Chapter 1
Invasive Plants: Their Role in Species Extinctions and Economic Losses to Agriculture in the USA

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Abstract The more than 50,000 species of plants, animals, and microbes introduced into the United States cause more extinction of native species than most any other threats and cause more than $120 billion in damages and control costs each year. An assessment of the invasive plants that have been introduced and their control and damage costs will be estimated.

Keywords Economic losses European purple loosestrife *Lythrum salicaria* Bog turtle Yellow star thistle *Centaurea solstitialis* European cheatgrass *Bromus tectorum* Exotic aquatic weeds *Hydrilla verticillata Pistia stratiotes* Eurasian watermilfoil *Myriophyllum spicatum* Yellow rocket *Barberia vulgaris* Canada thistle *Cirsium arvense* US Crop losses

1.1 Introduction

There are approximately 50,000 nonnative species in the United States, including plants, animals, and microbes (Pimentel et al. 2000). Some of these species are beneficial and include our introduced food crops and livestock species, and these species make up about 99% of agriculture. The value of US agriculture is more than $800 billion per year (USCB 2007).

However, there are many species of plants, animals, and microbes that have caused major economic and environmental damages to agriculture and other aspects of the US ecosystem. We have reported about $120 billion per year in environmental and public health damages in the USA (Pimentel et al. 2007). Estimating the full damage and control costs of invasive species is extremely difficult because

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the actual species that have been introduced and their impact on agriculture and other aspects of the US managed and unmanaged natural systems are not fully understood. In this article, an assessment of the invasive plants that have been introduced, and their control and damage costs will be estimated.

1.2 Native and Introduced Plants

Most alien plants introduced and established in the US were introduced for food, fiber, and ornamental purposes. An estimated 5,000 species of plants have been introduced and are present in the natural or wild ecosystem (Morse et al. 1995; Audubon 2007). In addition, there are an estimated 17,000 species of native plants in US (Morin 1995). Florida has the largest number of alien plants that have been introduced. Most of these 25,000 introduced species of plants were introduced for ornamental and agricultural purposes (Florida Native Plant Society 2005). An estimated 900 species have escaped and have become established in the natural ecosystems (Refuge Net 2007). Also in California, about 3,000 species of plants have been introduced and have become established in unmanaged natural ecosystems (Dowell and Krass 1992; Pimentel et al. 2007).

Some of the nonindigenous plant species that have become established in the US have displaced several native species of plants (Pimentel et al. 2007). Some of these plant species are serious weed species and have invaded an estimated 700,000 ha of US wildlife habitat each year (Babbitt 1998). For example, the European purple loosestrife (*Lythrum salicaria*) that was introduced in the early nineteenth century as an ornamental plant has been spreading at a rate of 100,000 ha per year. Purple loosestrife is changing the wetland ecosytems that it has invaded (Costly Invaders 2006). The invading plant has reduced the biomass of 44 native plant species in various habitats and reduced the numbers of some animals, including the bog turtle (Glyptemys muhlenbergii) and several duck species (Costly Invaders 2006).

The invading purple loosestrife now exists in 48 states, and the annual control costs are estimated to be $45 million per year (Aquatic Invasives 2007). In addition, several species of biological control insects have been introduced and are providing partial control of purple loosestrife in the Northeast and Mid-west (University of Illinois 2007).

Several other species of introduced plants are having an impact on natural federal lands (Christen 2007). In the Great Smoky Mountains National Park, for example, 400 of the estimated 1,500 vascular plant species are exotic, about 26% of the flora, and ten of these are currently displacing and threatening several native plant species (Pimentel et al. 2007). The problem of introduced plants is especially significant in Hawaii, where 946 of the 2,690 plant species are nonindigenous, about 35% of the flora (Eldredge and Miller 1997). Moreover, Hawaii is particularly vulnerable because it is an island.

In some cases, one invasive plant species competitively overruns an entire ecosystem. For instance, in California, yellow star thistle (*Centaurea solstitialis*) now dominates more than 4 million hectares of northern California grassland, resulting in the total loss of this once productive grassland, valued at an estimated $200 million (Campbell 1994). Similarly, European cheatgrass (*Bromus tectorum*) is dramatically changing the vegetative flora of many natural ecosystems. This invasive annual grass has spread throughout the shrub-steppe habitat of the Great Basin in Idaho and Utah, predisposing the invaded habitat to fires (Kurdila 1995). Before the invasion of cheatgrass, fire burned once every 60–110 years, and the shrubs had a chance to become well established. Now, the occurrence of fires about every 5 years has led to a decline in shrubs and other vegetation and to the occurrence of competitive monocultures of cheatgrass on several million hectares in Idaho and Utah (University of Nevada 2007). The animals and microbes dependent on the shrubs and other indigenous vegetation have been reduced and/or exterminated.

An estimated 138 nonnative species of tree and shrub species have been introduced into native US forest and shrub ecosystems (Campbell 1998). Some of the introduced trees include salt cedar (*Tamarix ramosissima* Ledeb), eucalyptus (*Eucalyptus globulus* Labill), Brazilian pepper-tree (*Schinus terebinthifolius*), and Australian melaleuca tree (*Melaleuca alternifolia*) (Randall 1996). Some of these trees have displaced native trees, shrubs, and other vegetation types, and populations of some associated native animals and microbes. For example, the melaleuca tree is spreading at a rate of 11,000 ha per year throughout the forest and grassland ecosystems of the Florida Everglades (Campbell 1994), where it damages the native vegetation and wildlife.

Exotic aquatic weeds are also a significant problem in the United States. For example, in the Hudson River basin of New York, there are 53 exotic aquatic weed species (Mills et al. 1997). In Florida, exotic aquatic plants include hydrilla (*Hydrilla verticillata*), water hyacinth (*Eichhornia crassipes*), and water lettuce (*Pistia stratiotes*), and these invasives are altering the aquatic ecosystem for fish and animal species. These invasives are choking waterways, changing nutrient cycles, and reducing the recreational use of rivers and lakes. Active control measures are needed in the aquatic ecosystems. For example, Florida spends an estimated $14.5 million each year on just hydrilla control, mostly herbicides (Center et al. 1997). Despite this control expenditure, hydrilla infestations in just two Florida lakes cost the state an estimated $10 million per year in recreational losses, such as swimming and boating (Center et al. 1997).

In the United States as a whole, an estimated total of more than $800 million is spent on the damages and control costs of aquatic weed species (Pimentel 2005). This includes an estimated $400 million for Eurasian watermilfoil (*Myriophyllum spicatum*), a total of $229 million for purple loosestrife (*Lythrum salicaria*), and $200 million for water chestnut (*Trapa natans*) (Pimentel 2005).

In the Great Lakes Basin, there are an estimated 85 exotic plant and algae species (Pimentel 2005). Including exotic plant species and all introduced animal species, the total damage and control costs annually in the Great Lakes Basin is $5.7 billion per year (Pimentel 2005).

1.2.1 Agricultural and Forest Invasive Plants

Many weeds and plant pathogens (primarily fungi) are biological invaders and cause several billion dollars worth of losses to US crops, pastures, and forests each year. In addition, several billion dollars are spent controlling these plant pests.

1.2.1.1 Weeds

In crop ecosystems, including forage crops, an estimated 500 introduced plant species have become serious pests. These include Johnson grass (*Sorghum halepense*) and kudzu (*Pueraria lobata*), which were actually introduced as crops and became pests (Pimentel et al. 1989). Most other weeds were accidentally introduced with crop seeds, soil used as ballast, or various imported plant materials. Two of the most costly accidental introductions were yellow rocket (*Barberia vulgaris*) and Canada thistle (*Cirsium arvense*).

In US agriculture, weeds cause an overall reduction of 12% in crop yields, and this represents approximately $32 billion in lost crop production each year (USCB 2007). On the basis of the research that found that approximately 73% of weed species in the US are nonindigenous, this suggests that about $23 billion (of the $32 billion above) per year are losses from invasive weeds (Pimentel 1993). However, nonindigenous weeds are often more serious pests than native weeds. Thus, the $23 billion per year loss is a conservative estimate. In addition to the direct losses, approximately $4 billion is spent each year on herbicides used to control pest weeds. Thus, the total annual cost of introduced weeds to US agricultural economy is about $26 billion.

Please note that in making the calculation, I simply calculated the proportion of potential losses caused by nonindigenous weeds on the basis of the percentage of weed species that were nonindigenous. Clearly, if there were no nonindigenous weeds in crops, native weeds would replace them. One way to assess the impacts of nonindigenous weed introductions would be to assess their impacts relative to native weeds.

The literature confirms that nonindigenous weeds have a greater impact on crops than native weeds, but there is no estimate as to how much more severe are the nonindigenous weeds. Even though our approach does not take into account the fact that native weeds would partially substitute for exotic weeds, any potential overestimation of the impacts of exotic weeds would be cancelled out by the fact that the cost figure did not include other potential losses caused by nonindigenous weeds. For instance, I did not include the approximately $11 billion in environmental and public health impacts caused by the large quantities of herbicides and other pesticides used to control exotic weeds and other pests each year in the United States (Pimentel 2005).

Also not yet taken into account has been the effect of exotic weeds on food prices. For every 1% decrease in crop yield, on average there is a 4.5% increase in

price value of the crop at the farm gate (Pimentel 1997). Consequently, because nonindigenous weeds cause more extensive crop losses than native weeds, they cause a greater increase in the cost of food.

Weeds, both native and exotic, are also a problem in pastures, where 45% of the weed species are nonindigenous (Pimentel 1993). US pastures provide approximately $10 billion in forage crops annually (USDA 2006), and the losses due to inedible weeds are estimated to be $2 billion per year. Forage loss due to nonindigenous weeds, therefore, amounts to about $1 billion per year.

Some introduced weeds, such as leafy spurge (*Euphorbia esula*), are toxic to cattle and other ungulates (Trammel and Butler 1995). In addition, several nonindigenous thistles have reduced native forage plant species in pastures, rangeland, and forests, thus reducing cattle grazing (Cotton Thistle 2007). According to Babbitt (1998), ranchers spend about $5 billion each year to control invasive nonindigenous weeds in pastures and rangeland; nevertheless, these weeds continue to spread.

Control of weeds in lawns, gardens, and golf courses makes up a significant proportion of the total management costs for lawns, gardens, and golf courses of about $36 billion per year (USCB 2007). In fact, Templeton et al. (1998) estimated that each year, about $1.3 billion of the $36 billion is spent on residential weed, insect, and disease pest control. Because a large proportion of the residential weeds, such as dandelions (*Taxaxcum officinale*), are exotics, the estimate is that $500 million is spent to control exotic weeds in residential areas and an additional $1 billion is spent to control nonindigenous weeds on golf courses. Weed trees also have an economic impact. For instance, $3 to $6 million per year is spent in efforts to control the melaleuca tree (*Melaleuca alternifolia*) in Florida (Pimentel et al. 2000). Valuable cropland may be devalued in the USA because too contaminated by Silverleaf Nightshade (*Solanum elaeagnifolium)* (Mekki 2007).

1.2.1.2 Plant Pathogens

There are an estimated 50,000 parasitic and nonparasitic diseases of plants in the United States, most of these are fungi (USDA 1960). In addition, more than 1,300 species of viruses are plant pests in the US (USDA 1960). Many of these plant microbes are nonnative and were introduced inadvertently with the seeds and other parts of host plants that were introduced. Including the introduced plant pathogens and other soil microbes, it is estimated that conservatively more than 20,000 species of microbes have invaded the United States.

US crop losses to all plant pathogens total about $33 billion per year (Pimentel 1997; USCB 2007); $21 billion each year of these losses are attributable to nonindigenous plant pathogens. In addition, growers spend $720 million each year on fungicides; about $500 million of that is used to combat nonindigenous plant pathogens specifically. The total damage and control costs of nonindigenous plant pathogens therefore amount to about $22 billion per year. In addition, on the basis of the fact that 65% of the plant pathogens are exotic, the estimated control costs of plant pathogens in lawns, gardens, and golf courses are at least $2 billion per year.

In addition, plant pathogens of forests cause a loss of about 9%, or about $7 billion of forest products each year (Hall and Moody 1994; USCB 2007). The proportion of introduced plant pathogens in forests is similar to that of introduced insects or about 30%. Thus, about $2.1 billion in forest products are lost each year to exotic plant pathogens in the United States. Again, damages from exotic pests appear to be more severe than those from native pests.

1.3 Conclusions

With more than 50,000 introduced species of plants, animals, and microbes in the United States, only a portion of these cause significant damage to agriculture, forestry, and natural ecosystems, and require costly control measures. Plants and plant pathogens are one group of invasive species that cause significant ecological damage. More research is needed for the prevention of these invasions and to improve management of pest species using environmentally safe methods.

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