse and ground cover decreases. Rills and gullies may form between mature junipers, which can concentrate runoff and accelerate soil erosion. When juniper is mature and exceeds 30 percent of canopy cover, the site can erode quickly, especially during intense storm events. For a 50-year return period runoff event, runoff can be almost three times greater on State III sites than on reference condition sites, and the soil loss rate can be six times higher, at 6.7 tons per acre.

Economic Impact of Treatment

In central Texas, the historical role of natural wildfires has been diminished. In the absence of fire or other management actions (use of hand thinning, herbicides, or mechanical brush management), Deep Redland ecological sites will eventually be invaded by Ashe juniper and other woody species and transition to closed woodlands with minimal grazing capacity, degraded hydrologic function, and altered wildlife benefits. If the site is allowed to reach and be maintained in this degraded state, the result will be accelerated soil loss except in very level areas. The site can cross an ecological threshold, resulting in a permanent loss of productivity and economic benefits. Rehabilitation to State IV most likely will not result in re-establishing the native tallgrass component to a great degree. Grass species that are more adapted to eroded soils (King Ranch Bluestem, sideoats grama, dropseed spp., etc.) are more likely to establish. Forage production in State IV could be reduced by as much as 50 percent (Engle and Kulbeth 1992).

The most cost-effective treatment option is to treat the area before junipers reach a height of 4 feet and canopy cover exceeds 10 percent. For sites with juniper cover of less than 10 percent, NRCS recommends that prescribed fire, mechanical brush removal, hand thinning, and/or herbicides be used to keep the area in a State I savannah plant community. This costs approximately $24 per acre once every 5 to 10 years (table 2). Grazing could be allowed following treatment depending on local weather conditions and site response. Treating the more than 129,000 Edwards Plateau (eastern part) rangeland acres that had transitioned to State I.2 at the time of NRI data collection would cost approximately $3 million. Waiting to treat these acres until they transitioned into State II.3 would cost about $10.7 million, while waiting until they were in the closed canopy State III.4 would cost close to $50 million.

When juniper canopy cover is between 10 and 30 percent (State II.3) and the trees are as tall as 12 feet, average treatment costs rise to $83 per acre (and can increase as juniper density and size increase). Technical assistance costs triple to $15 per acre because of the complex design and implementation requirements for more intricate management plans. Mechanical brush management, hand thinning, and herbicide use will all be more extensive and expensive than in State I.2. If prescribed fire is not allowed or desired and herbicides are required, costs can rise to $135 per acre. If there is substantial soil disturbance during mechanical treatments with heavy machinery, rangeland seeding may be needed which increases the cost to over $200 acre. Grazing may have to be deferred for up to 2 years to allow for establishment of seeded species or natural regeneration, depending on initial condition of the site and local weather following treatment. Treating the more than 137,000 Edwards Plateau (eastern part) rangelands acres that had transitioned to State II.3 at the time of NRI data

Table 2. Average costs (per acre) to implement recommended conservation practices to restore degraded Deep Redlands Ecological sites in the Edwards Plateau.

Vegetation State	Juniper cover	Acres occupied by cover class	Acres per AUM	Cost per acre
Reference	< 5%	2,339,228	3-10	$0
State I.2	5 – 10%	129,143	3-10	$24
State II.3	10 – 30%	137,323	10-30	$83
State III.4	>30%	574,642	30-50	$385

collection would cost approximately $11.4 million. Waiting to treat these acres until they transitioned into the closed canopy State III.4 would cost an estimated $53 million.

When juniper canopy cover is greater than 30 percent and trees are taller than 20 feet (State III.4), the expected minimum cost for treatment is $385 per acre. Technical assistance rises to $20 per acre, and mechanical brush management may require bulldozers to remove mature trees. Deferred grazing for 2 years is recommended. Treating the almost 575,000 Edwards Plateau (eastern part) rangeland acres in State III.4 would cost about $225 million, and would likely transition these sites to State IV.5 rather than the reference state.

Conclusions

Juniper species are common invasive plants in many rangeland plant communities in the United States. Juniper is found in semiarid tallgrass prairie in the Midwest and in many semiarid communities throughout the West. On many rangeland sites, juniper is a native woody species and its composition is not more than 5 to 10 percent of plant cover in historic reference conditions for healthy ecological sites. Where juniper is not native, increasing densities can have a profound negative effect on site productivity, biodiversity, hydrology, and soil health.

One of the prime reasons for juniper invasion in rangeland plant communities is the suppression of natural fire cycles without compensating with the use of prescribed burning or other treatment methods. Juniper seeds are spread by birds, and seedlings can grow quickly. When moisture and site conditions are adequate, juniper seedlings can reach 4 feet in 5 years. As juniper gets taller and densities increase, understory vegetation is shaded out and the likelihood of control by fire diminishes.

As the juniper overstory exceeds 30 percent and progresses towards total canopy closure, the productivity and diversity of understory plants begin to decrease. In time, with less understory cover, increased runoff will create concentrated flow paths, and rills can develop on ecological sites with slopes over 10 percent. Eventually, the rills can become gullies with bedrock exposed, and significant soil loss can occur during runoff events. On many rangelands, this level of soil loss is essentially irreversible, and restoration to historic reference conditions is not possible. A new state occurs that is less productive for livestock and wildlife.

On degraded sites the amounts of runoff and erosion during intense storm events can exceed long-term average runoff and erosion rates and may trigger a potentially irreversible ecological state change. If significant soil loss occurs on a site, the remaining subsoil is generally less capable of supporting native plants, and a form of desertification can occur. Degraded sites with dense woody cover are more prone to the excess runoff, continued soil loss, and drought effects from reduced soil moisture. Productivity declines, overgrazing can occur more quickly, plant community composition changes, native plants are lost, and less desirable weedy species fill niches.

The most cost-effective treatment option is to prevent the site from being invaded by treating the area before junipers reach a height of 4 feet and canopy cover exceeds 10 percent. For sites with juniper cover of less than 10 percent, conservation treatments including a combination of prescribed fire, mechanical brush removal, biological control, hand thinning, and herbicides can be used to maintain the savannah--grassland plant community. Grazing deferment may be required, depending on the speed of understory grass recovery. The cost for maintenance every 5 to 10 years would be approximately $24 an acre.

As juniper canopy cover increases to 10 to 30 percent and height increases to as much as 12 feet, more aggressive and costly measures are required to prevent further degradation and maintain or restore productivity, biodiversity, and ecosystem function. Treatment costs range from $75 to $200 an acre depending on site conditions, and grazing deferment for up to 2 years may be required, depending on the speed of understory grass recovery. When juniper cover reaches 30 percent, prescribed fire is no longer an effective control option because of the lack of fine ground fuels and the maturity and amount of live (green) juniper. Mechanical brush removal will be necessary, but this can cause a considerable amount of soil disturbance, and may necessitate reseeding and subsequent weed control. Sites in this condition cost upwards of $385 per acre to treat. If sites have had significant soil loss, and tree canopies exceed 30 percent, re-establishment of the more desirable tall grasses may not be successful.

It is more cost-effective to prevent soil loss than to try to restore a site after it has been significantly degraded. On shallow soils and where there is a significant texture change with depth, restoration of native species and productivity is impossible, except where extremely expensive restoration practices, such as importing topsoil, are applied. New tools like the Rangeland Hydrology and Erosion Model and Ecological Site Descriptions can help assess the risks associated with intense weather events. Identifying vulnerable sites and designing conservation plans to keep them in healthy condition can help reduce the impacts of intense weather events.

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