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# Assessing the Economic, Environmental, and Societal Losses from Invasive Plants on Rangeland and Wildlands[1]

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**Abstract:** A literature review was conducted to summarize information on environmental, economic, and societal losses caused by 16 key invasive plants on rangeland and wildlands in the United States. Results of the literature review indicated that scope of published information ranged from narrow to comprehensive. Extensive quantitative information is published about environmental impacts caused by leafy spurge, downy brome, saltcedar, purple loosestrife, and several knapweeds or starthistle. For other species, quantitative information was limited and references to impacts were mainly anecdotal or observational. The economic impacts of most species were poorly documented. Comprehensive economic analyses conducted on either a state or regional basis were published about leafy spurge, saltcedar, and the knapweeds. Agricultural costs including loss of grazing value were quantified for several additional species, but environmental and societal costs were not included in the analyses. Additional research is needed to quantify economic and environmental losses of invasive nonnative plants on rangeland and wildland sites.

**Nomenclature:** Downy brome, *Bromus tectorum* L. #[3] BROTE; leafy spurge, *Euphorbia esula* L. # EPHES; purple loosestrife, *Lythrum salicaria* L. # LYTSA; saltcedar or tamarisk, *Tamarix* spp., # TAASS; yellow starthistle, *Centaurea solstitialis* L. # CENSO.

**Additional index words:** Exotic plants, invasive plant impacts, noxious weed impacts.

## INTRODUCTION

Rangeland, pastureland, national parks, nature preserves, and other wildlands account for about 48% of the total land area in the United States (USDA NRCS 1997). These lands are vital for agricultural production and protecting integrity of ecological systems. About 3,310 nonnative plant species occur as self-sustaining populations within natural areas in the 48 contiguous United States (Kartesz 2004). Sixty of these species are considered of major economic and ecologic importance on rangeland and wildland areas (Mullin et al. 2000). Few comprehensive studies have assessed the magnitude of economic and environmental losses from invasive plants on range, pasture, and wildlands. This information is critical to quantify societal losses from invasive plants, prioritize management programs, and provide a basis for formulating consistent and rational management decisions.

The purpose of this article is to summarize literature regarding environmental and economic impacts of 16 invasive nonnative plants in the United States. Current information on area infested, spread rates, economic and environmental impacts, value and use, and data gaps are discussed. This information is described in greater detail in a Weed Science Society of America special publication (Duncan and Clark 2005).

## MATERIALS AND METHODS

The Weed Science Society of America Federal Noxious Weed Committee, western state weed coordinators,

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[3] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

*Table 1.* Invasive plants, area infested, and average annual historic spread rates in the United States (Duncan and Jachetta 2005).

| Invasive plants | Plant Bayer code | Area infested, 17 western states[a] | Area infested, eastern states | Average annual spread rate |
|---|---|---|---|---|
| | | ha | ha | % |
| Downy brome (*Bromus tectorum* L.) | BROTE | 22,680,785 | 204,371 | 14 |
| Musk thistle (*Carduus nutans* L.) | CRUNU | 1,889,711 | 1,205,969 | 12–22 |
| Russian knapweed (*Acroptilon repens* L.) | CENRE | 485,906 | 101 | 8–14 |
| Diffuse knapweed (*Centaurea diffusa* Lam.) | CENDI | 745,166 | 2,023 | 16 |
| Spotted knapweed (*Centaurea maculosa* Lam.) | CENMA | 2,117,809 | 693,242 | 10–24 |
| Yellow starthistle (*Centaurea solstitialis* L.) | CENSO | 5,979,741 | Present | 13–17 |
| Canada thistle [*Cirsium arvense* (L.) Scop.] | CIRAR | 2,856,184 | 2,285,475 | 10–12 |
| Leafy spurge (*Euphorbia esula* L.) | EPHES | 1,487,237 | 375,154 | 12–16 |
| Hawkweed (*Hieracium* spp.) | HIESS | 259,484 | 222,582 | 11 |
| Perennial pepperweed (*Lepidium latifolium* L.) | LEPLA | 828,171 | Present | 11–18 |
| Sericea lespedeza [*Lespedeza cuneata* (Dumont) G. Don] | LESCU | 2,226,356 | 1,277,640 | 24 |
| Dalmatian toadflax [*Linaria dalmatica* (L.) Mill] | LINDA | 161,618 | 202 | 8–29 |
| Purple loosestrife (*Lythrum salicaria* L.) | LYTSA | 18,267 | 112,884 | 15[b] |
| Tropical soda apple (*Solanum viarum* Dunal) | SOLVI | 0 | 503,272 | 35[c] |
| Medusahead [*Taeniatherum caput-medusae* (L.) Nevski] | ELYCM | 972,683 | Present | 12 |
| Saltcedar or tamarisk (*Tamarix* spp.) | TAASS | 1,488,176 | Present | 1.3–25 |
| Total Hectares Infested | | 44,197,299 | 6,884,918 | |

[a] The western area is represented by 17 states, from North Dakota south to Texas and west to the Pacific coast (not including Hawaii or Alaska). Area infested data are incomplete for eastern states.

[b] Calculated for western United States.

[c] Average annual spread rate in Florida from 1990 to 1995 was 117%.

and Dow AgroSciences selected the 16 invasive plants included in this review based on the extent of their infestation, perceived environmental or economic impacts, and geographic region. Species selected included Russian knapweed (*Acroptilon repens* L.), musk thistle (*Carduus nutans* L.), diffuse knapweed (*Centaurea diffusa* Lam.), yellow starthistle, spotted knapweed (*Centaurea maculosa* Lam.), Canada thistle [*Cirsium arvense* (L.) Scop.], hawkweeds (*Hieracium caespitosum* Dumort and *Hieracium aurantiacum* L.), perennial pepperweed (*Lepidium latifolium* L.), leafy spurge, sericea lespedeza [*Lespedeza cuneata* (Dumont) G. Don], purple loosestrife, downy brome, medusahead [*Taeniatherum caput-medusae* (L.) Nevski], Dalmatian toadflax [*Linaria dalmatica* (L.) Mill], tropical soda apple (*Solanum viarum* Dunal), and tamarisk or saltcedar. Of the above 16 species, 14 occur on range, pasture, or open woodland habitats and two species occur in riparian or wetland habitats.

The comprehensive literature review (Duncan and Clark 2005) included a minimum database search requirement of AGRICOLA, Plant Science, and Biological Abstracts, in addition to the authors' expertise regarding the literature of individual species. Information on environmental and economic impacts was summarized in eight categories: Livestock and Wildlife; Plant Communities; Rare, Sensitive, or Threatened Species; Community Function; Soil and Water Resources; Human Health; Economics; and Value and Use. General descriptions of the taxonomy, botanical characteristics, susceptible habitats, plant distribution, and spread and reproduction were also included for each invasive plant species.

Current information regarding area infested by the 16 species is limited in the published literature. To obtain this information, a questionnaire was developed and used to solicit data on the area infested from state weed management professionals involved with invasive plants in the 48 contiguous states (Duncan and Jachetta 2005). Survey respondents included university scientists, The Nature Conservancy biologists, state weed coordinators or biologists, and federal agency ecologists, biologists, or range scientists. The questionnaire included the number of acres infested for each of the 16 species, method for reporting acres (estimated or surveyed), and percent accuracy of the acreage reported. When available, published literature regarding area infested was used in states where current estimates could not be obtained. The annual rate of spread for each species was either calculated using generalized expansion rates based on constant average rates of spread over time (a simple interest model) or reported from published literature.

## RESULTS

**Environmental Impacts.** A total of 51 million ha are infested by the 16 selected invasive plants in the United States (Table 1). Scope of published information about environmental and economic impacts of the 16 species ranged from narrow to comprehensive. Extensive quantitative information is published about environmental impacts caused by leafy spurge (Lym 2005), downy brome (Rice 2005a), saltcedar (McDaniel et al. 2005), purple loosestrife (Brown 2005b), and several *Centaurea* species (DiTomaso 2005; Duncan 2005a, 2005b). For other species, quantitative information was limited and references to impacts (Table 2) were mainly anecdotal or suggested (Duncan and Clark 2005).

**Economic Impacts.** The economic impact of most species is poorly documented. This is generally due to lack of quantitative information on ecosystem impacts and challenges in assessing nonmarket costs such as those to society and the environment (e.g., changes in fire frequency, wildlife habitat, aesthetics, biodiversity) (Evans 2003).

Comprehensive economic analyses have been published for leafy spurge (Leitch et al. 1994), knapweeds (Hirsch and Leitch 1996), and *Tamarix* in the western United States (Zavaleta 2000). Direct and secondary economic impacts of leafy spurge infestations on both grazing and wildlands in Montana, North Dakota, South Dakota, and Wyoming was about US$130 million, which represented a loss of 1,433 jobs (Leitch et al. 1994).

Direct and indirect economic impacts of spotted, diffuse, and Russian knapweed on Montana's economy were $42 million annually, based on an infestation level of 809,000 ha (Hirsch and Leitch 1996). The model by Hirsch and Leitch (1996) assumed no livestock or wildlife forage value from knapweeds.

Economic feasibility studies to estimate cost and benefits from *Tamarix* control have been conducted for some western U.S. waterways (Brotherson and Field 1987; Great Western Research 1989). A comprehensive economic analysis estimated ecosystem-based services lost to *Tamarix* invasion in the western United States (Zavaleta 2000). Values lost from *Tamarix* included irrigation and municipal water, flood control, hydropower, wildlife habitat, and river recreation. Dove hunting and sedimentation were considered benefits provided by *Tamarix*. Based on estimates of 0.47 to 0.65 million ha infested, the presence of *Tamarix* in the western United States will cost from $7 billion to $16 billion in lost ecosystem functions over the next 55 yr. This loss amounts to an average of $15,600 to $24,600/ha of land infested with *Tamarix*. The 20-yr cost of a hypothetical eradication and revegetation program was estimated at $7,428/ha. Long-term benefits outweighed costs by $8,184 to $17,235/ha or $3.8 billion to $11.2 billion across the entire region (assuming a 0% discount rate) (Zavaleta 2000).

Thompson et al. (1987) performed a benefit-cost analysis of resources and values at risk to purple loosestrife compared with costs of a 10-yr biological control program for 19 eastern and northcentral states. Annual realty value of threatened wetlands, wild hay and pasture, fur harvest, migratory bird hunting expenditures, and wildlife observation and photography were estimated at $229.3 million. Implementation of a successful biological control program was estimated to save 20% of these resource values annually or $45 million. Losses related to purple loosestrife control included the cost of biological control ($0.1 million), 10% of annual honey sales ($1.3 million), and 5% of annual herbaceous ornamental sales ($0.3 million) for a total of $1.7 million. Ogrodowczyk and Moffitt (2001) reported direct economic impacts of purple loosestrife in the United States by calculating its value to beekeepers as a source of nectar and pollen compared with short-term control expenditures and diversity loss. Wildlife-associated recreation losses (bird watching, fowl hunting, and habitat viewing) and soil erosion due to purple loosestrife were estimated between $1.4 and $2 million. Total research costs to develop and implement a 3-yr biological control program for purple loosestrife nationwide ranged from $1.9 to $2.4 million. Loss of nectar and pollen forage that may result from biological control of purple loosestrife was estimated at $1.5 million annually (Ogrodowczyk and Moffitt 2001).

Tropical soda apple was reported to cause an estimated $11 million annually in production losses to Florida cattle ranchers (Mullahey et al. 1994). Sericea lespedeza reduced the 30-yr net present value of grazing land in Kansas from $726/ha for noninfested lands to $183/ha for sericea-infested lands (Fechter and Jones 2001). The state of Oregon reported a cost of $100 million/yr for 21 noxious weeds with an asset value of about $1 billion (The Research Group 2000); 9 of the 16 species in this review were also included in the Oregon study. Economic data were not available for Canada thistle on range or wildland sites, but these sites serve as a reservoir for invasion of cropland where impacts are documented. Weed control costs of $5 billion/yr were reported for noxious weeds in the United States (Babbitt 1998) and also for weed control in pastureland (Pimentel et al. 2000). The basis for calculating the $5 billion dollar figure was not reported; thus, the validity of the number cannot be quantified.

Costs of controlling downy brome–fueled fires were

*Table 2.* Quantitative research or anecdotal information on environmental impacts reported for 16 invasive plants in the United States.[a]

| | Invasive plants | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Environmental impacts[b] | Leafy spurge | Downy brome | Tamarisk | Knapweed, biennial[c] | Purple loosestrife | Yellow starthistle | Canada thistle | Tropical soda apple | Musk thistle | Sericea lespedeza | Dalmatian toadflax | Russian knapweed | Perennial pepperweed | Medusahead | Hawkweed spp. |
| Impacts to community structure | | | | | | | | | | | | | | | |
| Desirable forage or plant community productivity | × | × | × | × | × | × | × | × | × | | × | × | × | × | × |
| Plant species richness/diversity | × | × | × | × | × | × | × | | | × | | | × | × | |
| Allelopathic compounds | | | | × | | | × | | × | × | | × | | | |
| Displacement of native plant species | × | × | × | × | × | × | × | | | × | | | | × | × |
| Rare or threatened plants | × | × | × | × | × | × | × | | ×[d] | × | × | | | | |
| Avoidance by livestock and wildlife | × | | × | × | × | | × | | | | | | | × | |
| Changes in livestock production | × | | | | | | × | | | | | | | | |
| Modify wildlife populations or habitat | × | × | × | × | × | × | × | | | × | | × | × | | |
| Rare, sensitive, or threatened animals | | | × | | × | | | | | | | | × | | |
| Direct detrimental impacts (poisoning) | × | | | | | × | | | | | | × | | | |
| Soil properties (organic matter, nutrients) | | × | × | × | | × | | | | × | | | × | | |
| Soil arbuscular mycorrhizal fungi | | × | | × | | | | | | | | | | | |
| Litter accumulation/decomposition rates | | | × | | × | | | | | | | | × | × | |
| Impacts to community function | | | | | | | | | | | | | | | |
| Changes fire frequency | | × | × | | × | | | | | | | | | × | |
| Modify fuel characteristics | | × | × | × | × | × | × | | | | | | | × | |
| Nutrient cycle | | × | | | × | | | | | | | | × | × | |
| Soil moisture | | × | × | | | × | | | | | | | | | |
| Soil physical or chemical properties | | | × | | | | | | | | | | × | | |
| Increased soil erosion and sediment yield | | × | | × | | | | | | | | | | | |
| Increased sediment deposition | | | × | | × | | | | | | | | | | |
| Subsurface hydrology (water use) | | | × | | | | | | | | | | | | |
| Impacts to human health | | | | | | | | | | | | | | | |
| Allergen | | | | × | | × | | | | | | | | | × |
| Skin dermatitis | × | | | | | | | | | | | | | | × |
| Tumor-promoting compounds | × | | | | | | | | | | | | | | |
| Poisoning | | | | | | | | × | | | | | | | |
| Mechanical injury | | × | | | | × | | | | | | | | × | |

[a] Summarized from Duncan and Clark (2005).

[b] × indicates an impact or effect on that parameter.

[c] Includes both spotted and diffuse knapweed.

[d] Includes indirect impacts from *Rhinocyllus conicus.*

estimated at about \$20 million/yr (Knapp 1996), or \$10 to \$15 million/yr in southern Idaho alone, including rehabilitation costs (Knick 1999). A 1991 program to rehabilitate 688 ha burned in the Snake River Birds of Prey Area cost about \$100,000 (Devine 1993).

**Value and Use.** Reported value and use of some invasive plants included use by livestock or wildlife, wildlife habitat, use as honey source plants, medicinal or ornamental value, and erosion control. There were reports of livestock use for all invasive plants, except *Tamarix*, included in the review. However, use of many plants was limited due to development of prickles, low palatability, or minimal nutritional value. Five species were reported to have historical or potential medicinal value (Duncan and Clark 2005).

## DISCUSSION

There are limited data for the eastern half of the United States regarding area infested by the 16 selected invasive nonnative plants. Tropical soda apple was the only species occurring in the eastern United States for which comprehensive information on area infested was available (Duncan 2005d; Duncan and Jachetta 2005).

Research quantifying environmental impacts was limited for 9 of the 16 species. Of those nine species, sericea lespedeza, Canada thistle, Russian knapweed, tropical soda apple, and musk thistle infest large areas, and literature suggests that they have significant impacts on the environment (Duncan and Clark 2005). The environmental impact of these species should be quantified. Impacts of perennial pepperweed on community function are published (Renz 2005), but additional information regarding desirable forage production, wildlife habitat, and species diversity should be quantified for this species. Environmental impacts caused by medusahead (Rice 2005b) would be similar to downy brome, with additional effects from high litter accumulation and physical injury resulting from spines (Rice 2005b). Information is limited for Dalmatian toadflax (Brown 2005a) and hawkweeds in the United States (Duncan 2005c).

Regional comprehensive economic data are lacking for all species except leafy spurge and *Tamarix*. Economic assessments of leafy spurge and knapweeds should be updated and the region encompassed by the assessment expanded. Adequate environmental and production data are available to conduct regional economic assessments for downy brome and yellow starthistle. Tropical soda apple should be a high priority for a comprehensive economic analysis because of potential for rapid spread and significant impacts from trade restrictions and embargos on cattle, grass seed, and sod.

Assessing the overall impact of invasive nonnative plants is a challenging but critical goal. Comprehensive economic data are lacking for most species, and additional research is needed to quantify environmental effects caused by invasive plants on range and wildlands. Decision makers require accurate economic and ecological data to formulate consistent and rational management decisions for invasive plants.

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