Chapter 11
The Tragedy of the Common Narrative: Re-telling Degradation in the American West

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Abstract Stories—with a beginning, middle and end, and a moral message, have had a major role in how desertification, and range condition, have been understood on western rangelands in the United States. Stories that attempt to make sense out of vegetation change, whether the bad guy is the self-interested human exploiter or the low-statured ruderal species, take hold in the scientific and public imagination and influence interpretation of policy and management outcomes. The development of policy and management for western grazing lands was shaped by a declensionist narrative of human greed and unrestrained self interest that developed in a parallel and an eventually mutually reinforcing way with a similarly declensionist ecological narrative, creating a story that is deeply embedded in existing institutions for rangelands. This narrative underpins retention of half of the American West in government ownership, how grazing resources are allocated to graziers, and the way that rangeland conditions, including indicators of desertification or degradation, are assessed and monitored. Once such stories take hold, new ideas about ecological dynamics that have a non-linear story and more complex characters have a hard time supplanting or even augmenting old paradigms. This in turn supports policy and management decisions. The reader is warned against charismatic stories–stories encourage and conceal deep-rooted, untested assumptions, simplify complex relationships, and universalize truths that may hold true only in a single time and place.

Keywords Succession · Public land policy · Forestry · Holistic resource management · State and transitions · Equilibrium · Rangeland ecology

The arid rangelands of the western United States include cold desert steppe from eastern California to the base of the Rockies, Mediterranean rangelands along the Pacific Coast, and southwestern deserts down to the border with Mexico (Fig. 11.1). The Rocky Mountains cut the continent in half north to south. Rain-fed agriculture is

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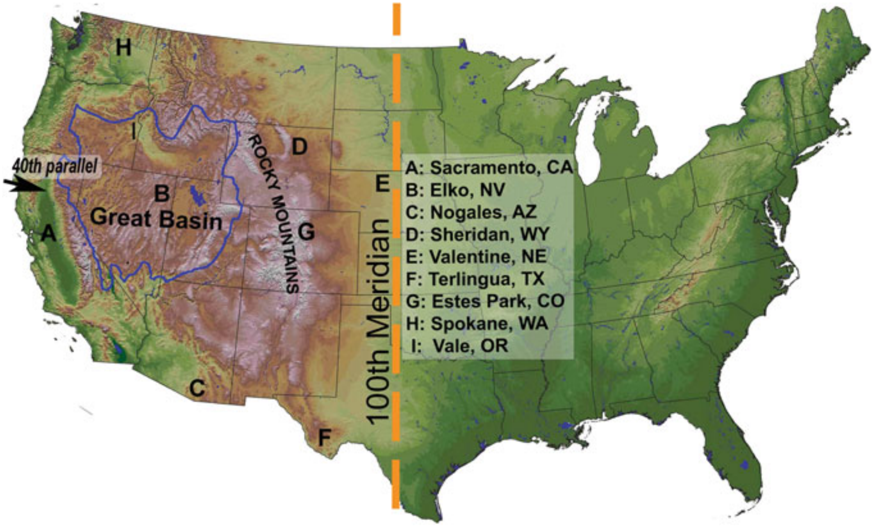

Fig. 11.1 The continental United States. West of the 100th Meridian, rainfed agriculture is generally no longer feasible. Figure 11.2 presents climate graphs for each town listed.

found mostly to the east of the range; to the west, farming takes place on irrigable plots near water or where irrigation projects bring water to fields, capturing snow melt from the many mountain ranges or dipping into groundwater. The geographer John Wesley Powell, considering the possible development of this western country, recognized in 1878 that here "the lands without water have no value" (Powell 1879). This land with no value has been used for grazing and mining since the 16th century.

Historical concerns about what was termed rangeland degradation or desertification in the nineteenth century gave impetus to the development of the current system of federally administrated and managed western rangelands. Changing theoretical paradigms explaining the causes and processes of degradation and desertification have shaped management and policy on the federal lands since 1900. Livestock grazing was introduced into North America a little over 400 years ago, concurrent with sweeping changes in environment, culture, and economy. Given such a history, how can the role of livestock and other factors in shaping conditions on U.S. rangelands be determined? Introductions of new plants and animals, suppression of traditional peoples and their management practices, political and scientific cultures that have shaped the definition and interpretation of degradation, and the institutions governing arid lands have each played a part.

In his essay "A Place for Stories" the environmental historian Bill Cronon (1992) points out that historians interpret and report the past through stories that have a beginning, middle and end, present a moral message, and feature a change in the main protagonist(s)—whether environmental or human. His argument that stories are innately appealing ways to transmit complex information also sheds light on the development of policy and management for western grazing lands, where a declensionist narrative of human greed and unrestrained self interest developed in a parallel and an eventually mutually reinforcing way with a similarly declensionist ecological story, creating the justification for how rangelands have been allocated, assessed, and managed for more than one hundred years.

Deconstructing the founding narrative of western rangelands, and the use of the concept of degradation or desertification, is important because it underpins retention of half of the American West in government ownership, how grazing resources are allocated to graziers, and the way that rangeland conditions, including indicators of desertification, are assessed and monitored. This in turn supports policy and management decisions. The story is a key component in the education of those specializing in the management and ecology of western arid lands. This chapter explores the origins of the concept of rangeland degradation as a result of livestock grazing, how degradation has been identified, the attempted remedies, and the complications of livestock grazing as simultaneously a cause and a cure. An interplay of ecological science and social norms evolves through time in the arid west. Outcomes are illustrated with the story of fire and invasive species as agents of desertification in the Great Basin.

11.1 The Geographical Setting of Western Rangelands

There are more than 3.25 m km^2 of arid rangelands in the United States (Lal et al. 2004), encompassing a diverse geology, vegetation, topography, and climate. Internal variation in physiography is pronounced: elevations ascend from a low in Death Valley at 86 m below sea level to alpine zone summits and volcanic peaks of some 4000 m. Western montane regions are an important element in livestock mobility patterns (Huntsinger et al. 2010).

The morphology and physiography of the North American west ranges from the glacially-eroded continental shield in central Canada and the slowly westward upward-ramping Great Plains of the United States to a massive cordillera that extends from mid-Mexico through the Rocky Mountains of the United States into the Canadian Rockies (Fig. 11.1). The 100th longitudinal meridian bisects the continent: To the west, the landscape is distinguished by fault-shaped landforms, often-dramatic relief, and aridity (Fig. 11.2). A transect from west to east can help put this geomorphology into perspective (Huntsinger and Starrs 2006) (Fig. 11.3).

Land ownership along the transect is linked to ecological regions and topography. At the Pacific Coast, in California, the land is about 50 % publicly owned, montane areas mostly managed by the federal United States Forest Service (USFS), and lowland deserts by the federal Bureau of Land Management (BLM). There is a significant amount of land in other forms of public ownership, and also in large private ranches. Continuing east, traversing the mountains of the Sierra Nevada to the Great Basin's cold desert steppe, most land is under government management, with small private landholdings along rivers and streams. From the Pacific to the Rocky Mountains, no state in the United States has less than 30 % government

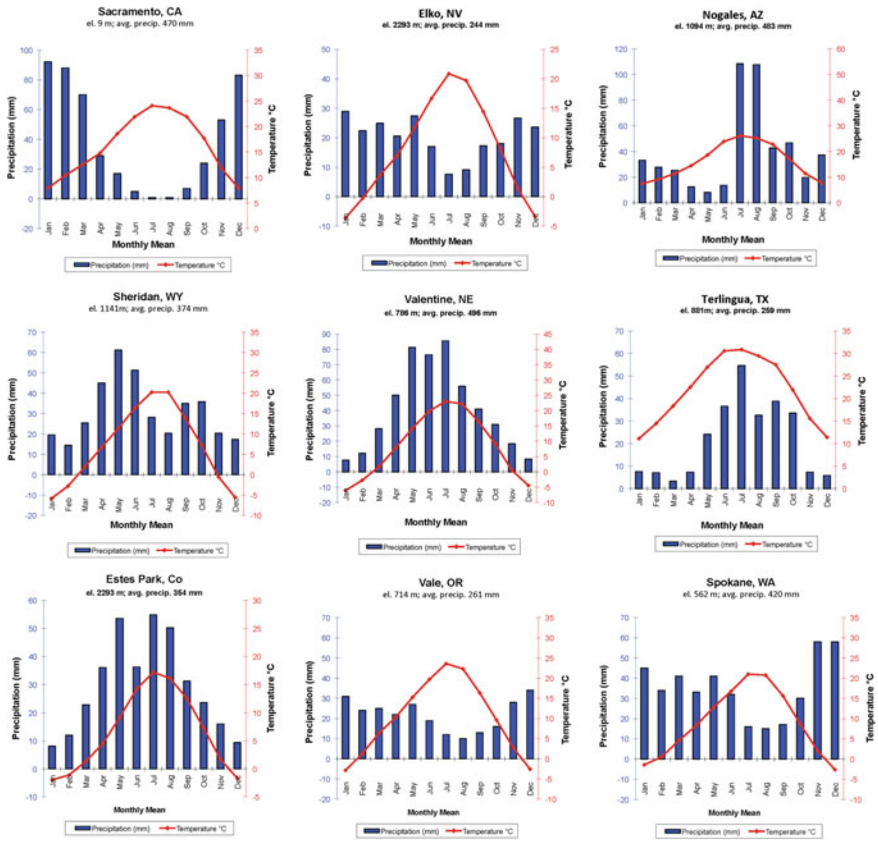

Fig. 11.2 Climate in selected areas identified in Fig. 11.1 (adapted and augmented from Huntsinger and Starrs 2006).

land, and some, like Nevada in the cold desert steppe, are more than 80 % owned and administered by federal agencies. East across the Rocky Mountains are the Great Plains and Midwest, where as the climate becomes wetter and the shortgrass prairie gives way to the mixed and then tall grass prairie, rainfed agriculture prevails and most lands are in private hands. The tallgrass prairie is now almost entirely converted to crop production.

Livestock use of federal lands in the western states today is declining, but still is around 15 million animal unit months annually (AUMs, where one AUM represents forage use by a cow and nursing calf, one horse, or five sheep for one month), controlled through grazing permits that require an annual fee per AUM and specify the timing, amount, and location of grazing. Permitted grazing occurs on approximately 63 m ha managed by the BLM, 38 m ha managed by the (USFS), and on much less of the land managed by the National Park Service (NPS) and the US Fish and Wildlife Service (FWS) (BLM 2015a, BLM 2015b, USFS 2015). Department of Defense lands, Indian Reservations, state lands, and the holdings of municipalities,

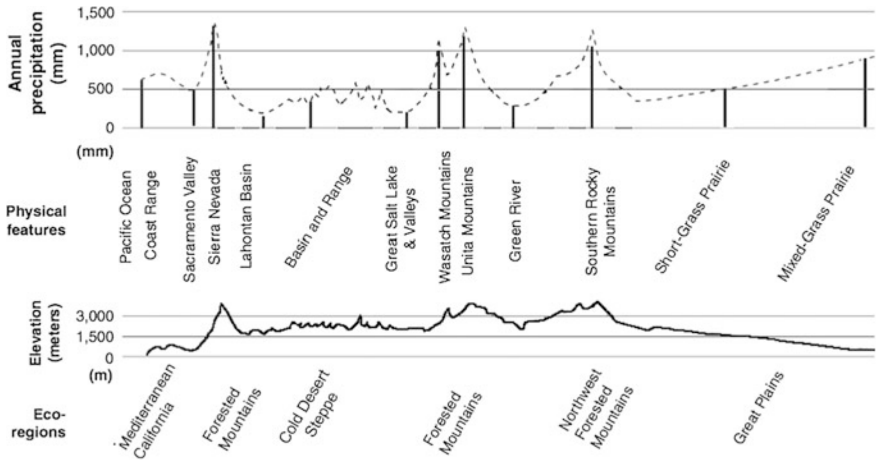

Fig. 11.3 A transect across the continent, west-east on the 40th parallel (adapted from Huntsinger and Starrs 2006). The 100th Meridian runs perpendicular to the transect through the short and mixed-grass prairie.

utility districts, and small public agencies are also sometimes grazed by livestock, on more than an additional 10 million ha.

11.2 Framing the Ecological Setting for Livestock Grazing

In 1998, Perevolotsky and Seligman posited that ecosystem conditions on rangelands adjacent to the Mediterranean Sea were changed sharply with the advent of animal domestication, then reached a relatively stable situation subject to the ups and downs caused by drought, and changes in land use and human populations (Fig. 11.4). Their figure presents the traditional view of degradation in the Mediterranean Basin (1-solid line) compared with the model presented in their paper (2-dashed line). The y-axis represents a descriptive conceptual measure of ecosystem status that "integrates soil characteristics, productivity, and diversity." The authors point out that in the last 50 years, there has been mounting concern among ecologists and range scientists that technological and demographic developments have accelerated the process of environmental degradation on many rangelands worldwide. This view, when applied to the Mediterranean Basin, assumes that local ecosystems were relatively stable until the 1950s and have been intensively degraded since then (model 1).

In contrast, the authors argue that any major changes that may have occurred to the "pristine" ecosystems of the Mediterranean Basin and the Near East are related to the domestication revolution that took place between 5000 and 10,000 years ago (1). Subsequently, the state of local ecosystems declined initially but then began to

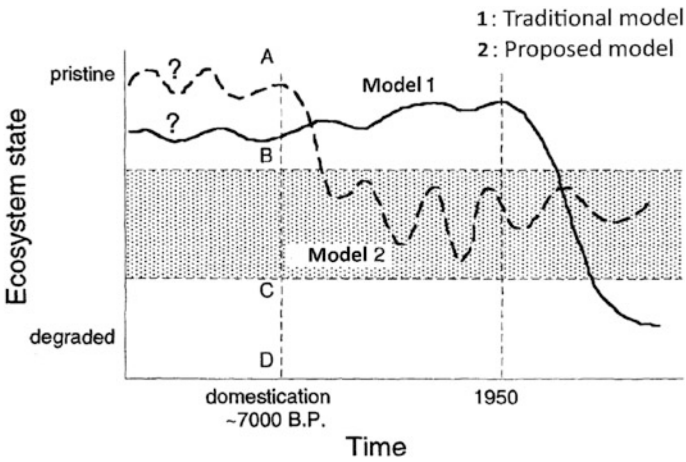

Fig. 11.4 The 2 models contrasted in Perevolotsky and Seligman (1998) for ecosystem change in the Mediterranean Basin.

fluctuate in a cycle between relatively stable limits. The domain A-B indicates the assumed change in ecosystem state following domestication and evolution of pastoralism, while B-C (shaded area) indicates the domain of ecosystem fluctuations within a relatively stable limit cycle.

In North America, livestock were not introduced into the West until 1598 in the Southwest, and 1769 on the Pacific coast. Yet Native populations have been shaping ecosystems since the Pleistocene, primarily by using fire, hunting, and cultivation. Fire was used to open up forests, clear brush, drive game, improve game habitat, reduce pests, and increase the production of foods and other useful plants (Blackburn and Anderson 1993; Anderson 2005). The ecosystem state was heavily influenced by frequent burning, perhaps achieving a B-C domain for anthropogenic fire.

Yet the managed and shaped ecosystem that European colonists confronted is the one long thought of by many ecologists as the "pristine" backdrop against which the settlement of the United States took place. Restoration projects today still look to this ecosystem as the goal, although it was shaped and maintained by human activities beginning thousands of years ago, a product of cultures that no longer have the opportunity to manage most U.S. lands. Rather than thinking in terms of a value-laden directionally downward shift to a "degraded" state on the y-Axis, a "distancing" without inherent positive or negative connotations from the pre-anthropogenic landscape might be a better conceptualization.

With the introduction of livestock, the massive re-allocation and use of water that began in the 19th century, and suppression of fire beginning in the 20th century, a period of huge change in western arid ecosystems was inaugurated. It seems very likely that current ecosystems have as yet not reached any sort of stability in response to these changes, even in the sense of the domain B-C in Fig. 11.4.

Yet it is in this context that government rangeland managers, assigned to manage the arid lands of the United States for grazing and a variety of other uses, have struggled for nearly a hundred years to assess the ecological status of western rangelands, deliberating how grazing should be managed to maintain or improve ecological conditions and forage productivity. Answers to these questions are needed to identify the existence of desertification or degradation, and to understand the human role in it, yet in fact huge gaps in knowledge are often filled by solely theoretical assumptions.

11.3 The Story of Government Management

The federal government manages more than 1.44 m km^2 of public lands in the 11 western states exclusive of Alaska, nearly half the total land area (Gorte et al. 2012). A simple version of the narrative that supported government retention of rangelands has all the characteristics of a story as defined by Cronon. The story begins with a pristine wilderness exploited by rapacious settlers. A failure to privatize most western rangelands, due to inappropriate policies and impracticality, left them open to abuse by avaricious miners, speculative grazing enterprises, and railroads that distributed land-hungry settlers willy-nilly. According to the story, public concern about damage to watersheds and a growing interest in nature made it essential for the government to step in. The story concludes, in the "happily ever after" sense, when the government removes the abuse, restores the land, and maintains productivity in the interest of all the people, unleashing the power of science and technology. A typical statement appears in a 1982 federal report on desertification: "overgrazing in the United States occurred previous to the 1930s, but it has since been largely controlled due to regulatory control and better grazing management systems by livestock producers… in 1977 range condition was improving in 13 of the 17 major range states, remaining static in three, and declining in one" (Sabadell et al. 1982).

That livestock grazing brought about great changes in western ecosystems is likely (Mack and Thompson 1982; Cole et al. 1997; Lal et al. 2004), but the idea that overgrazing and threats to the U.S. natural endowment were driven by irresponsibility and greed, as well as an influx of transient immigrants, fits a bit too conveniently into the founding narrative. In the nineteenth century, much of the West was part of the "public domain," land resulting from the acquisition by the United States of a large part of the North American continent, but as yet not allocated, according to the stated goal of the government, to private citizens for farming and private enterprise. Public domain was used freely by settlers for grazing, mining, and woodcutting. Observing some the of the environmental consequences, in 1895, soon-to-be President Theodore Roosevelt wrote:

> It is almost needless to say that this country needs a thoroughly scientific and permanent system of forest management in the interests of the people of to-day, and, above all, in the interests of their children and grandchildren… Many of the people in these imperiled regions are not permanent inhabitants at all; they are mere nomads, with no intention of remaining for any great length of time in the locality where they happen to be for the moment, and with still less idea of seeing their children grow up there. They, of course, care nothing whatever for the future of the country; they destroy the trees and render the land barren, often from sheer brutal carelessness, often for a pecuniary reward which is absolutely trivial in comparison with the damage done; yet their selfish clamor is allowed to stand in the way of a great measure intended to benefit the whole community. (Bowers et al. 1895)

In 1891, the Forest Reserves began to be set aside for government management in order to provide for the "protection and improvement of forests for the purpose of insuring a permanent supply of timber and the conditions favorable to a continuous waterflow" for the people of the United States (Roth 1901). This came on the heels of a period known for the overstocking of western rangelands, and grazing was initially halted in the Reserves. Stockmen argued that these montane ranges had been grazed for decades and the industry was dependent on them, and after 1897 policy provisions began to be made to allow for livestock grazing where it did not do injury to forest growth or water supply (Roth 1901). Eventually, grazing was constrained to specific districts at specific times, and the number of animals was limited. In getting permits, residents had precedence over "tramp owners" from other states. As is apparent from Roosevelt's remarks, immigration, transience, selfishness, and greed were common arguments at the time for why unrestricted use was degrading the land.

The majority of Forest Reserves were established early in the 20th century. At the time, grazing enterprises were of several kinds, ranging from small family homesteads to massive speculative operations fueled by foreign investment. The development of large herds on western rangelands was abetted by an enormous over-supply of imported financial capital, which until the 1893 trans-Atlantic depression enabled aspiring producers to increase herds rapidly on credit (Sayre and Fernandez-Gimenez 2003). Family ranches on small areas of private land found themselves competing for the surrounding rangelands with widely roaming herds of cattle and sheep. Unable to control grazing on the public domain, many ranchers called for government oversight, with the American National Livestock Association passing resolutions asking that public lands be protected from overgrazing as early as 1884. Congress heard a report from the Public Land Commission in 1906 lamenting overgrazing on the public grazing lands, and a survey of stockmen used for the report found 78 % favored some sort of government control of grazing (Fleischner 2002). The Dust Bowl of the 1930s, though quite different in origins, lent further support to a movement for government oversight and control of arid lands (Cronon 1992; Worster 1979), and in 1934 the Taylor Grazing Act created a system of regulation for the arid rangelands that would eventually come under the aegis of the BLM.

Although generally portrayed in the canon of rangeland science as the savior of rangelands from private greed, closer examination makes it clear that the federal government was far from innocent in creating a system that fostered abuse. As early as the 19th and into the 20th century, government policy contributed to the lack of control of grazing in the arid west by deliberately maintaining an open access system on rangelands (Starrs 1998; Nelson 1995). Two main aspects of this were first, a settlement policy that restricted the allocation of rangelands to unsustainably small parcels for ranching, and second, quashing efforts at the range management and control efforts of ranching communities (Starrs 1998; Nelson 1995). A review of the history of the introduction of grazing and settlement highlights these influences.

11.4 The Introduction of Grazing and the Homestead Act

A general history of livestock grazing in the western United States begins with the implantation of livestock in the Southwest. In 1598, Spanish settlers brought cattle, sheep and goats into what is now New Mexico. For about 200 years, Spanish and Mexican land grants, thousands of hectares in size, were given to individuals and communities for farming, grazing, and woodcutting. Tribes such as the Navajo adopted livestock grazing very early on (Bailey 1980). In California, a short-lived Spanish colonization began in 1769, and as in the Southwest, was superseded by Mexican control in 1822, and finally by the United States in 1848.

In the mid-19th century settlers from eastern regions moved rapidly into the arid western territories, drawn by the California Gold Rush and other mineral finds, and by abundant open land available for settlement. Once Native Americans were displaced, land allocation policies were implemented that, beginning with the 1862 Homestead Act, limited settler land claims to first 64 and then 256 ha. These claims were generally made in the rare areas with decent soils and water for irrigation, leaving arid and mountainous land in the public domain. In the Southwest and California, under American governance, the majority of community and individual grants given out by the Spanish and Mexican governments were abrogated by the courts by the late 1860s, ceded to clever entrepreneurs and lawyers, or returned to the federal or state governments for back taxes, and only rarely remained in the hands of grantees (de Buys 1985). Yet these old claims remain responsible for some of the larger ranches in the arid west.

Powell estimated it would take more than 1000 ha to support a ranching enterprise in the arid regions (1879). He proposed selling irrigable parcels, but allocating rangelands and timberlands to communities based on watersheds to be managed as a common resource. By the time his report made it to Congress, too much was at stake in development and speculation schemes, and in timber interests, to make Powell's suggestions palatable to politicians. In addition, surveying and assessing land potential before allocating it for homesteading would have led to delays that many settlers found unacceptable (Hutchinson 2000).

Instead, the U.S. government pursued a policy of fragmentation based on notions of farmland use from wetter climes. With rangeland allocation limited to small parcels, ranchers throughout the West claimed land near water and then grazed the non-arable surrounding public domain. They created patterns of livestock mobility that suited local geographies, moving stock from arid lowlands in the winter to montane meadows in the summer in some areas, or using crop aftermath or irrigated pastures during forage short seasons in others. In an effort to piece together a reasonably large private ranch, various strategies of subverting the Homestead Act were employed, including hiring people to make false claims, but also, purchasing the homesteads of failed claimants—a not uncommon occurrence (Raban 1996). The majority of ranchers practicing extensive grazing in the arid regions today remain dependent on the use of federal lands that were never successfully transferred to private owners.

11.5 Community Control Attempts

A strategy of "control of the range by control of the water" emerged in much of the West in the nineteenth century. In ranching communities, absent a national programme for managing access to rangelands in the public domain, informal rules and practices evolved that helped control grazing, including legal fencing of private home properties, illegal fencing of public domain range, grazing agreements among members of a community, and extra-legal threats and pressures to fend off outside intruders (Nelson 1995; Starrs 1998). An informal 19th century rule in Arizona held that the owner of a water source had the rights to graze the public domain halfway to the next water source (Sayre 2002). Common gathers where livestock were sorted, with reciprocal labor and herding, and brands to monitor cattle ownership, reflected a nascent pastoral culture as well as Hispano influence (Farquhar 1930; Starrs 1998).

An influx of speculative money in the 19th century fueled the rapid development of a commercial livestock industry based on access to low-cost, uncontrolled land, with few ties to local communities. The patenting of barbed wire in 1867, and its proliferation in the 1870s, changed the face of open range grazing across much of the west. Barbed wire dramatically reduced the cost of restricting free-ranging cattle. Conflicts erupted between sedentary farmers and ranchers, and the graziers of free-ranging herds who came across newly constructed barbed wire fences and cut them. The resulting excess of animals on the range contributed to the impact of severe winters late in the nineteenth century.

In the early 1880s, livestock prices dropped. Livestock producers who had accumulated debt were reluctant or unable to sell off their herds at low prices, because that meant defaulting on their loans (Sayre and Fernandez-Gimenez 2003). This augmented an excess of animals on the range. Following on decades of relatively abundant grass, the mid– to late–1880s had droughts and some particularly severe winters. It has often been reported that in places 85 % of cattle were lost (Fleischner 2002), sometimes found piled up against fences that prevented them from migrating south. While this has become known as "the Big Die-Off" and is part of range lore, economic research has recently challenged the actual severity and impact of these events on the cattle business, arguing that the industry continued to increase into the 1890s when financial upheaval finally constricted the enterprise and rancher net earnings dropped (McFerrin and Wills 2013).

Congress forbade stretching barbed wire across the public domain in 1885. Unfortunately this enforcement of the open access character of government rangelands fostered continued tensions over pasture use between settled communities and 'outsiders' such as widely roaming shepherds, in-migrant homesteaders and speculative cattle enterprises (Nelson 1995). John Muir describes a race to California's Sierra Nevada every year by sheep herders trying to be the first into high elevation range in the late 1800s when the mountains were largely open access public domain (1911). He wrote in 1895:

> Incredible numbers of sheep are driven into the California forest pastures every summer, and their courses are marked by desolation. Not only the moisture absorbing grasses are devoured, but the bushes also are stripped bare. Even the young conifers, which are not eaten by sheep when they can find anything else to stay hunger, are greedily devoured in their famishing condition; and to make destruction doubly sure, fires are set during the dry autumn months to clear the ground of fallen trunks and underbrush in order to facilitate the movements of the flocks and to improve the pastures by letting in the sunshine. (Bowers et al. 1895)

He continues, stating that:

> One soldier in the woods, armed with authority and a gun, would be more effective in forest preservation than millions of forbidding notices. I believe that the good time of the suffering forests can be hastened through the War Department… (Bowers et al. 1895)

A failed settlement policy for open public range that restricted private claims to small areas, and laws that limited community control, were major factors in the heavy livestock grazing of the time. Typical in open access tenure of a common pool resource, when users are prevented from organizing and controlling use, whoever can access the resources first gets them. The chosen solution, well-described by the "leviathan" model defined by Ostrom (1990), was to turn to the government for increased control of grazing lands.

While the open range of the late nineteenth and early 20th centuries was an open access system rather than a community managed resource, Hardin's *Tragedy of the Commons* (1968) is often used to support the need for government retention and management of most of the arid rangelands in the United States. The founding narrative as it has persisted in the history of the rangeland management profession blames a destructive period of overgrazing on the Homestead Act and its subversion; the failure to privatize and divide the range and the subsequent lack of accountability; the influence of outside investment; ignorance or discounting of range carrying capacity; and human greed (Holechek et al. 2010), but neglects the richer story that includes the destruction of emerging local management institutions, the loss of indigenous management, and the impact of financial interests lobbying Congress. This shaping of the founding narrative reflects the formative role of federal management in creating the field of rangeland management itself.

11.6 The Origins and Shaping of Rangeland Management and Science

In 1905 management of the Forest Reserves was transferred from the Department of the Interior to the Department of Agriculture, to be managed by the United States Forest Service. The number of reserved forests grew rapidly during this period. Gifford Pinchot was the first Chief Forester of the agency, under the administration of President Theodore Roosevelt. The Forest Service began charging a fee to graziers in 1906 to support the management of grazing. Grazing "allotments" were created with more specific boundaries than before. They were designated for use by a certain number of animals, for a specified time period, by an individual rancher. It was believed that allotting a well-defined area to each grazier would "would induce the stockman to care for his range, to protect it against fire, and to improve it by seeding or otherwise, and would prevent heedless overgrazing" (Roth 1901, p. 348). A defined a carrying capacity was sought for each allotment, designed to prevent an overabundance of animals that might over-use the range. A set carrying capacity also gave the allotment an indirect market value that could be exchanged in the market along with private lands (Merrill 2002; Sayre and Fernandez-Gimenez 2003). Setting fees, establishing carrying capacities, monitoring range impacts, and mapping allotment boundaries became the tools of a national-scale administration for grazing.

The grazing allocation process on Forest Service lands was highly contentious. Nearby and sedentary ranchers were given precedence in obtaining allotments. Reflective of Roosevelt's 1895 remarks about the abuse of the forests, an implicit goal was the exclusion of foreign-born and "outsider" herders and their "tramp" herds. An explicit social goal was to promote the development of the West by supporting family industry. In addition to determining who would get allotments, deciding on the appropriate carrying capacity was sometimes a contested and difficult process, as it was obviously an issue crucial to the financial welfare of graziers. Ranchers might use different criteria or have a different view of appropriate stocking than foresters, or Forest Service range managers. An authoritative basis for making grazing decisions was needed.

Range science "did not grow out of 'pure' scientific inquiry," but was "dominated from the beginning by government institutions" (Sayre and Fernandez-Gimenez 2003). Study of grasses and forage plants was encouraged by Congress in 1895 through the creation of the Division of Agrostology (Sayre 2002). Early grassland science was adopted for the purposes of the agency within an institutional setting dominated by a cadre of foresters educated in accordance with the vision of Gifford Pinchot, the first chief of the Forest Service, and that of his German-trained mentor Bernhard Fernow. Amid the faith in science and invention characteristic of the Progressive Era, a scientific method was developed for the management of forests. Highly simplified, forest management was driven by a belief in the need for a sustainable, maximized, supply of timber to support the development of the United States (Fairfax et al. 1999). The premise of a coming "timber famine," which was a driver of the development of practices oriented to "maximum sustained yield," is well challenged—and indeed the U.S. has yet to experience a timber famine of any sort. However, under scientific management the salient features of policy were an absolute focus on maximizing sustainable production, trees and technology as a solution to social problems, science and technical expertise as the basis for decision making, and large scale comprehensive planning (Fortmann and Fairfax 1989). These rapidly became professional norms in the Forest Service, a lens through which forest related issues were viewed and filtered.

These tenets of scientific management are reflected in the development of rangeland management and science. If timber was considered the goal for forests at the time, it followed that "food and fiber" were the appropriate goals for rangelands—with productivity and efficiency the key to community and national development. Local or traditional goals were pushed aside for those of a central authority, in the interests of protecting the range from ill-informed, self-interested graziers. The role of the Forest Service and BLM in enforcing forest and range policies and regulations is exemplified in the pseudo-military uniforms that were and are standard issue for Forest Service personnel working with the public. Science and technology needed to be developed to replace out-moded and inefficient local practice. However, though the science of silviculture was well developed in France and Germany (Schama 1996) by the nineteenth century, and was promulgated by Fernow and Pinchot in the new Forest Service, there was no similar northern European science to be adopted for arid rangelands. North African and Mediterranean grazing knowledge was ignored by the East Coast-oriented national administration (Davis 2007). A scientific management approach for evaluating grazing and setting a sustainable carrying capacity, close to the heart of Pinchot and his professional management cadre, was called for.

11.7 The Succession Story

In 1916 a professor of botany at the University of Nebraska named Frederick Clements published *Plant succession, an analysis of the development of vegetation*. Based on observations of vegetation patterns on Midwestern tallgrass prairie that had been plowed in different time periods, he created a model for plant community change after a "disturbance" like plowing. This "secondary succession" predicted a linear, predictable development of the plant community through seral stages or states, from post disturbance weedy species to a final, "climax," assemblage that he suggested was an equilibrial, steady state. The plant community was like a living organism, proceeding from infant to maturation. Some disagreed with the Clementian view (e.g. Gleason 1917), but as is well discussed by the environmental historian Worster (1994) Clements' account became the plant ecology story of the century, with the vegetation as an organism-like protagonist. First, it allowed the characterization of a disturbance that changes the ecosystem away from the climax assemblage as a setback, and even further, a bad thing. As the plant community develops over time, initial colonizers, or weedy species, are considered subsidiary, temporary interlopers that disappear with "recovery" or restoration to the final state, where nature is in balance. The final state is conferred with positive value by this model. This "story" was not only easily understood, with its beginning, middle, end and moral message, it provided a scientific foundation for rangeland management, and a model that foresters could apply to predict forest growth after harvest or fire.

The norms of scientific forestry were incorporated into Forest Service policy and practice. One of the major "disturbances" foresters and reserve managers sought to control was fire. Because in this view fire reduces climax forest to weedy, early successional species, consumes valuable timber, and can cause erosion, fire was quickly brokered to the role of a major evil, ignoring its valuable place in Native American management, and its use by early ranchers and farmers to clear woody vegetation for cultivation and grazing. Huge fires in the western U.S. in 1910 contributed to an anti-fire sentiment (Pyne 2008). Along with a focus on producing timber, the Clementian model, with its implicit devaluation of "disturbed" vegetation and high valuation of climax stages, fit well with efforts to control and stop all fire in the forest in the 20th century, and to manage post-harvest to maximize forest regrowth. In an 1895 published letter on how to manage Yosemite National Park, where native Californians had burned regularly for centuries, Pinchot wrote that "There is no doubt that forest fires encourage a spirit of lawlessness and a disregard for property rights." Bernhard Fernow explained that "the whole fire question in the United States is one of bad habits and loose morals. There is no other reason for these frequent and recurring conflagrations" (Bowers et al. 1895).

Ranchers using fire to clear the understory on Forest Service ranges were accused not only of damaging the forest, but of being unpatriotic. In 1918 the Shasta Trinity Forest Supervisor sent letters to local stockmen quoting President Wilson:

> Preventable fire is more than a private misfortune. It is a public dereliction. At a time like this of emergency and manifest necessity for the conservation of national resources, it is more than ever a matter of deep and pressing consequences that every means should be taken to prevent this evil. (Morrow 1918; Forero 2002)

The Forest Supervisor goes on to imply that, with World War I ongoing, the crime of burning is especially heinous. He states that it took the equivalent of 400 men working every day for four months to suppress human-caused fires, and these men were needed at the front. It was therefore the patriotic duty of stockmen to prevent fire (Morrow 1918; Forero 2002; Huntsinger et al. 2010).

Yet the role of fire in western ecosystems was not invisible to those looking from outside the perspective of scientific forestry. In 1890, Powell, who spent considerable time exploring the western frontier and spoke several Indian languages, wrote on indigenous use of fire and the impacts of the fire suppression:

> …[U]nder conditions of civilization, the great forests of the arid lands are being swept from the mountains and plateaus. Before the white man came the natives systematically burned over the forest lands with each recurrent year as one of the great hunting economies. By this process little destruction of timber was accomplished; but, protected by civilized men,

> forests are rapidly disappearing. The needles, cones, and brush, together with the leaves of grass and shrubs below, accumulate when not burned annually. New deposits are made from year to year, until the ground is covered with a thick mantle of inflammable material. Then a spark is dropped, a fire is accidentally or purposely kindled, and the flames have abundant food. (Powell 1890)

Once again, Powell's ideas were badly timed and largely ignored in the face of the Progressive Era conservation mandate.

In fact the widespread suppression of indigenous, rural, and natural burning that began in the 20th century is credited with increasing the density of trees and drought stress to forests. Together with climate change, increased tree density has contributed to pest outbreaks devastating millions of ha of US forests (Taylor 2000; Gallant et al. 2003; Raumann and Cabik 2008), and to increasingly massive and intense wild fires. Compared to the average year in the 1970s, in the past decade there were seven times more fires with an extent greater than 10,000 acres each year (Climate Central 2012). Suppression has also led to the invasion of montane grasslands and meadows by shrubs and trees, drying formerly moist habitats, as trees consume and transpire soil moisture (Raumann and Cabik 2008).

11.8 Development of Range Condition Assessment

On Forest Service and then BLM rangelands, the positive values attributed to the climax state were put to use to evaluate grazing impacts and management. Arthur Sampson, a grassland ecologist with the Forest Service (1909), adapted the model developed by Frederick Clements for understanding grazing effects on rangelands. Like Clements, Sampson accepted the idea that there is a single climax or *equilibrium* state for grasslands of a particular climate (i.e. "climatic climax"), and that this was the ideal state. He explicitly added excessive livestock grazing in the equilibrium-based model as the cause of "range retrogression" away from the climax state, and that the reduction or removal of livestock would allow for competition and other biotic processes internal to the system to drive succession back towards the climax state. The existing state relative to the climax was used to evaluate the "condition" of the range (Spiegal et al. 2015).

In the late 1940s, E.J. Dykesterhuis, a U.S. Soil Conservation Service range scientist who eventually became a professor of range science at Texas A&M University, emphasized the importance of explicitly delineating sites by their inherent edaphic and topographic characteristics (1949). Dyksterhuis posited that a range landscape had a "polyclimax." Each "range site," defined by its climatic and physical features, had its own climax. Grazing remained the primary reason for a range site's departure from climax. This work represented a step forward in defining site potential not with current vegetation, but with soils, climate, and physiographic factors. Plant species were grouped and identified as "decreasers," "increasers," and "invaders" depending on their response to herbivory, with climax species often in the decreaser category, as they are by definition the least adapted to disturbance (Humphrey 1947; Dykesterhuis 1949).

Reinforcing the Clementian model as used in management, the climax species became the presumptively “good” species and those most sensitive to grazing, so the presence of these species could be used to gauge the quality of the livestock management. Too much grazing caused “retrogression” toward the “bad” early successional conditions, while an absence of grazing would lead to recovery of the equlibiral condition of the “climax” vegetation believed to dominate grasslands prior to the introduction of livestock. “Range Condition Classes” were developed based on the proximity of the vegetation on a specific kind of site to the climax community believed to represent its potential. The BLM adopted range condition assessments and allocation practices similar to those of the Forest Service, including the succession based method of assessing range condition.

The ecological story that was forged in the crucible of scientific management proved compelling, stubborn, and adaptable. Despite a long series of ecologists who attempted to modify or better explain vegetation change, the organism-like, beginning-middle-end characteristics of the linear succession model has proved intractable to this day. With this model, managers found that degradation in the biotic sense could be defined as the distance from the steady state, balanced, equilibrium endpoint termed “climax.” Like degradation, desertification in this model is considered the distancing of vegetation from the ideal state in arid lands. Maintenance of the climax community was also assumed to protect soils from erosion and maximize biodiversity. Armed with this conceptual tool, government managers believed they now had specific, measurable goals for rangelands that could be used to set numbers of livestock and other parameters “scientifically,” evaluate the efficacy of management, and determine where restoration was needed and how to get there. Recovery, or restoration, required the reduction or removal of disturbance, according to the evolving story, and it became gospel.

11.9 Lost in the Story

The convergence of succession-based science, government management and authority needs, and a narrative of heedless destruction by early settlers created a big story with good and bad actors and moral lessons. It starts with a pristine natural world, in balance, with climax plant communities supporting climax wildlife species. Then the settlers arrive on stage, and driven by competition, need, and greed, begin to disturb and upset the virtuous native ecosystems. Bad plants start to increase at the expense of good plants. Soil washes away. Biodiversity declines. Fires destroy native plant communities. Finally, in this story, the government white hats arrive, with the mandate of science and eternal, sustained production of goods for human society.

While it took time to tease out, it has become apparent that there are things wrong with this story. Foremost, perhaps, is that despite continual reductions in stocking, rangeland “recovery” has been slow and unpredictable on U.S. arid lands. The data show that after decades of effort, massive areas of rangeland have not yet recovered to the former, supposedly, pristine state or “potential plant community.” The long-held notions of “pristine state” are easily challengeable because the state of rangelands prior to the introduction of livestock was the outcome of indigenous management and native grazers. This context had been lost to the Clementian world.

The preamble to the 1978 Public Lands Improvement Act (3 U.S.C. §§1901–1908) states that “(1) vast segments of the public rangelands are producing less than their potential for livestock, wildlife habitat, recreation, forage, and water and soil conservation benefits, and for that reason, are in unsatisfactory condition;…(3) unsatisfactory conditions on public rangelands present a high risk of soil loss, desertification, and a resultant underproduction….” The legislation defines “range condition” as “the present state of vegetation of a range site in relation to the potential plant community for that site,” among other measures, including productivity.

Livestock production on government ranges is in decline, with public lands supporting far fewer livestock than when government management began. After a peak during WWI, the amount of grazing on public range has declined every subsequent decade, due to a combination of thickening trees and other woody plants, removal of livestock for restoration, and changing uses and policies for public lands. Uncounted ranchers and sheep herders have left the business. The deterministic linear succession model has proven a weak predictor of response to grazing, and efforts to remove disturbance and restore the climax remain largely unrealized. The model simply does not fit most rangelands outside of mesic Midwestern grasslands, with ecosystems neither “succeeding” or “retrogressing” reliably in response to grazing management.

It is important to remember that models are not reality, and ecosystems do not conform perfectly to any model. Managers have developed ways of simplifying complex systems using models to identify critical components and processes and to link those processes to possible interventions. Clements’ model is one example, but it proved to be of low utility for predicting the consequences of management on arid rangelands.

11.10 New Models for Arid Lands

In the 1930s, A.G Tansley from Oxford took issue with the concept of climax conditions as a management goal, and a measure of environmental quality. He noted that in a given zone there may be many apparently permanent types of vegetation that could be termed climaxes, including those maintained by soils, heavy grazing, or recurrent fires. He contested the underlying assumption that human activities were an external factor that inevitably had the effect of undermining an ideal, pristine, climax and degrading an ecosystem. He promoted the concept of an “anthropogenic” climax instead, one that was not automatically inferior (Tansley 1935; Worster 1994; van der Valk 2013).

In 1988, Ellis and Swift challenged the notion that arid rangelands in Africa can be modeled as equilibrial systems that can be managed by assigning a set “carrying capacity” for grazing animals. Shortly thereafter, Westoby et al. (1989) had major impact on U.S. range management by publishing an article in the *Journal of Rangeland Management* arguing that arid rangelands are not well-described by models based on equilibrium systems, and comparing management using models based in equlibrial versus non-equilibrial ecological dynamics. The non-equilibrial model holds that instead of developing in a linear, progressive pattern, and responding to grazing with directional shifts along a continuum from ruderal to climax conditions as grazing influences plant competitive relations, rangeland vegetation in arid lands at a given site can develop into more than one “stable state” depending on abiotic factors, such as rainfall and temperature, and the history of the site with respect to fire, floods, and so forth. Grazing, as a factor, is under this model often a relatively minor influence compared to the influence of abiotic factors, especially rainfall on arid lands, and removing grazing does not necessarily change the state or change it back to a state that existed before livestock grazed it, a challenge to traditional paradigms for rangeland management worldwide (Behnke et al. 1993). In fact, certain constellations of factors with or without grazing could cause irreversible, or difficult to reverse change, something termed a threshold effect. Based on this, livestock management has to be opportunistic, rather than strategic, to take advantage of irregular rainfall, and vegetation response is to some degree “decoupled” from grazing effects. Rather than focusing on establishing and enforcing a set carrying capacity, in this conceptualization, management should focus on conserving and developing pastoral systems that can cope with and adapt rapidly to unpredictable conditions.

Instead of relying on a linear map to potential vegetation change on a specific type of site following disturbance, a map of this type of model has many stable states. A “states and transition” model identifies such states and lists drivers that cause transitions leading to different states—these drivers are not termed “disturbances,” but factors that shape vegetation. In other words, fire is not a disturbance that sets vegetation back, but an occurrence that under some conditions causes transitions or serves to maintain states (Fig. 11.5). For a specific site, livestock grazing can act as a driver, but at moderate levels may not have any affect on the vegetation state, because the state is most strongly influenced by rainfall. Another way to say it is that while deterministic succession is based on competition and other plant-plant interactions as the major driver of vegetation change, on arid lands plants are competing with the environment, rather than each other. There is no single, predictable end state, particularly one that inherently optimizes ecological “goods” like native climax species diversity or protection from erosion. Each state has differing implications for biodiversity, soils, and forage production.

State and transition models take many of the value judgments out of assessing vegetation change. They require the manager to decide what the goal is and why. This is politically less useful than having the decision made for you in the linear

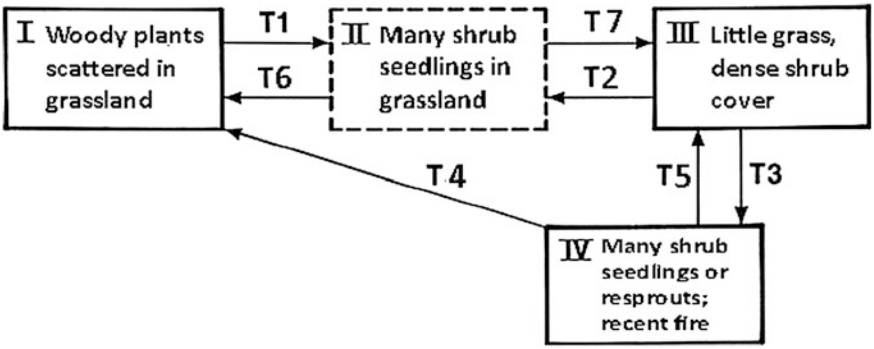

Fig. 11.5 A simplified state and transition model for a semi-arid grassland with potential for increase in shrubs presented by Westoby et al. (1989). Vegetation types stable in a management relevant timeframe and the transitions among them are identified. Researchers, managers, and practitioners work to understand the causes and effects of transitions, the feedbacks that stabilize states, and the nature of the thresholds between them. Thresholds maintain state stability. For example, transition 3 (*T3*) does not occur without fire, while transition 1 (*T1*) has a low threshold, requiring only time to occur. State III might be optimal for some bird species, while states I, II, and IV might be better for livestock and wildlife grazing.

succession paradigm, but it does allow the collection, use, and testing of data in building models for specific sites. Rather than a story that drives how vegetation change is seen, it provides a framework for documenting and eventually explaining how vegetation changes in response to various events. Unfortunately, the "multiple stable states" model of vegetation change does not have the same simple, moralistic and appealing story as linear succession—there really isn't a beginning, end, or moral lesson. There is a site, it rains and things change or it doesn't rain and things change. Changes may be permanent. Rainfall is unpredictable and not influenced by human actors. We need to watch, experiment, and record to learn what is going on. This is in fact very like Cronon's version of a "non-story" (1992).

Non-equilibrium models make it obvious that the terms degradation and desertification are subjective, and based on criteria set by the manager or scientist. Perevolotsky and Seligman (1998) discuss the concept of degradation as follows:

> "degradation" refers to a change of state with a negative value assessment that is related to subjectively chosen criteria. A shift in the nutrient status of soil may increase biodiversity or the persistence of rare species; the result would then be judged as improvement if higher biodiversity or longer persistence of certain species were the criterion. However, if the shifted nutrient status resulted in decreased primary production, the same phenomenon could be judged as degradation. Assessment of vegetation damage also depends on management goals: A forester or environmentalist may regard the domestic ruminant as a pest that degrades the woodland, whereas a herder is more likely to regard the woodland as a source of livestock forage. That is, for the herder, an oak grazed down to a dense dwarf shrub is simply a well-used forage plant.

In the multiple steady states model, the manager must make the decision about which are desirable and undesirable states. This includes being explicit about what constitutes degradation or desertification. It may be change to a state with lower productivity, or with accelerated erosion. To define desertification in this model then, it is necessary to be clear about causes and outcomes, rather than relying on value judgments, or narrative flow. Assumptions can be made visible and tested.

11.11 Degradation/Desertification

As in much of the world, in the U.S. it is difficult to sort out the effects of variations in aridity, climate change, and human influences. The role of livestock grazing, as it interweaves with other factors, is complex. Federal management has led to large reductions in livestock grazing, but there are processes of what could be termed "degradation" that have been exacerbated by government policy and the land tenure institutions that place vast areas of arid lands under "one size fits all" government management, most notably suppression of natural and anthropogenic fires. The relationships among wildfire, invasive plants, and grazing illustrates the interactions that may lead to devastating forms of undesirable vegetation change, how states and transition models are a better fit than linear succession models, and why land allocation and management institutions may ultimately be in large part responsible for causing desertification.

Evidence is accumulating that in the forests of the western United States, as dry material has built up and vegetation thickened due to fire suppression, wildfires are becoming more intense and extensive, converting forests and shrublands to grasslands for an unknown period of time (Hagman et al. 2013; Miller and Safford 2012; Miller et al. 2009; Goforth and Minnich 2008). It is likely that eventually shrubs and trees will regrow on most of these areas, though this is by no means certain. In some cases the new conditions, and unfortunately efforts to reintroduce burning or treat vegetation to reduce the probability of wildfire, benefit invasive plants and contribute to their spread (Keeley 2006). Some of these plants may support more frequent fires, or change moisture dynamics on the site. In the meantime, fire releases methane and carbon in the short term, and over a longer period, carbon storage is reduced, contributing to climate change. There is greater risk of erosion following severe fires, with soil loss potentially reducing the productive capacity of the site—also a form of desertification. Desirable habitats and timber production will be reduced. This could be considered degradation.

Invasive species are new actors on the stage in the fire drama that can interact with fire and grazing in ways that result in what might be termed "desertification." The advent of colonization from Europe began a process of wave after wave of invasive species arriving in North America from around the globe. In addition, with changes in fire and fauna, native species that have undesirable impacts on soils and vegetation may expand their known ranges and become more dominant in regions formerly occupied by grasslands, acting as native invasives. In some rangeland systems, invasives have changed ecosystem dynamics in ways that could be argued to be a form of desertification, with species of less value to wildlife as well as livestock becoming dominant. Occupation by invasive annual species may mean a less complex or shallower root structure that is subject to more erosion, a longer period of dry vegetation conditions that once were buffered by perennial plants drawing moisture from greater depth, and greater risk of wildfire.

The case of the invasive non-native annual grass known as cheatgrass, *Bromus tectorum*, in the cold desert is a useful example of interactions among fire, livestock grazing, and invasive species. The cold desert steppe of the Great Basin region starts in the rain shadow of California's Sierra Nevada, extends east into Utah, north into Idaho, and northeast as far as parts of Wyoming and Montana (Fig. 11.1). Several subspecies of sagebrush (*Artemisa* spp.) intermix with perennial bunch-grasses (*Pseudoroegneria, Achnatherum, Poa, Leymus, Oryzopsis* spp. and others). Much of the region has now been invaded by cheatgrass. Cheatgrass creates an even grass cover, rather than the "bunched" grass cover with spaces between the grass plants that prevailed previously. It is fine stemmed, and dries out every summer as soil moisture declines, creating excellent conditions for the ignition and spread of wildfire. Cheatgrass has substantially altered the regional fire regime, supporting larger and more frequent fires (Balch et al. 2013). Cheatgrass was a major fuel contributor to the six most significant wildfire seasons since 1960, all of which have occurred since 2004 (NIFC 2015). Studies have found a shortening of fire return intervals from 30–110 years to 3–5 years (Brooks et al. 2004; Chambers et al. 2007; Baker 2011).

Accidentally introduced from southwestern Asia in contaminated grain in the 1890s (Mack and Pyke 1983), with seeds that can be carried by livestock, the Bureau of Land Management (BLM 1991) estimated in 1991, that of the lands it managed, 3.6 million hectares contained cheatgrass as the dominant understory, and it had the potential to dominate 16.2 million acres of BLM land in the future (BLM 1991). The National Science and Technology Center mapped 12.4 million hectares of cheatgrass in the Great Basin in 2000 (Menakis et al. 2000). Although grazing and cultivation facilitated the spread of the grass (Young and Clements 2009), rangelands never cultivated and ungrazed since 1944 have been invaded by it (Brandt and Rickard 1994). Daubenmire, in a classic paper in plant community ecology, argued that cheatgrass could invade native perennial grass communities that never had been grazed and were in excellent ecological condition (1940). Once cheatgrass was introduced, for him it was only a matter of time until virtually all sagebrush plant communities in the Great Basin were invaded.

Ironically, in the 1970s and 80s government ecologists were concerned with an increase in sagebrush, and chain dragging to uproot shrubs and herbicides were used to control it (Sabadell et al. 1982). Now cheatgrass invasion, together with increased fire, has led to the loss of woody vegetation and deep-rooted perennial grasses, and reduced forage capacity. Along with declining forage production, frequent fires that cause the loss of perennial grass and shrub species, and the creation of a moisture regime that is annual, with rapid use of water in early spring and senescence and death of the plant life in mid summer and fall, the changes may be seen as a form of desertification. If climate change leads to more aridity, and more frequent wildfire, cheatgrass invasion is likely to expand. Many ecologists believe that a threshold is crossed once cheatgrass is common on a site, and only expensive treatments and reseeding have a chance of restoring the native shrub-grass complex (Young and Clements 2009) (Fig. 11.6).

In one of the few studies that used long term data to examine vegetation changes in the bluebunch wheatgrass-sagebrush steppe of southern Oregon, Allen-Diaz and Bartolome (1998) found that in the absence of fire, grazing practices had no effect on transitions to or away from dominance by cheatgrass. Weather and time seemed to be most closely related to this transition, supporting Daubenmire's observations. Other studies failed to show a link between grazing and vegetation change, except perhaps at very intensive levels of grazing (Laycock 1987; Eckert and Spencer 1987). Bagchi et al. (2013), assessing historical records of cheatgrass invasions, found no relationship with grazing regime and the frequency of transitions among states in the absence of fire. Cheatgrass establishment was related to periods of average to below-average annual rainfall, and its growth and fecundity related to patterns of infrequent rain in fall and early spring. Both Bagchi et al. (2013) and Allen-Diaz and Bartolome (1998) found that transitions away from cheatgrass dominance may occur over time in the absence of fire without any relation to grazing, though in the Bagchi et al. study, reversibility was more common at the site with grazing. Young and Clements (2007) argue that under rest-rotation grazing cheatgrass benefits from deferral of grazing until after seed ripe, or complete rest from grazing. These types of findings lead some to argue that grazing, once a facilitator to invasion, may be a way to control the impacts. The problem has not proved amenable to the default approach of reduced stocking.

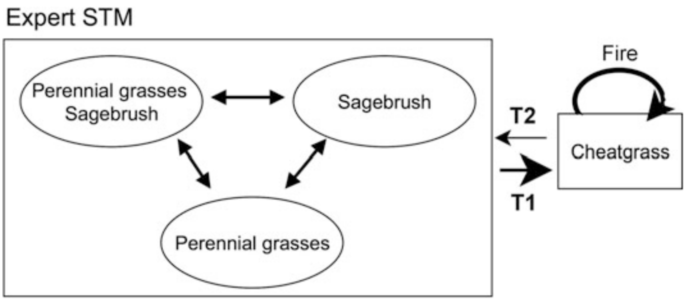

Fig. 11.6 An "expert" states and transition model for sagebrush steppe vegetation dynamics (adapted from Bagchi et al. 2013). The three sagebrush and perennial grass-dominated states are often referred to as "phases" that do not have strong thresholds between them, while the transition to cheatgrass (*T1*) is often argued to be irreversible, because of the difficulty of crossing the strong threshold leading back to perennial grass and sagebrush types (*T2*). While researchers generally agree that *T1* is strongly facilitated by fire (Young and Clements 2009), the role of grazing today is less clear. Two studies using long term data have found that *T2* does sometimes occur over time in the absence of fire (Allen-Diaz and Bartolome 1998; Bagchi et al. 2013). Fires are one way the cheatgrass state is maintained.

The role of grazing in this scenario is one of many interacting dramatic changes, and changes without directionality. Removal of grazing may have little or no impact, and threshold dynamics may result in multiple stable states that have little to no relation to a "climax" or previously identified "potential" vegetation. There is no simple story here.

11.12 Holistic Resource Management: A New Story

The states and transition format, based on non-equilibrium theory, lacks the directionality and purpose of a good story— lacks a moral compass, as it were. Instead, a states and transition model is a set of boxes representing vegetation states and a "catalogue of transitions," a simple listing of what drives change from one box to another. While it may be possible to see a moral message in some transitions, it is not as simple or compelling as the linear, Clementian succession story. Perhaps an analogy to the succession story is a story with stereotypical characters that "make sense" to the reader, like an old style western pulp novel, or a bodice-ripping romance: In a states and transition model, on the other hand, things just happen. Within this narrative vacuum, the concept of Holistic Resource Management has flourished.

"Holistic Resource Management" is a package of rangeland management concepts and practices with origins in the early 1980s, oriented around a central, powerful, story. As the most well known promoter of the programme puts it, livestock grazing should mimic the herds of wild grazers that once wandered the grassland (Savory and Butterfield 1999). The wildlife mimicry carries a positive moral loading: this must be a better, "natural" way of doing things. Livestock are moved regularly from one pasture to another, in what has been termed a "rotational" grazing scheme, attempting to emulate, though at a much smaller scale, the way a wild herd moves from one grazing ground to another, allowing plants that have been grazing to "recover" before the next visit. Part of the HRM canon is that the soil surface should be broken by hooves, allowing seeds to be worked into the soil. In fact, the first range research carried by the USFS was a test of Sampson's theory that you could rest or sow seed, then run sheep through to plant seeds. It failed when he tried it in Oregon in 1908 and has never been shown to work since (Sampson 1909; Skovlin et al. 2000).

Typical of ecological or environmental stories, the wild herd narrative that is used to support HRM has if nothing else been over-extended to ecosystems that not only have a different climate, but that never had such animals. Perhaps more important, scientific review has shown a lack of ecological benefits from rotational grazing in arid systems (Heady 1961, Bartolome 1993; Briske et al. 2008). However, the herd management aspect comes with a variety of other interventions that may or may not be effective in improving management. For one example, encouraging the manager to spend more time observing and working with the stock is probably beneficial (Briske et al. 2011), and ranchers mention other benefits, including that it makes stock more gentle because of frequent human contact.

Implementing the required grazing system can be costly to ranching enterprises, while fencing and rotational grazing may be detrimental to some ecosystem services. But the story is so compelling that it continues to attract adherents in the livestock and management communities. Holistic resource management might even be seen as a story that helps a producer communicate good intentions, and a commitment to protecting the environment, to agency regulators and managers.

Both Clementian succession models and HRM are based on compelling stories that overshadow the need for evidence, particularly on arid lands.

11.13 Conclusions

Desertification is an ill-defined term that has been used sporadically to discuss grazing issues in the United States. Unlike in many parts of the world, it is not a part of everyday discourse about grazing. The terminology of rangeland condition used widely on public rangelands has seemingly supplanted the language of desertification. A review of journal articles reporting research in the United States with desertification in the title according to the Web of Science shows only about a dozen published in the last 10 years, and they use differing definitions of the term. It has mostly been applied in the Southwest, in research on the causes of shrub encroachment, usually mesquite (*Propsopis* sp.), into warm desert grasslands, and the possible roles and inter-relationships of grazing, fire, warming temperatures, and rainfall in that encroachment. There are more papers with "desertification" as a keyword term, but a cursory review reveals that many of these do not actually mention desertification within the paper.

Despite the difficulties of identifying and defining desertification, estimates of the amount of "desertification" for North America have been published a number of times. In 1976 a symposium on the topic was held at the University of Arizona in Tucson (Paylore and Haney 1976). In the introduction, the definitional problems are discussed, and the following definition adopted, stating that desertification is a process that:

> …deals with the extension of typical desert landscapes and landforms to areas where they did not occur in the recent past, one taking place for our purposes in marginal arid zones bordering deserts under average annual rainfalls of approximately 50–300 mm, areas characterized by increasing aridity and intensification of distinct geomorphological processes, desiccation and increasing salinity of soils, and a manifest degradation of vegetative cover. The term implies a change, whether by the long term (in the geologic sense) climatic change or by short term climatic fluctuation, or by man's intervention through careless extension of agricultural developments, burning, overgrazing, urbanization, and increasing population pressures.

The purpose of the symposium is stated to be to contribute to the development of measures for reversing desertification. It is implied that the most important measure is population control, and the document calls for the establishment of reserves by the government, with compensation for those excluded. The author of the lead article provides a map of desertification in North America (Fig. 11.7; Dregne 1976). Desertification is attributed to the combined impacts of "man's activities and drought." The symposium includes a paper on the Papago Indians of the southwest,

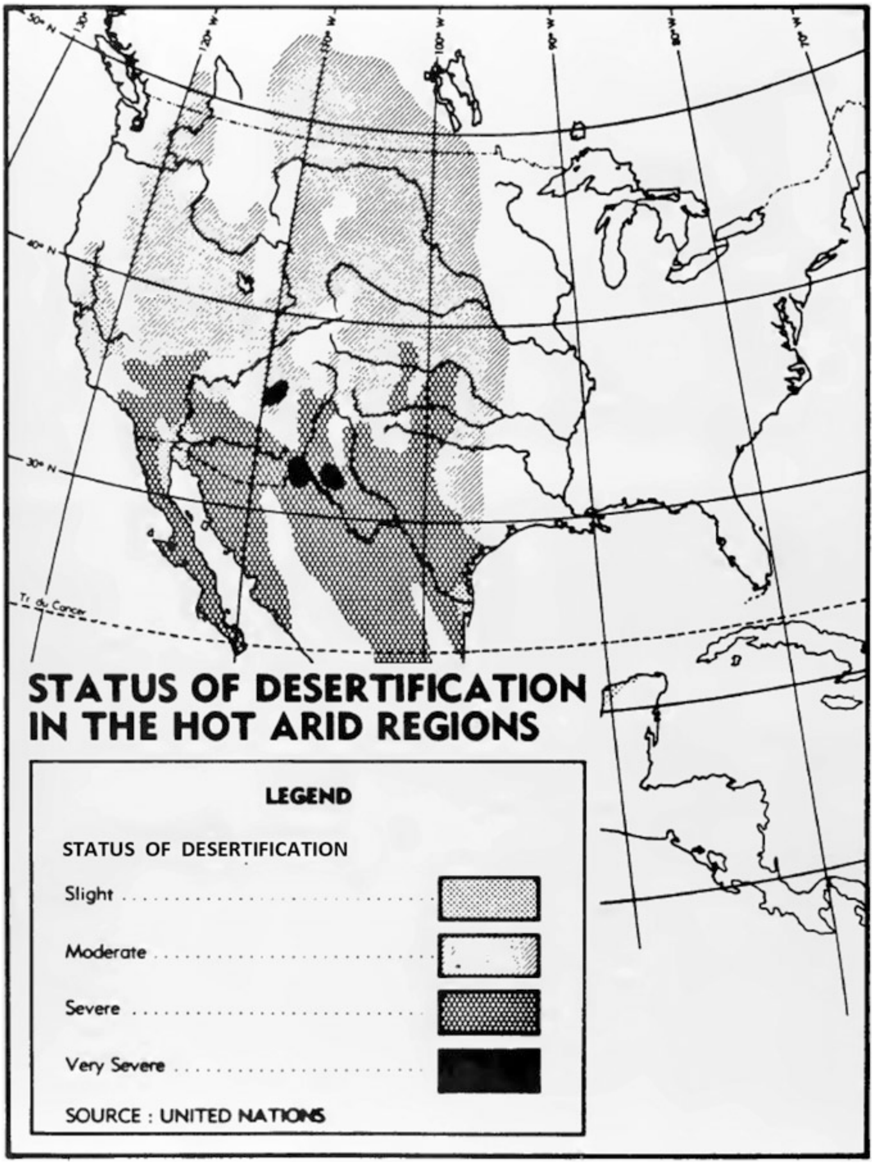

Fig. 11.7 Map of desertification in the United States from the United Nations published in a 1982 BLM report on desertification (Sabadell et al. 1982). Aside from a few spots, degree of desertification seems cartographically strongly linked to prevailing temperatures and aridity.

but only to discuss their livestock grazing practices. Their use of fire, once a feature of the hunting economy (Stewart et al. 2002), is not mentioned.

In 1982 the federal agency managing the largest area of U.S. arid rangelands, the Bureau of Land Management, published a document titled "Desertification in the United States: Status and issues" (Sabadell et al. 1982). The document states that "an assessment of the problem at the national and regional levels has been recognized by world and national organizations as a first priority in combating and preventing desertification." Desertification is defined as "the sustained decline and/or destruction of the biological productivity of arid and semiarid lands caused by man-made stresses sometimes in conjunction with natural extreme events. Such stresses, if continued or unchecked, over the long term may lead to ecological degradation and ultimately to desert-like conditions." Range condition is defined as "The present productivity on a range site as related to the potential natural plant community for that site. Range condition is expressed as excellent, good, fair, or poor, on the basis of how much the present plant community has departed from the potential."

Several factors were identified in the report as contributing to desertification, including farming, grazing, herbivore population growth, mining, energy production, urbanization, recreation—particularly the use of off road vehicles, and in general, competition for the land base among diverse uses. The loss of indigenous management is not mentioned. For grazing, the report argues that a balance must be maintained between livestock numbers and the land's carrying capacity, and that during drought years, grazing must be reduced and shifted to feed or other pastures. The report states that the Agricultural Research Service in 1974 estimated that more than 71 percent of the rangelands in the 17 Western States were in only fair to poor range condition, and that there is a high correlation of range condition to degree of erosion. The report comments that although conditions are improving under federal management, "the damage done by excessive grazing prior to the turn of the century is still largely present."

In 2004, Lal et al. estimated that about 2.75 m km^2 or about 85 % of arid U.S. rangelands have moderate to severe desertification. The authors used a 1992 UNEP definition of desertification stating that it is "land degradation in arid, semiarid, and dry subhumid areas resulting mainly from adverse human impact." They argue that the degradation of rangeland vegetation is primarily caused by excessive prolonged grazing and removal of vegetation by anthropogenic perturbations. Changes in biodiversity, especially the species mix leading to the predominance of undesirable species, and use of irrigation water with a high mineral content in areas with poor drainage, among other things, are also mentioned as causal factors. It is interesting that three of the U.S. studies published in the last 10 years with desertification in the title found by this author evaluated some type of faunal diversity and two found higher or equivalent species diversity on the "desertified" sites (Kerley and Whitford 2000; Bestelmeyer 2005; Klass et al. 2012).

None of these papers and documents considers the role of the suppression of indigenous practice in desertification. Aggressive, nearly paramilitary fire suppression, accompanied by the criminalization of indigenous burning and the destruction of native cultures, has a complex role in processes of desertification that have vast implications for western rangelands and forests. Rather than leading to the "recovery" of a "climax" state, the removal of grazing and fire suppression can mutually reinforce the frequency and intensity of conflagrations. In some climate zones shrublands and woodlands may become more fire prone in the absence of grazing. Dried grasses on ungrazed grasslands make fire starts more common. On rangelands, some invasive species were introduced and spread as part of livestock grazing and cultivation. Livestock dispersed seed, and disrupted native vegetation, creating opportunities for invasives. How much livestock continue to influence erosion, species introductions, and species change is the subject of debate, and no doubt varies place to place and time to time, but in many cases they remain branded as the bad actors behind it all.

The changes in ecosystems that are occurring as a result of all these factors are often irreversible and widespread. The science of "novel ecosystems" has developed to study such unprecedented assemblages of vegetation (Seastedt et al. 2008). In some cases livestock grazing is a tool used to control non-native species that are the new actors in desertification, prevent fires like those in cheatgrass, or to control the encroachment of shrubs and trees that once were constricted by indigenous burning. However, the "deviation from pristine" model for evaluating rangeland conditions, and the mythology of the "untouched" American wilderness, has fed into a still powerful ideology of avoiding management interventions and relying on natural "recovery" that challenges rangeland managers today as they attempt to cope with changing species and climatic conditions. Doing nothing often becomes the most viable alternative for government land managers faced with lawsuits and controversy over management practices. There is little institutional accountability for the results of "hands off" management.

Against the background of vast changes on rangelands, climate change is a factor today. In fact, in rangeland management discourse, climate change or the specter of climate change has begun to overshadow the recognition of a legacy of mismanagement of western ecosystems. The story is perhaps shifting away from correcting past management to laying most of the blame at the foot of a situation beyond the manager's control. Yet the lessons learned from the past should not be forgotten as we move forward. In particular here we find a warning against charismatic stories—somewhat as Elinor Ostrom warns against policies rooted in compelling metaphors (1990). Stories encourage and conceal deep-rooted, untested assumptions, simplify complex relationships, and universalize truths that may hold true only in a single time and place.

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