The Tumbleweed Centennial in the Antelope Valley, California

David A. Bainbridge
Soil Ecology and Restoration Group
Biology Department MS 4614
San Diego State University, San Diego, CA 92182

Environmental Studies Coordinator
United States International University
10455 Pomerado Road, San Diego, CA 92131

Those who cannot remember the past are doomed to repeat it . **George Santayana**

The tumbleweed, a.k.a. Russian thistle, *moujiks* (the wind witch), or more formally, *Salsola tragus, (S. kali* or S. *australis)* was apparently the *first exotic pest plant* indicted in California (Shinn 1895). It probably arrived in the Antelope Valley in the late 1880s. The failure of initial efforts to control tumbleweed was inevitable given the residents' failure to see this weed (and the many others we are now struggling against) as a symptom of land degradation, not an isolated disease. The lessons we should learn from its escape include: control weed seed entry and spread, understand the ecology of the weed and its role in degraded ecosystems, attack isolated weeds before they reproduce and maintain vigilant suppression; and most critically, adopt a more holistic approach to the problem of weed management based on land health.

The importance of viewing land management within its larger context is also essential (Blaikie l989; Trudgill 1991; Hallsworth 1987). We will make the large investments in land rehabilitation and improved land management practices we need only when we understand that this will yield net economic benefits. Tumbleweed will not persist on healthy land; but like many weeds (Cocannouer 1964), can be a useful step on the return to soil health (Cannon et al. 1995).

The initial invasion of the Antelope Valley

The cultural history of the tumbleweed reflects religious struggles taking place in Europe and Russia. The persecution of the Mennonites led these Dutch and Swiss reformers to move into Russia in the 1700s. Further changes in Russia led to massive emigration to the West in the late 1800s, with more than 20,000 Mennonites emigrating and settling in the western U.S. Among the barley, wheat, and flax seeds they brought with them were tumbleweed seeds from the Russian plains. The major source of seeds in the United States apparently was a farm in South Dakota. Seeds probably reached the Antelope Valley in contaminated livestock feed from North Dakota, as the outbreak began near cattle yards along the railroad near Lancaster, CA (Shinn 1895). The source of an outbreak in Yakima, Washington in 1896 (Young 1991) was traced to weed seeds in animal feed. The seeds may also have come along with the first settlers in the 1880s (from the Mennonite-rich Lancaster, PA area). In any case, by April of 1895 it prevailed over about 11 sections of land, but was most thick within the town itself, where the slender reddish leaves "cover the ground" along the streets (Shinn 1895). A second tumbleweed colony had also formed ten miles west of Lancaster in areas cultivated for wheat, throughout sections 25 and 26, township 7 range 14.

The response

If the expenditure of ten thousand dollars would utterly destroy the Russian thistle in the Antelope Valley it would be a good investment (Shinn 1895).

The arrival of the Russian thistle was not taken lightly by Mr. Shinn, the University of California Experiment Station Inspector, or Mr. W.S. Melick, then publisher of the Lancaster Gazette. The tumbleweed problem in South Dakota had been well studied and the loss to wheat farmers in 1894 was estimated at two million dollars. The county supervisors were approached and contributed some money for control, amounting to some $400 in the winter of 1894-5. This was used to burn plants (which often left many viable seeds) and to harrow the emerging seedlings in spring (Shinn 1895). But as Mr. Melick noted, a public sentiment would have to be created to eliminate this weed and this was never accomplished.

Why is tumbleweed such a troublesome weed?

This species developed its special adaptation for dispersal on the wide open plains of Russia in association with humans. It's a fast growing herbaceous annual (C4) with a fast growing tap root and the ability to germinate under a wide range of conditions (Young 1991). In adapting to human disturbance caused by grazing and agriculture it developed a rounded, wind responsive canopy. As the plant dries out it has a root separation mechanism similar to those for fruit drop and the round top can roll for many miles, leaving a trail of seeds as it tumbles (Young 1991). Since a mature plant may set more than 250,000 seeds it can rapidly establish itself over very large areas (Young 1991). Initial spread in the Lancaster area was limited by "the sage brush and other shrubby growths standing up on little mounds of sand and belts of tree yuccas" which stopped the rolling weeds even with the wild wind that may occur in the valley (Shinn 1895).

Salsola tragus, like many other weeds, is adapted to disturbed sites that have dysfunctional nutrient cycling and low organic matter. It is also associated with more intensive land management (agriculture) resulting from ecosystem deterioration (Bainbridge 1985). Seeds are found in the first human sites in Europe and without human intervention tumbleweed would probably have remained an innocuous plant (Young 1991). It's also salt tolerant, which provides a further edge on lands degraded by agriculture, and can even be found on ocean strandlines, where its adaptation to severe stress and concentration of phosphorus has proven useful for its survival (Pakeman and Lee 1991).

The oxalates that tumbleweed produces make phosphorus more available, increasing phosphorus content of litter and creating islands of fertility that can become a first step in the successional recovery of highly disturbed areas (Allen and Allen 1988; Allen and Allen 1990; Cannon et al. 1995). It's non-mycorrhizal and in fact attempted mycorrhizal infection proved pathogenic rather than symbiotic (Allen and Allen 1988; Allen et al. 1989). This explains why sites that are only slightly disturbed will often fight off the infection of tumbleweed within a few years as soil health recovers. Like many other weeds, it will disappear if it is left alone and the land is not overgrazed, tilled, or degraded. Common practices used to fight tumbleweed, including repeated disking and piling their carcasses in ditches and burning them, may merely maintain populations and enhance spread, as the seeds that survive burning are sluiced into fields with irrigation water (Jackson 1994).

Economic folly, human optimism and natural variation

Farming operations spread through the Antelope Valley desert as a result of external factors including migration from Europe, the completion of the railroads, heavy railroad advertising, the wheat bonanza, improved markets as a result of World War I and II, and human optimism in the face of natural variation and environmental limitations. It may also owe something to the widespread belief that rain follows the plow - a dictum that was promulgated in the mid to late 1800s by the most ardent proponents of western settlement.

The initial areas of cultivation in the Antelope Valley included an extensive artesian belt, small colonies irrigated by streams and reservoirs, and 70,000 acres of grain (Shinn 1895). As the natural barriers to tumbleweed were removed and agriculture spread, the conditions became much more favorable for weed dispersal. Agricultural development declined with the collapse of the wheat bonanza, but various other crops were tried and tilled land area expanded rapidly. Improved electric pumps, low electricity rates, and crop subsidy and support programs led to other boomlets. But hard frosts occur periodically and it is a desert, so profits were marginal and unpredictable.

The artesian wells disappeared rapidly and as depths to water increased and higher energy prices increased pumping cost active farming has declined. This aberrant farm experiment would not have been possible if the value of the ecosystems services of these lands and the economic cost of land degradation had been considered in the economic cost. This was agricultural mining, and like more traditional mining, vegetation recovery is very slow. This was exacerbated by rapid expansion of urban areas and perceived development potential over vast areas. At the present time abandoned agricultural land predominates in the Antelope Valley, with limited production of onions and other crops occurring. Many thousands of acres are barren and fugitive dust causes health problems and economic damage.

Why is recovery so slow

Studies in the Mojave Desert suggest that without intervention it may take 180 years for reasonable recovery of species diversity on disturbed *non-compacted* soils (Webb et al. 1983). Lathrop (1983) calculated a recovery period of more than 200 years to reach predisturbance cover. Allen (1988a) suggests that severe disturbance may result in an alternative trajectory of succession in arid and semi-arid areas that will never return to predisturbance conditions.

The rate at which a desert ecosystem recovers from human or natural disturbance is a function of the nature, magnitude, and frequency of the impacts. Seeds and related symbionts (mycorrhizal fungi, for example) may no longer be present and critical aspects of soil structure, soil fertility, and air/water interchange can be adversely affected (Bainbridge and Virginia 1990; Allen 1988b). Extreme temperatures, herbivory, limited moisture and low fertility soils combine to make plant establishment very slow even without disturbance, with conditions for widespread native shrub establishment occurring only a few times a century. The presence of non-mycorrhizal weeds can further hinder recovery by limiting inoculum required for successful establishment of more common mycotrophic plants (Allen and Allen l988; Allen et al. 1989).

Areas disturbed by agriculture may recover very slowly as a result of profound changes in soil structure, soil symbionts, soil fertility, groundwater, and the soil/air/water interface (Bainbridge 1990). Sections of abandoned agricultural land in Antelope Valley, like those north of Tucson, Arizona, have exhibited little recovery after many decades, even when relatively undisturbed plant communities nearby can act as seed sources (Jackson et al. 1991; Jackson 1994).

While desert soils may appear lifeless much of the year, living organisms, from bacteria to animals and plants, strongly influence their fertility, structure, and response to disturbance. Small organisms such as ants (Majer et al. 1987), bacteria, fungi, mites, and other microfauna play important roles in desert soils. Yet much more research has been conducted on the above ground interactions than on the critical characteristics of the soil ecosystems (Allen 1988a).

Some of the most profound impacts of human activity are the unseen effects below ground. Key changes include: reduced infiltration, reduced water holding capacity, unbalanced fertility, compaction, increased soil strength, increased erodability, and reduced biological activity. Infiltration is reduced by changes in pore size and distribution, reduced surface roughness, and loss of plant mediated infiltration benefits (stem flow, litter, etc.). In one study infiltration in dry creosote bush soil was double dry bare soil and infiltration in wet creosote bush soil was almost five times higher than wet bare soil (Tromble 1980). Areas with good plant cover may hold and save much of the rain that falls in intense storms while areas that have been disturbed experience sheet flow, flash floods, and severe erosion with resulting economic damage. The biological health of the Antelope Valley soils has been seriously affected by disturbance, as shown in Table 1.

Nutrient cycling has been further disturbed by dryfall of nitrogen rich particulates from urban areas (Allen et al. 1996). These are primarily from auto exhaust, swept east from Los Angeles and south and east from the increasingly urbanized San Joaquin Valley. The ready availability of nitrogen can favor annual weeds and grasses over slower growing perennial natives, which may be almost permanently excluded from disturbed areas without intervention.

Disturbance markedly increases the severity of the microclimate. Temperature swings are larger on disturbed sites, radiation is more intense, evaporation is increased, and wind speeds and sandblast are more severe. Vegetation removal eliminates sheltered areas and makes plant establishment more difficult. Plants in the open are more likely to suffer from sand blast, herbivory, drought, and radiation frost.

Table 1.

Soil characteristics of disturbed sites in Antelope Valley.
Means of 3 samples, except column 2. Per gram of soil.
Extreme values are shown in bold type.

Site description	Meters hyphae	Meters hyph (*)	Million bacteria	µg NH_4	µg NO_3
Good	**2.66**	**1.30**	94	**1.92**	1.54
Moderate	0.70	0.70	92	0.66	0.60
Moderate	0.72	0.60	88	0.79	0.41
Moderate	1.06	0.30	94	0.22	0.35
2nd worst	0.39	0.30	87	1.62	4.16
Worst	1.47	0.30	**34**	1.23	**7.76**

Site condition reflects survival of transplants and cover
*less highest of three

Potential interactive effects of disturbance on plant establishment

The adverse effects of anthropogenic disturbance on existing plants and plant establishment are interactive and in many cases appear to be synergistic. These interactions are not well understood, but the following formula is a preliminary attempt to assess these interactions and relate them to plant establishment. Plant establishment becomes increasingly difficult as the number of important environmental factors deteriorating increases.

NET DISTURBANCE = [(d1 - compaction) (d2 – reduced infiltration) (d3 - microclimate severity) (d4 - herbivory increase). (d5 - nutrient cycling disrupted) … (d*n*)]

No study has clearly evaluated all of the factors related to establishment, but Bainbridge (1994) suggests that a site disturbed by off road vehicles may have roughly 3% of the predisturbance potential for plant establishment. The fact that disturbances caused by Anasazi farmers more than 900 years ago are still visible (Sandor and Gersper 1988) suggests these estimates are not unreasonable.

Lessons for exotic weed management

For tumbleweed, and most other weeds, a better understanding of its ecological role and function could lead to much better control strategies, such as minimizing repeated disruption, facilitating recovery of mycorrhizal fungi, and perhaps addition of added organic matter to the soil (see for example: Mitchell and Bainbridge 1991). The response of Russian thistle to attempted mycorrhizal infection suggests that adding soil organic matter may prove useful for suppression. Enormous quantities of organic matter are becoming available as "green waste" reduction requirements for land fills are implemented and biomass power plant subsidies are removed, returning tens of thousands of tons of once burned agricultural waste to the fields. This should be composted to eliminate weed seeds and then applied to degraded lands to rehabilitate many tens of thousands of acres a year. Even at relatively low application rates it may prove useful. Dreniman (1996) found that mulch can be useful as a control agent for Yellow star thistle (*Centaurea solstitialis*), which currently occupies some 3.2 million hectares in California alone, and continues to spread. This could lead to more effective control and speed recovery of disturbed ecosystems.

In some cases it may be possible to modify some aspects of the environment to better than original conditions. Making one factor much better than pre-disturbance condition may have a notable effect on recovery. If soil structure, water retention, nutrient availability, and infiltration can be made more suitable for native plants than before disturbance, weeds can be controlled and the difficulty of establishment may be reduced. For many areas this may include pitting, imprinting, mulching with carbon rich slow to degrade mulch, container planting, and for very extensive areas, inoculating with appropriate mycorrhizal symbionts (Bainbridge and Virginia 1990, Bainbridge et al. 1995; Zink and Allen 1995). Assessing the nature and magnitude of changes in key factors can improve weed control planning and reduce weed management cost by enabling limited resources to be directed at critical factors. The wild card of nitrogen deposition is especially troubling, as these high levels of nitrogen input from dryfall can favor non-mycorrhizal weeds. Adding slow to degrade mulch may help negate this nitrogen addition and favor perennial native plants (Zink and Allen 1995).

Weeds are commonly a symptom of ecosystem disease and cannot be treated in isolation. Ecosystem health assessments (Yazvenko and Rappaport 1996) with much more detailed soil ecosystem component analysis will be a very useful first step (Conners et al. 1995; Allen and Friese 1992). Control efforts should include a detailed assessment of weed ecology and economic factors leading to weed establishment and spread.

Developing a better accounting system for economic benefits of ecosystem services and costs of ecosystem deterioration is a fundamental requirement for improved weed management in general. One of the ways of assessing cost of damage is determining the cost to repair damaged systems. For degraded desert farmlands a meaningful repair effort can cost $5-10,000 per acre and take many years. In addition, the cost of ecosystem services also need to be calculated. What are the health costs of increased dust? What is the cost associated with increased flooding, erosion, and sediment buildup? A net budget for farming operations in much of the Antelope Valley would probably reveal that opening and plowing these lands led to a net economic loss. Until these full costs are clear the commitment of resources will not be made to foster ecosystem health (the problem) and eliminate weeds (the symptom).

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