I. INTRODUCTION

A. Study Purpose

The objective of this study was to perform a preliminary economic evaluation of the economic impact of noxious weeds in Oregon. These weeds, all non-native invaders of agricultural and natural ecosystems and of forest and range lands of the West generally, and Oregon specifically, began to appear with European settlement of the area. Invasions of individual species, some with the potential to become serious weeds, continue. In Oregon, one such species, tansy ragwort, is known to have caused annual losses on the order of $6 million. Economic studies in other states have ascribed losses to individual species of related species groups: $129 million to leafy spurge in Montana, North and South Dakota and Wyoming (Leitch et al. 1994); and $42 million to knapweeds in Montana (Hirsch and Leitch 1996), for example. As part of the process of development of a strategic plan for the management of invading noxious weeds, we were tasked with the following assignments:

1. Ascertaining the magnitude of foregone production in Oregon's economy resulting from direct production losses, crowding of desirable species, and loss of habitat for wildlife.

2. Developing general guidelines that may be used to measure the benefits to society of controlling the spread of existing noxious weeds or the potential benefits that may accrue of controlling new invasive plants. Such benefits may then be compared to program costs that may be implemented.

Estimating the economic impacts that are associated with non-indigenous species is difficult; nevertheless, enough data were available to quantify some of the impacts on agriculture, forestry, and wetlands in Oregon. In this paper, we present our assessment of the magnitude of the economic impacts associated with 16 noxious plant species and species groups (of 99 species listed as noxious) identified by Oregon Department of Agriculture (ODA) as having a substantial impact on Oregon's economy. Many of Oregon's listed noxious weeds have not yet fully invaded, and their potential to cause losses is much greater than the losses that might be currently ascribed to them. We examined the potential of six of the 99 species in an effort to quantify their potential for harm to the economy and environment.

In this paper the terms "weeds," "noxious weeds," "non-indigenous species," and "exotic species" are used interchangeably. "Legally, a noxious weed is any plant designated by a federal, state, or county government to be injurious to public health, agriculture, recreation, wildlife, or any public or private property… We also use the term 'noxious' to refer to those weeds that have invasive characteristics, regardless of whether they have been legally designated 'noxious' at some government level (Sheley and Petroff 1999)."

Section I of this report examines weed problems in general. Sections II and III discuss the methodologies used to evaluate the economic impacts resulting from noxious weeds. Section IV describes the results of these evaluations in terms of total lost production (economic impacts) and lost economic benefits (net economic value). The final section discusses the results in terms of uncertainties in the data and public policy.

B. Problem Statement

1. Public Involvement

Noxious weeds are a problem for private landowners and resource managers because they reduce the usefulness of productivity or the land. Loss of productivity may be measured in terms of increased costs as well as decreased outputs and revenues. Some plants may also be detrimental to other than private productivity functions (e.g., wildlife habitat, watershed protection, protection of rare native plants, etc.). The costs for control, damages (animal mortality, etc.), productivity decreases, and loss of environmental quality can be estimated in terms of regional economic impacts (REI) and net economic value (NEV) to the state and nation.

An underlying goal of this project is to quantify the threat of particular noxious species to native populations, species, communities and ecosystems. There is a need to build up a catalogue of data in a standardized manner, in order to coordinate and improve both control and research efforts for existing invaders. Such information can provide a general framework for predicting the impacts of future introductions.

There are two basic cases why a public agency may be involved in control and preventative programs for noxious weeds. The first is externalities. In a market economy, it is assumed that all of the consequences of a decision are borne by the agent making the decision - there are no "spill-over" effects. An externality exists wherever this is not the case. Externalities can be either negative or positive and can be associated with the production or consumption of a good. An example of a negative production externality is when a nursery introduces a flowering plant that escapes and expands uncontrolled and affects fish stocks and the quality of water. Unless anglers are also managers of the company, an efficient level of invasion will not result. That is because the party that benefits from polluting the river with the introduced plant is not the party than bears the cost of the pollution.

Traditional market economies do not adequately deal with public goods. These are goods for which one person's consumption does not diminish another person's consumption of the same good. Examples include vistas and biodiversity. The private market will underproduce these goods due to the free rider problem. This is when a consumer has an incentive to understate his true willingness to pay, since he can enjoy the benefits from someone else's contribution. A public good is a product or service that many actors in the private sector may not have the incentive to produce in amounts desired. A pure public good cannot be withheld from some consumers who refuse to pay (non-exclusion), and consumption of that good by one person does not reduce its usefulness to someone else (shared consumption). Due to non-exclusion and shared consumption, private firms have no means of profiting from production of public goods, even though society may value these goods highly.

Eradication or control of unwanted and noxious weeds with biological agents is an example of a public good. The background research, establishment, monitoring, and maintenance costs can be prohibitive for any single individual or even single industry. Once the control agent has been established, people cannot be excluded from benefiting from the program. The benefits of such a program can be shared by a variety of agricultural producers and the public at large.

The ODA approaches noxious weed control with an integrated, multidisciplinary approach (Integrated Weed Management). Integrated Weed Management (IWM) is a decision making process based on the best available science and experience of weed managers. Control options are based on site specific information and the best strategy or combinations of strategies for effective management are chosen. Integrated Weed Management uses all available methods and techniques for noxious weed control including prevention, mechanical, cultural, chemical and biological control.

Prevention: Prevention and early intervention are the most effective techniques that can be deployed against weeds. Prevention is the process of stopping or reducing the distribution of reproductive plant parts to uninfested areas. Prevention activities include: minimizing soil disturbance, reseeding disturbed sites, use of weed free planting stock, cleaning of equipment to minimize transport of weed propagules from infested areas and the use of good management practices to keep desired vegetation and provide competition to prevent noxious weed invasion.

Biological Control: Biological control is the purposeful introduction of selected natural enemies to reduce the population density of targeted pest species below economic and ecological injury levels. This is the reassociation of an exotic pest with its natural enemies.

Biological control of noxious weeds is and continues to be the major emphasis of IWM programs in Oregon. The ODA and cooperators collect and redistribute 67 biological control agents for 30 targeted noxious weeds. Acquiring and introducing new biocontrol agents, monitoring of weed populations, and the introduction of biological agents into appropriate areas is a primary objective throughout the state.

Mechanical: Mechanical control is the use of physical methods to control weeds. These methods are important for use in an integrated control program. Manual and mechanical control can be used in sensitive areas where chemicals are not appropriate or on small infestations where biocontrol and chemical application are not practical.

Cultural Control: Many weeds contribute to the degradation of natural resources. Weeds may also be a symptom of degradation caused by other factors. Either way, it is important that the cause of the weed problem be identified and treated. The use of land management activities that favor desirable vegetation and reduce or hinder the spread and establishment of invasive undesired species are cultural control methods. The use of competitive planting, grazing practices, fertility management, sanitation and cleaning of equipment, the use of clean seed, weed free forage, clean construction materials, etc., all help to prevent the spread and introduction of weeds.

Chemical: Chemical control is an effective method of control, and will continue to be an important and useful tool as part of an IWM program. Chemicals have proven successful at eradicating new introductions of noxious weed species and containing larger or wider spread infestations.[1]

1. Draft - Noxious Weed Strategic Plan. Oregon Department of Agriculture. July 2000.

The ODA policy on IWM can be summarized as a preventative program and education and treatment program. The preventative program includes tracking information from surrounding states on new threats. This program also includes surveying potential sites for new invader species within Oregon. Early detection and preventive programs are not highly visible. However the payoffs may be substantial in that costs of early detection and prevention may be very low in relationship to future benefits.

Treatment programs involve participation by private individuals and other agencies. Treatment may be costly for individuals because of the externality problem. Statewide coordination that includes awareness of costs as well as potential benefits to individuals as well as the public are important in designing treatment programs. Biological control programs of specific noxious weeds are an example where the initial research cost of programs may be very high and subsequent streams of annual benefits of a successful program may also be very high. Biological control programs are an example of a positive externality and a public good.

2. Public Costs of Noxious Weeds

Most plant introductions have been intentional. In the past 40 years, the rate of introductions and risks associated with invasive species have increased enormously because of human population growth, rapid movement of people, and alteration of the environment. Most alien plants now established in the United States were introduced for food, fiber, or ornamental purposes.

For example, Scotch broom was introduced into Oregon as an ornamental plant and a stabilizer of beaches. The Siuslaw Oar (Aug. 25,1950) reported an event that explains the intentions for the introduction. "This year's supply of Scotch broom seed has been collected locally by the nursery division of the U.S. Conservation Service working out of the Siuslaw Soil Conservation district office. Sixty-five pounds of seed were harvested for eventual planting in the dunes. Wilbur Ternyik, local nurseryman, explains that the 65 pounds collected is without pods, as with pods it would amount to at least six times this weight. He also laments that he did all collecting; he was unable to hire anyone to do this work for a dollar an hour.

"The planting cycle is planned so that the beach grass shades the young Scotch broom plants, which provide nitrogen and shade for the shore pines. After the shore pines become established, they will choke out the Scotch broom and grass plantings, according to Tom Flippin, farm planner."

Unintended spread of introduced species such as illustrated in the Scotch broom example has turned them into an undesirable plant in a very short time.

Loss of productivity due to invasive plants has always been a concern. The costs of direct control, such as herbicides, are often substantial, especially in extensive rangeland environments. Concerns about the cost effectiveness of chemical treatment and growing public concern about environmental safety have led to more research and use of control of weed species using insects or microorganisms that adversely affect the plant. More emphasis has been placed on biological controls.

In Oregon, one example of success of biological control is the use of biological controls against St. Johnswort, also called Klamath weed or goatweed (Richter 1966). This is an undesirable poisonous weed of foreign origin, which at one time was abundant in many parts of Oregon, before its control by biological means. The plant is unattractive to livestock and crowds out desirable grasses. Cattle feeding on the plant develop a hypersensitivity of the white skin areas to sunlight. Animals feeding on small amounts of the plant have sore mouths and generally fail to gain weight. Spectacular control of St. Johnswort in western Oregon has been achieved since the introduction in 1948 to 1950 of a French, Chrysomelid leaf beetle. It is believed that the success of this program was due to its synchronization with both climate and the growth of its host plant. The adult beetles strip the plants in the spring and early summer when they are beginning to flower, and the larvae feed in the fall and winter, destroying the prostrate growth before the plants can recover from the summer damage.

A more recent success story has been the biological control program for tansy ragwort. An economic evaluation of the State program to control tansy ragwort is reported by Coombs et al. (1996). "Successful biological control of tansy ragwort in Oregon provides an estimated annual benefit of more than US $5 million, with a minimum benefit to cost ratio of 13:1. Losses of livestock have been reduced by $3.7 million/year. Additional savings have accrued through increased productivity of pastures ($1.27 million/year) and by reducing herbicide use ($0.85 million/year). Control of ragwort was achieved with a cost of about $5.00/ha. Non-market benefits include return of desirable flora in habitats once dominated by ragwort and a reduction in herbicide use in the environment. Several correlative observations substantiate evidence used in estimating benefits of regional control of ragwort. In western Oregon, control of ragwort reduced propagule production, which correlated with a decline in the number of new infestations in eastern Oregon, despite increased detection efforts. The number of releases of the cinnabar moth, *Tyria jacobaeae*, the ragwort flea beetle, *Longitarsus jacobaeae*, and the number of cattle deaths attributed to pyrrolizidine poisoning both decreased by more than 90 percent in relation to declining ragwort densities."

Evaluation of biological control has attracted increased attention in research. This is especially evident in such places as New Zealand, which is very susceptible to introduction of foreign and undesirable weeds. Such economic evaluations have recently been completed for Hieracium (crowd out desirable plants) (Grundy 1989a), Clematis vitalba or old man's beard (a serious threat to native forests) (Greer and Sheppard 1990), and sweet brier (a noxious weed) (Grundy 1989b). In the case of sweet brier control, the evaluation concluded that an internal rate of return of 17.8 percent could be achieved by a biological control program. For another weed in New Zealand, gorse, a benefit-cost analysis showed that a high degree of control would result in a ratio of benefits to costs of at least 12:1.7 (Hill 1986). This is especially significant to Oregon agriculture in that gorse has become a troubling invader in many agricultural areas. Weeds reduce forage for livestock, costing the industry millions of dollars and, in some cases, render public lands and family ranches useless for grazing. Oftentimes, weed infestations will significantly lower land values in surrounding areas.

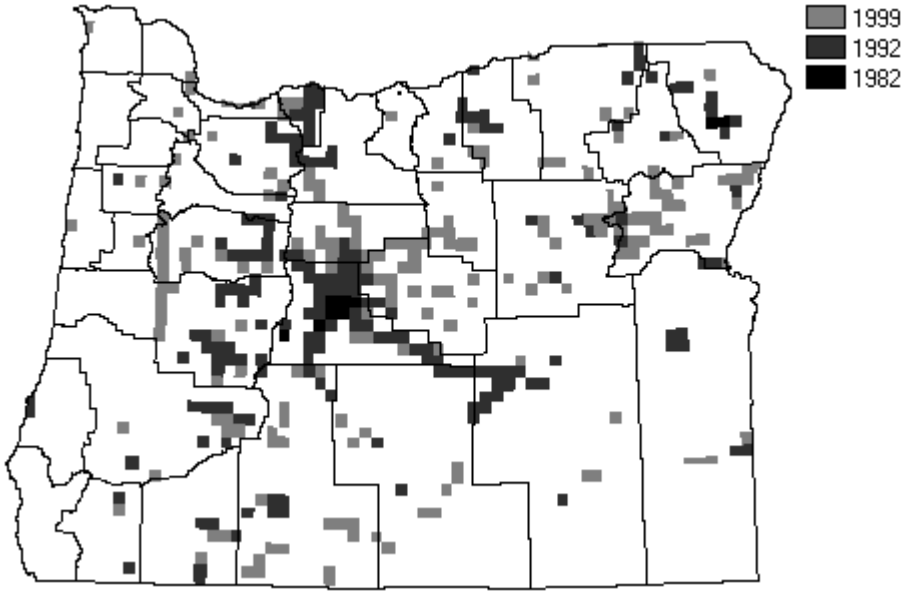
Other studies have provided economic evaluations of certain noxious weed species in Oregon and Idaho. A preliminary analysis of the economic impact in personal income of the 12 worst noxious weeds in Oregon estimated the foregone income to Oregon of these weeds to be $67

million annually (Radtke 1999). Based on information from private lands, and federal, state, and county organizations, an estimated total direct cost for all Idaho lands is $300 million annually (Idaho State Department of Agriculture 1999). The true costs to Idaho citizens from the impact of aquatic and terrestrial noxious weeds are unknown. Even though an estimate of a dollar value for the loss of forage production, plant diversity, wildlife habitat, watershed health, recreation and tourism, human life and property has not been completed for Idaho, the perception is that such costs are substantial.

An economic study of leafy spurge's competition with desirable plants in Montana, Wyoming, and both Dakotas found reduced carrying capacity and therefore reduced ranchers' annual net income and income to the regional economy estimated to be nearly $129 million (Federal Interagency Weed Committee 1999). The same study reported that, if spotted knapweed is allowed to continue to spread to the fullest extent of its range, it will cost Montana's agriculture industry $155 million each year (Idaho State Department of Agriculture 1999). This includes the total economic impact, in terms of lost income to farmers, suppliers, and the general economy. In Oregon, one type of knapweed (spotted) has spread from three areas in 1982 to throughout the state by 1999 (Figure 1). Without an integrated weed management system it has the potential to have a similar negative effect on Oregon's economy.

The estimated annual loss of productivity caused by noxious weeds in the U.S. is $20 billion in the agricultural sector alone (Federal Interagency Weed Committee 1999). In the agricultural sector, losses and control costs associated with weeds in 46 major crops, pasture, hay and range, and animal health were estimated to be more than $15 billion per year. In non-crop sectors including golf, turf and ornamentals, highway rights-of-way, industrial sites, aquatic sites, forestry, and other sites, losses and control costs totaled about $5 billion per year.

Figure 1
Spotted Knapweed Spread in Oregon Between 1982 and 1999



Source: ODA 2000(b).

3. Research Procedures

The following tasks were completed in order to meet the project's objective.

Species Identified: The Weed Board of the ODA has identified and designated 99 weeds as noxious. The staff of the ODA Noxious Weed Program selected 21 of the most extensive 99 weeds in Oregon for inclusion in this study. The extent of the problem, in terms of gross and net acres affected, was estimated by ODA staff for each of these species (Table 1). Appendix A contains a description of the listed species and maps of areas affected by the species identified by ODA staff. Appendix B provides a list of applicable past studies of the selected noxious weeds.

Economic Models: Economic models for the analysis of REI and NEV were developed. Only market values or estimates of market values were identified in most cases. Values associated with reduction of a noxious weed where the weed threatens some endangered species were included only when information was available on the value of such species or on the crowding effects of the weed.

Most of the economic indicators used are in terms of production revenues and costs. Figure 2 shows the methodological approach for completing the economic analysis in terms of economic impacts and NEVs. Both estimates are based on production losses that may occur due to plant infestation. The expenditures related to production (agriculture, forestry, recreation) generate income which is the measure of economic impacts. Where market values exist, these were used to estimate NEVs. In other cases other studies provide guidance in the amount of net value that people place on activities such as wildlife based recreation.

As applied in this study, a measure of NEV estimates the value of the goods or services that one is willing to pay for use of those goods or services. For land values that may be lost, a land lease charge per acre or per animal unit month (AUM) is used. The basis of these per unit values are the Oregon State University (OSU), Extension Service - Enterprise Budgets. For goods that are not easily traded in the market, studies that have estimated the value of such goods through processes such as consumer surplus estimates are used. These results should be viewed as preliminary estimates.

Table 1
Status of 16 Groups of Oregon Noxious Weeds and Their Impact on Range, Forests, and Wetlands

Affected Lands/Noxious Weed Names /1	Oregon Dept. of Agriculture (ODA) Listing /2	Potential Threat /3	CAST present status and ODA /4	Estimated Affected Acres in U.S. /7	Species is Native From /5	ODA Policy /6	ODA Method of Control /6	Resource and Industry Affected /6	Negative Impacts /8	Potential Future Impacts /8	Beneficial Use /8	Geographic Distribution in Oregon /6	Economic Loss Measurement /9
A. Rangeland													
(2) Yellow Starthistle (Centaurea solstitialis)	B		Western States	8 million	Mediterranean Region of Europe	Biocontrol and Containment	Biocontrol, Chemical, Manual	Agriculture/ Range; Wildlife; and Recreation	Livestock injury (chewing disease) especially horses; Range and habitat degradation; and Displacement of desirable species.	Potential to spread in S.E. Oregon. Currently at 40% of biological potential. This could affect 2.5 million additional acres in Oregon.	Some forage for cattle and sheep in pre-spring stage. Nectar for honey bees.	Widespread in southern Oregon (Douglas, Josephine, and Jackson) and Northeast Oregon (Morrow and Umatilla). Some sites in Eastern Oregon and the Willamette Valley.	Cattle losses. 10% of Tansy ragwort, 7.3 acres per AUM cattle and wildlife.
(3) Distaff Thistle (Carthamus lanatus)	A	X	California	No estimate	Mediterranean area.	Eradication and Containment	Chemical, Manual	Agriculture/ Range; Wildlife; and Recreation	Limits access, degrades pasture; displaces desirable species; Animal injury from spines deters grazing and access by livestock and wildlife.	Existing economic problem is minimal. Potential problem may be similar to Yellow Starthistle. Currently less than 1% of potential spread in Oregon. An additional 2.5 million acres in Oregon could be affected.		Southern Oregon (Douglas and Josephine)	Cattle losses 10% of Tansy ragwort, 4 acres per AUM.
(5) Knapweeds			U.S.	8 million	Mediterranean Region of Europe and Africa, Central Europe and Asia	Biocontrol and Control/Containment. Squarrose: Eradication and Containment	Biocontrol, Chemical, Manual	Agriculture/ Range; Wildlife; and Recreation	Highly competitive for range and wildlife forage. Is a road and right of way invader.	Squarrose at less than 1% of potential in Oregon. All have potential for additional expansion in Oregon.	Forage for deer and bighorn sheep. Nectar and pollen for bees. Some grazing for cattle and sheep.	Squarrose is limited to one site in Grant. Spotted, diffuse, and Russian limited distribution in Western Oregon and are widely distributed in Central and Eastern Oregon.	Rangelands at 7.3 acres per AUM. Wildlife
Diffuse Knapweed (Centaurea diffusa)	B												
Spotted Knapweed (Centaurea maculosa)	B												
Russian Knapweed (Centaurea repens)	B												
Squarrose Knapweed (Centaurea virgata)	A												
(7) Leafy Spurge (Euphorbia esula)	B	X	Western U.S.	3 million	Europe and Asia	Biocontrol and Containment.	Biocontrol, Chemical, Manual, Cultural (Sheep and Goats)	Agriculture/ Range and Wildlife	Riparian degradation, range degradation and livestock health problems. Displaces desirable species. Cattle will not graze in 10% infected areas.	Has expanded to almost 2 million acres in Montana, North and South Dakota. From 1950 to 2000 it increased 20 fold. An additional 3.6 million acres could be affected.	Leafy spurge has been shown to provide some forage for sheep and goats.	Small scattered sites in Central and Eastern Oregon. Few sites in Jackson County.	Cattle losses 10% of Tansy ragwort grazing at 2 acres per AUM. Wildlife
(10) White Top and Perennial Pepperweed (Cardaria draba and Lepidium latifolium)	B		Expanding in the West	No estimate	Asia	Containment/ Control	Chemical and Manual	Agriculture/ Range and Wildlife	Highly competitive, displaces desirable species, pasture, competes for moisture, may be toxic to livestock.	Potential for additional impacts to pasture and wildlife. Potential invader in croplands.	Provide nectar for honeybees	Small infestations found throughout Central and Eastern Oregon	Cattle losses at 10% of Tansy ragwort, 2 acres per AUM grazing and wildlife.
(11) Scotch Thistle (Onopordum acanthium)	B		Western U.S.	No estimate	Europe and Asia	Containment/ Control	Chemical and Manual	Agriculture/ Range and Wildlife	Competes with and decreases desirable forage. Sharp spines deter livestock and wildlife from grazing	Potential for wider distribution in the state.		Eastern and Central Oregon.	Range grazing at 7.3 acres per AUM
(12) Mediterranean Sage (Salvia aethiopis)	B		Expanding in Western States	1.3 million	Northern and Eastern Mediterranean Area	Limited Biocontrol/ Control	Biocontrol, Chemical, Manual	Agriculture/ Range and Wildlife	Reduces forage production on rangeland and pasture. Unpalatable to grazing animals.	Potential for additional spread in Eastern Oregon.		Eastern Oregon	Range grazing at 7.3 acres per AUM
(13) Purple Starthistle (Centaurea calcitrapa)	A	X	Expanding in the West, especially in California	No estimate	Mediterranean area	Eradication	Chemical and Manual	Agriculture/ Range and Wildlife	Limits access, degrades pasture, displaces desirable species. Animal injury from spines. Deters grazing by livestock and wildlife.	Existing economic problem is minimum. Potential problem is similar to Yellow starthistle. An additional 2 million acres in Oregon could be affected.		One site in Clackamas County declining under eradication program. One site eradicated in Sherman County in 1991.	Range and irrigated pasture at 2 acres per AUM
(14) Hawkweeds	A	X	Expanding in the Pacific N.W.	No estimate	Europe	Eradication	Chemical and Manual	Agriculture/ Range and Wildlife	Highly competitive in natural meadows, pasture, hay, range, forest openings. Expands rapidly.	Hawkweeds have quickly spread throughout the U.S. since their arrival 30 years ago. An additional 1.5 million acres in Oregon could be affected.	Livestock, deer, and elk consume hawkweed foliage and bulbs at certain times of the year.	Two sites, Clackamas and Wallawa Counties.	Rangeland and irrigated pasture. Grazing and wildlife at 2 acres per AUM.
Orange Hawkweed (Hieracium aurantiacum)													
Yellow Hawkweed (Hieracium floribundum)													

Table 1 (Continued)

Affected Lands/Noxious Weed Names /1	Oregon Dept. of Agriculture (ODA) Listing /2	Potential Threat /3	CAST present status and ODA /4	Estimated Affected Acres in U.S. /7	Species is Native From /5	ODA Policy /6	ODA Method of Control /6	Resource and Industry Affected /6	Negative Impacts /8	Potential Future Impacts /8	Beneficial Use /8	Geographic Distribution in Oregon /6	Economic Loss Measurement /9
B. Rangeland and Farmland													
(1) Tansy Ragwort (Senecio jacobaea)	B	X (Eastern Oregon)	Pacific N.W.	3 million	Europe and Asia	Biocontrol in Western Oregon and Eradication in Eastern Oregon	Biocontrol, Chemical, Manual	Agriculture/ Range and Wildlife	Livestock injury (liver damage); Rangeland and habitat degradation; and Displacement of desirable species	Potential to spread in Eastern Oregon.		Widespread in Western Oregon. Limited in Eastern Oregon.	2% of Western Oregon 1999 cow herd, plus horses to liver damage. 2 acres per AUM. Agriculture production
(8) Rush Skeletonweed (Chondrilla juncea)	B		Expanding in the West	6.2 million	Asia and Mediterranean Region	Biocontrol	Biocontrol, Chemical, Manual	Agriculture/ Range and Wildlife	Reduces wheat production. Range degradation. Reduces foliage available for livestock and wildlife.	Currently at only 10% to 20% of potential in Oregon.	Is palatable and nutritious for sheep. Source of pollen for honeybees. Natural overall for wildlife.	Southwestern Columbine Basin and Northeastern Oregon.	Grazing and wildlife at 2 acres per AUM. 50% loss of wheat production.
C. Forestland													
(4) Scotch Broom (Cytisus scoparius)	B		Pacific Coast		Europe	Biocontrol	Biocontrol, Chemical, Manual	Forestry; Agriculture/ Range; and Wildlife	Highly competitive shrub. Limits access; forestry production, pasture and habitat degradation. Right of Way maintenance problems.	Once established the economics of control are questionable. Central and Eastern Oregon forests are at risk.	Used as an attractive nursery crop and stabilizes sand dune areas.	Western Oregon; limited to a few sites in Central and Eastern Oregon.	Timber production. Agriculture Production. Wildlife. 2 Acres per AUM.
(6) Gorse (Ulex europaeus)	B		Isolated in Pacific Coast	No estimate	Europe	Biocontrol and Containment.	Biocontrol, Chemical, Manual	Forestry; Agriculture/ Range; Wildlife; and Recreation	Highly competitive shrub. Limits access; forestry production, pasture and habitat degradation; Right of Way maintenance/access; and recreation. Is a fire hazard. May close access to recreation at coastal parks.	Once established the economics of control are questionable		Concentrated in Coos, Curry, Douglas, and Lane Counties. Small infestation in Clackamas, Tillamook, Clatsop, Lincoln, and Columbia Counties.	Timber production, grazing at 2 acres per AUM
D. Wetlands													
(9) Purple Loosestrife (Lythrum salicaria)	B		Found throughout the U.S.	No estimate	Europe	Biocontrol and Containment.	Biocontrol, Chemical, Manual	Recreation areas/ Wetland; Agriculture/Range; and Wildlife	Wetland degradation. Decreases water quality and stream flow. Reduces waterfowl habitat.	Currently at 10% of potential in Oregon.	Nectar for bees. Is an ornamental.	Small infestations found through the state.	Riparian areas. Wildlife production and wildlife viewing.
(15) Spartina (Spartina SPP.)	A	X	Expanding in the Pacific N.W. in Washington and California	No estimate	East Coast North America	Eradication (Eradicated in 1999)	Chemical and Manual	Estuarine Areas and Wildlife	Ecosystem alteration/habitat modification (mudflat to salt marsh). Impacts to shore and to migratory birds, fish crustaceans and mollusks.	In Washington infestations have grown from 4.5 acres in 1945 to 3,600 acres in 1999. Washington spends $1 million per year for control. Potential affected gross acres in Oregon is 64,000. Net acre potential is 20% of gross acreage or 12,800 acres.	Used in coarse paper production.	One site in Siuslaw Estuary eradicated. Monitoring and detection efforts in other Oregon estuaries.	Riparian acres. Wildlife, shellfish production and wildlife viewing.
(16) Brazilian Elodea (Egeria densa)	B		Widespread in several regions in the U.S.	No estimate	South America	Containment	Chemical and Manual	Aquatic areas, Lakes, and Recreation.	Impacts native plants; Organisms and fish, boating and recreational use. Alters water quality and impacts stream flow.	Exists in most coastal lakes. Has potential to expand to 54,000 acres in Oregon.	Used in tropical fish aquarium.	Widely established in many if not all coastal lakes. One lake has lost 3000 boating days.	Recreational boating, wildlife viewing.

Table 1 (continued)

Notes:

1. As identified by Oregon Department of Agriculture staff.
2. Refer to "Noxious Weed Policy and Classification System" Oregon Department of Agriculture - Noxious Weed Program. 2000. Noxious Weed Control Rating System.

   Noxious Weed Rating System.

   "A" designated weed - a weed of known economic importance which occurs in the state in small enough infestations to make eradication/containment possible; or is not known to occur, but its presence in neighboring states make future occurrence in Oregon seem imminent. Recommended Action: Infestations are subject to intensive control when and where found.

   "B" designated weed - a weed of economic importance which is regionally abundant, but which may have limited distribution in some counties. Where implementation of a fully-integrated statewide management plan is infeasible, biological control shall be the main control approach. Recommended Action: Limited to intensive control at the state or county level as determined on a case-by-case basis.

3. Identified by staff of Oregon Department of Agriculture as real and expanding potential threat to Oregon's agriculture and natural resources.
4. Council for Agricultural Science and Technology. Issue Paper. Invasive Plant Species Number 13. February 2000.
5. Various sources that include Monographs and specialized weed publications.
6. ODA Staff, personal communication, July 2000.
7. Various articles in "Biology and Management of Noxious Rangeland Weeds." Edited by Roger L. Sheley and Janet K. Petroff. Oregon State University Press. Corvallis, Oregon. 1999.
8. ODA Staff, personal communication, July 2000; and see note 7 - various articles. Also Pacific Northwest Extension Publications - various.
9. Grazing capacity and agricultural land productivity is taken form Oregon State University Extension Service Enterprise Budgets and from discussion of ODA field staff. Wildlife are taken from "The Impact of Knapweed on Montana's Economy" by Steven A Hirsch and Jay A. Leitch. Agricultural Economics Report No. 355. Department of Agricultural Economics. North Dakota State University. Fargo, N.D. July 1996. Timber production from Radtke, Hans D. and Shannon W. Davis, "Economic Consideration of Municipal Water Use: to Grow Timber or Water". Prepared for Oregon Natural Resources Council. April 1996. Tidal and estuary economic considerations taken from "Economic Impacts from Potential Management Plan Actions". Prepared for Lower Columbia River Estuary Program. Prepared by The Research Group. Corvallis, Oregon. April 1999.

II. ECONOMIC ANALYSIS MODELING PROCEDURES

A. Economic Definitions

The economic analysis of the noxious weed problem in Oregon uses measurements for REI and NEV. REI measurements from a producer's perspective, are actual or potential expenditures made in a defined geographical region. For example, a farmer will purchase herbicides at a local supplier. A portion of this purchase will be retained in the local economy to pay for wages and salaries at the supplier. The first round and subsequent re-spending of the original purchase that finds its way to household income from wages, salaries, and proprietorships profits is the economic impact from the purchase. The measurement units can be personal income, job equivalents, or business sales. When personal income is estimated, a job equivalent can be calculated by dividing the annual average earnings received across all affected occupations in the geographical area by the total personal income created from the purchases. Business sales are the total purchases created within all affected industries.

NEV attempts to measure the relative value placed on a resource by what someone would be willing to give up (pay) for goods or services, less the costs to produce the resource. That is the economic value net of costs. A common mistake that is often made is to include the costs associated with using the plant resource (e.g. fuel costs, feed costs, equipment) as part of the economic value of the resource. This definition describes an anthropocentric view of value, that is, value to people. Therefore, in order for a grazing resource to have economic value, people must be willing to give up other valuable resources (which can be represented by money) in order to have the resource. This makes economic value a function of peoples, preferences and their ability to pay (income).

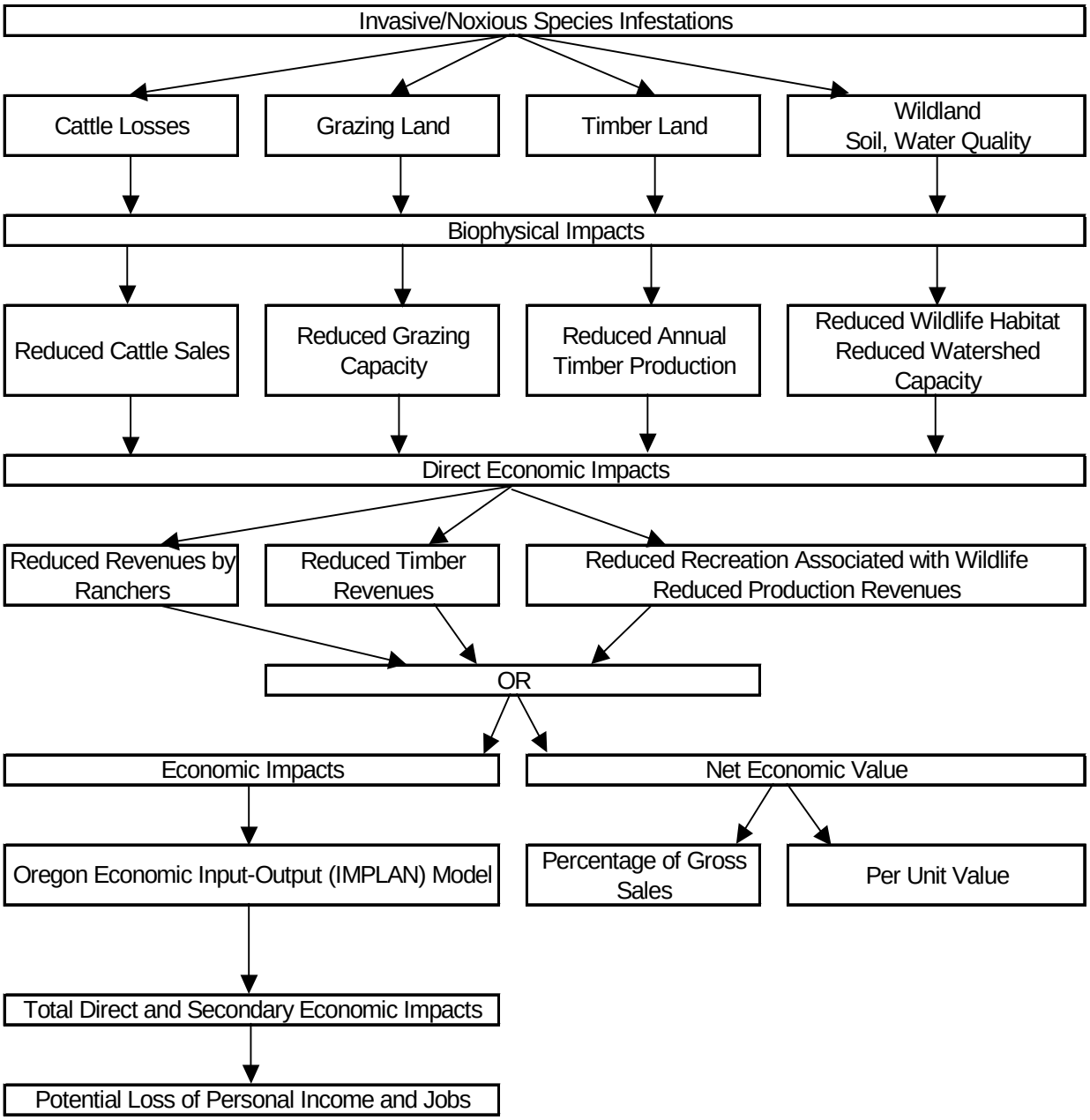
B. Economic Impact Modeling

1. The Basic Input-Output Model

An input-output model approximates an economy (country, state, region, or county) by defining the economic relationships among economic sectors. These economic relationships are expressed as dollar values of purchases or sales between specified economic sectors. Depending upon the model, there can be from a few dozen to as many as several hundred economic sectors. A sector is defined as any homogeneous grouping of businesses, organizations or industries (e.g. tree fruit industry, insurance industry, charitable organizations).

Each sector purchases goods and services from itself and/or from other sectors. Sectors will sell goods and services both to themselves and to other sectors. The annual dollar amounts of these transactions are organized into a table called a transaction matrix. The transaction matrix table generated by an input-output model provides detail about the dynamics of an economy, describing which sectors contribute to the production of representative goods and services and which sectors are the markets for those goods and services. The relationships among sectors are arrayed in a matrix format, and an algebraic technique (matrix inversion) is used to calculate the

Figure 2
Economic Analysis Modeling Procedures



direct and indirect impacts of changes in the sectors of the model. These changes are expressed in the form of multipliers and response coefficients.[1,2]

2. The IMPLAN Model and Database

The IMPLAN model used in this study was originally designed by the U.S. Forest Service in the early 1980's in response to the mandates of the National Forest Management Act and the National Environmental Policy Act (U.S. Department of Agriculture, Forest Service 1983). These two acts required the Forest Service to consider economic efficiency and economic effects in the formulation, evaluation and selection of land management planning alternatives. The IMPLAN system was designed for the construction of regional input-output models in order to evaluate the potential economic effects of alternative management actions in local areas. For example, a timber management plan with associated harvest activities, mill operations, and recreational activities could be evaluated using IMPLAN based on estimated economic impacts in the affected local communities. Data are organized by counties, which can be aggregated into appropriate geographical units (regions, states, nations) relevant to the analysis.

Over time, researchers, analysts, and managers have adapted IMPLAN to a wide array of resource planning applications. Operation of the IMPLAN model and database was subsequently transferred to the University of Minnesota, where it is now administered by the Minnesota IMPLAN Group, Inc. (Alward et al. 1989). The IMPLAN database consists of 21 economic and demographic variables at a 528 industrial sector level for all 3,000 counties and 50 states in the United States. The variables include employment, value-added, government purchases, and household purchases by county and by state. All of the data is from state and federal government sources.

3. Input-Output as a Basis for Disaggregated Industry Models

The basic IMPLAN database provides multiplier and response coefficient estimates for 528 sectors. These sectors are aggregated national industry composites based upon the SIC classification system described above.

The model used in this study is a disaggregated input-output model. Disaggregation allows for the targeted industries to be further divided into supporting sectors. These supporting sectors reflect the economic activities such as housing, utilities, transportation, etc. Both basic IMPLAN sectors and unique groupings are utilized. The most important reason for using the disaggregated model is that it provides the user with a detailed analysis of specific industry

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1. An input-output multiplier reflects the difference between the initial effect of a change in final demand and the total effects of that change. Once a transaction has been made it will normally cause a chain reaction of other transactions – as these transactions occur (called "turnover") additional output and income will be generated. The compounded result of these transactions divided by the initial change is called a multiplier. Several multipliers are estimated for output, employment, and income.
2. A response coefficient is analogous to a multiplier, but expresses relationships between different economic variables. Where the multiplier has the same units (income, output, or employment) in both the numerator and the denominator, a response coefficient has different units in the numerator and denominator. A response coefficient is the response of income (or output, or employment) to increases or decreases in output.

operations, and a thorough evaluation of resulting economic impacts on the affected communities.

4. Model Specification

The model is production driven, based upon the physical flows of goods and services. For example, output is measured in terms of the cattle, forage, or wheat sold.

Output or total sales is a common reference in business statistics, but it reflects only the level of gross economic activity; it does not convey economic efficiency or well-being. A preferable measure of economic change in a community or region is represented by income. To convert output information into income data, the level of production activity is first transformed into industry revenues based on the prices received for the goods or services sold.

For the goods-producing industries such as ranching, sales revenues are divided into cash (expenditure) flows on the basis of industry accounting models. The cash flows are then multiplied by response coefficients from the IMPLAN I/O model to determine the estimated contribution in regional income resulting from the stated production.

Only the impacts related to increased (or decreased production) are measured. The impacts could actually increase if control costs increase, e.g. if more manpower were needed to produce a unit of output a larger economic impact would occur in the short run. In the long run the increased costs may be so high as to cease total agricultural production. In that case local impacts would also be reduced. Increase or decrease of control costs and the related impacts are subjects of specific species investigations. This project does not include such detailed analysis.

III. ECONOMIC MODELING APPROACH

A. Identified Noxious Weeds

Twenty one invasive/noxious weeds in 16 groups were chosen by ODA to be evaluated (Table 1).[1] They were chosen from a weed classification system of the ODA Noxious Weed Control Program. Noxious weeds, for the purpose of this system, are designated "A," "B," and/or "T." The rating system designation definitions follow (ODA 2000a).

- "A" designated weed - a weed of known economic importance which occurs in the state in small enough infestations to make eradication/containment possible; or is not known to occur, but its presence in neighboring states makes future occurrence in Oregon seem imminent. The recommended action is to address infestations with intensive control when and where they are found.

- "B" designated weed - a weed of economic importance which is regionally abundant, but which may have limited distribution in some counties. Where implementation of a fully integrated statewide management plan is infeasible, biological control shall be the main control approach. The recommended action is limited to intensive control at the state or county level as determined on a case-by-case basis.

- "T" designated weed - a priority noxious weed designated by the State Weed Board as a target weed species on which the ODA will implement a statewide management plan.

The 21 noxious weeds were chosen for evaluation based on two main criteria; 1) the extent of total acres infested, and/or 2) the potential for future infestation that may cause economic and environmental damage to the State. The noxious weeds identified as being particularly threatening in potential expansion are marked with an "X" in Table 1.

Information on the origin of these noxious weeds, estimated total acres affected in the U.S. and in Oregon, policy and method of control, industries affected, and other considerations are summarized in Table 1. Also included are estimates of total budgets from ODA that are specifically targeted at these identified species.

B. Economic Loss Measurement

The lands affected by these identified species are categorized into four general groups: 1) rangelands, 2) farmlands, 3) forestland, and 4) wetlands (Table 1). The following is a general discussion of the measurement units used for these categories. A more extensive discussion and layout of the calculations for each or these species are contained in Appendix C.

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1. See Appendix A for a detailed description of the chosen species. Appendix B provides a list of applicable past studies about the chosen.

1. Rangelands Affected

Identified Species:

- Yellow starthistle
- Knapweeds
- Leafy spurge
- Mediterranean sage
- Purple starthistle

The production from rangelands is grazing for cattle and wildlife. The estimated acres to feed a cow for one month (AUM) for these affected lands range from 7.3 acres to 2.0 acres. Sales per AUM are estimated to be $26.54 (Radtke 1998). The IMPLAN total personal income coefficient is 0.54, resulting in a $14.33 total personal income impact per AUM. A relationship between cattle AUM use and wildlife use of 16 percent with a recreation IMPLAN total personal income coefficient of 0.66 yields an impact per acre for recreation based wildlife for these lands of $2.84 (Hirsch and Leitch 1996). Cattle losses are estimates of 10 percent of tansy ragwort losses (Radtke 1993). Economic value is 100 percent of cattle losses. The private lease rate of $10 per AUM and a value of $12.38 per acre are used in this study (Feather et al. 1999).

2. Rangelands and Farmlands Affected

Identified Species:

- Tansy ragwort
- Rush skeletonweed

Tansy ragwort information was taken from a study by Radtke (1993) and updated with 1997 IMPLAN coefficients. Wildlife estimates are similar to rangeland impacts. Sales of wheat are taken from OSU's Extension Service Budgets. The average yield per acre is 45 bushels at $3.30 per bushel. The IMPLAN total personal income coefficient for wheat production is 0.68.

3. Forestlands Affected

Identified Species:

- Scotch broom
- Gorse

Gorse and Scotch broom are mainly found along the Oregon Coast with some infestations in the Willamette Valley. The productivity of this land is estimated to be two acres per AUM for cattle and wildlife production. For timber the unrealized timber production is estimated to be 0.125 million board feet (MBF) per acre per year. The distribution between the two lands is set at 50 percent each. Timber sales per MBF are estimated to be $500. The timber industry IMPLAN total personal income coefficient is 0.88 (Angle et al. 1996 and Radtke and Davis 1996).

4. Wetlands Affected

Identified Species:

- Purple loosestrife
- Spartina
- Brazilian elodea

These aquatic plants are evaluated on production losses that may occur to marine culture (oysters) and/or other estuarine production such as salmon smolt overwintering and bird attractions. The wildlife impact of a restored wetland acre is estimated to be $1,273 (The Research Group 1999). These impacts per acre are partly based on wildlife viewing which are estimated at 25.6 days per acre per year. Wildlife viewing per day is estimated to by $26 per day. These estimates are taken from Tillamook Bay wildlife and viewing surveys. Also included are additional salmon production and resulting harvests.

In addition spartina may reduce oyster production. The annual value of a producing wetland acre may be $4.30 per year based on the State Lands lease price. The oyster production and sales from such an acre may be at a rate of $220 per year. The IMPLAN coefficient for oyster production is 1.49; therefore each producing acre has the potential of generating $326 of personal income impacts. These calculations use a 50 percent oyster producing to net acre potential.

Brazilian elodea chokes lakes and waterways. The experience is that a coastal lake may produce 15 boat days per acre (ODA 2000a). The economic impacts are $29.96 per day; while economic value of boating is $26 per day (Oregon Coastal Zone Management Association 1997).

IV. ECONOMIC EVALUATION RESULTS

Noxious weeds are a problem for private agriculturists or State resource managers because they reduce the usefulness or productivity of the land. Loss of productivity may be measured in terms of increased costs or decreased revenues. Some plants may also be detrimental to other than private productivity functions (e.g. wildlife habitat, watershed production, protection of rare native plants, etc.).

Twenty one noxious/invasive plants (in 16 groupings) are identified by the ODA as being of special economic threat to the state of Oregon. Five of these are presently not very pervasive throughout Oregon, but they do cause a very real potential threat to Oregon's natural resources. Tansy ragwort is present in western Oregon, and presents a potential threat to eastern Oregon's cattle industry. The evaluation is based on generating a market value (or estimates of market value) for production lost as a result of crowding or poisoning from noxious weeds. These valuation are very general and should be viewed as indicators of a problem and not a clear calculation of each noxious weed's impact. The 16 evaluated noxious weed groups (21 identified species) are taken from the 99 noxious weeds listed as being of economic significance to Oregon's natural resources by the ODA, Noxious Weed Control Program. Not enough is known about all of the 99 identified species to suggest that the economic costs to Oregon's economy are in direct ratios of 21 to 99. However it can be concluded that the total amount of economic costs to Oregon's economy would be much higher if all 99 noxious weeds were to be evaluated.

A. Geographic Scope

These sixteen identified noxious weed groups are present in about 32 million acres in Oregon (gross acres, see Table 2). They crowd out an estimated 6.5 million acres (net) of rangeland, farmland, forestland, and wetland in Oregon. Several species were identified as being a very real potential threat for further expansion into Oregon lands. These species are: tansy ragwort into eastern Oregon rangelands and farmlands; distaff thistle, purple starthistle, leafy spurge, and hawkweeds into Oregon rangelands; and spartina into Oregon wetlands. These have the potential to crowd out 10 million acres of productive lands in Oregon (Table 2).

B. Foregone Economic Benefits

In most cases these plants crowd out desirable cattle and wildlife forage or timber producing trees. In some cases they also cause illness, disease, and death in cattle and horses. The presence of some species also contributes to soil erosion and degrades water quality. This report does not attempt to quantify many other serious environmental impacts of noxious weeds such as displacement of endangered flora and fauna.

In this analysis there are two basic approaches to placing a value on foregone benefits. These are the income (and resulting jobs) lost to the regional economy. The second is estimation of net economic benefits that are given up by individuals and society resulting from the invasion of noxious weeds on the previously productive lands.

The net value approach (market approach) assumes that a person will not pay more for a property than the amount for which a comparable substitute property can be bought (Godfrey et al. 1988). The amount willing buyers pay for comparable lands is used to estimate the value of lands that may be sold. The lease value for rangelands, farmlands, or forestlands is one such estimate. For wildlife and other habitat values, estimates of environmental benefits are based on consumer surplus estimates expressed as the value placed by society on these lands. "Loosely speaking, consumer surplus is the amount of money, above and beyond the market price, that a consumer would be willing to pay for a given good (Feather et al. 1999)."

The estimated amount of total foregone sales by affected sectors is $119 million due to lost productivity. This decrease in cattle sales, wheat sales, timber sales, tourist expenditures, and other attributes would result in a decrease of $83 million in personal income or 3,329 annual jobs at $25 thousand per job (Table 2 and Figure 3). The largest loss is in terms of timber production caused by Scotch broom crowding or delaying tree growth.

The potential for new and expanding noxious weeds represents an additional 10 million acres (net) to be affected. This would result in a decrease of affected industry sales of about $91 million. A total of $54 million of total personal income or 2,134 annual jobs may be lost from these potential expanding noxious weeds (Table 2 and Figure 3).

The value of the potential threat is the greatest for spartina. The potential is that spartina may change mud flats and eelgrass areas into deep channel flows and non-productive shallow spartina marsh lands (Figure 4). This results in loss of salmon smolt over-wintering areas, bird feeding areas, and oyster production. Containment programs so far have kept tansy ragwort from becoming an economic problem in eastern Oregon. There is a real threat for this noxious weed to expand into range lands of eastern Oregon. The potential loss to agriculture and supporting industries for such on invasion could be $10 million in total personal income or 400 annual jobs.

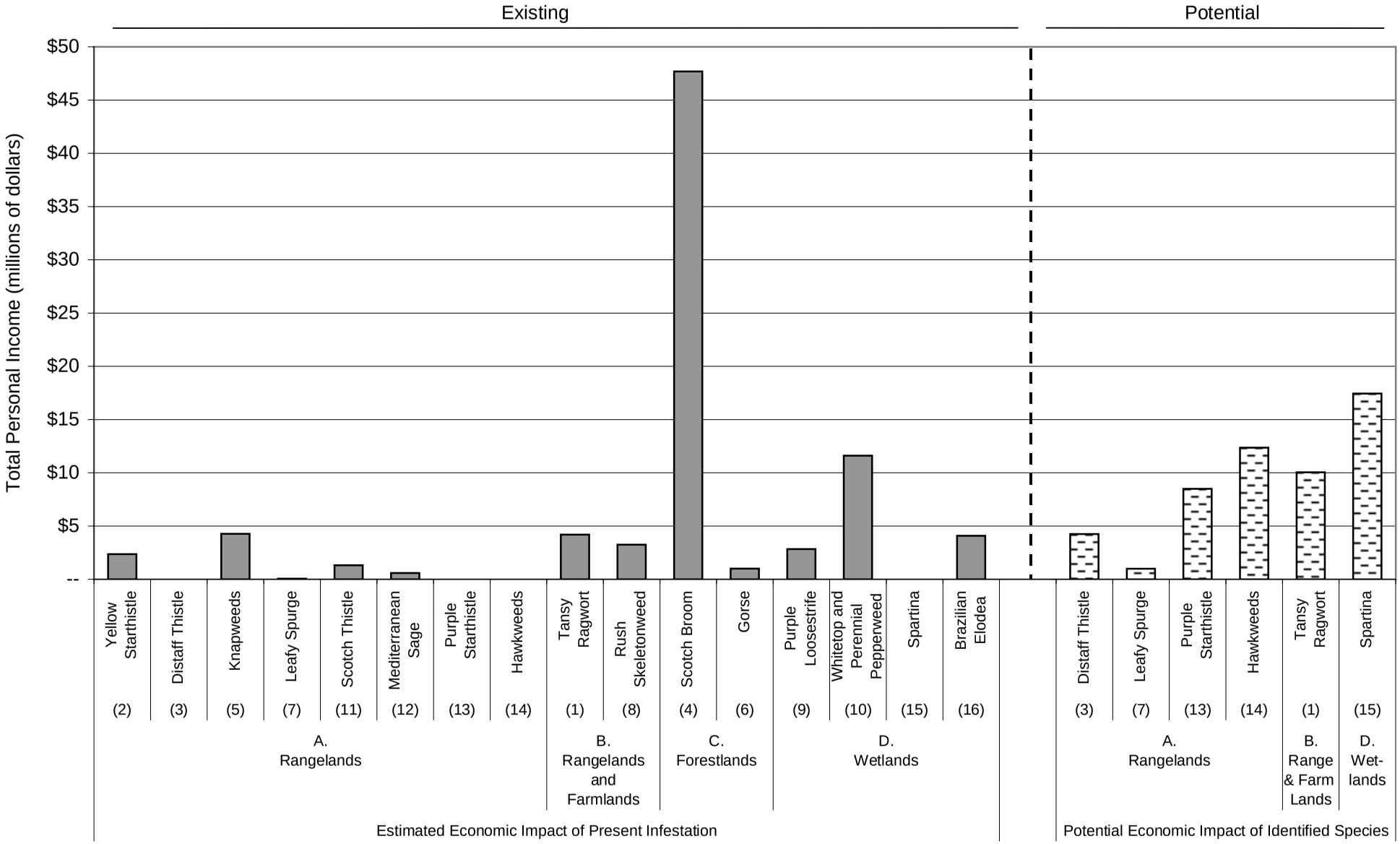
Table 2
Economic Evaluation of Existing and Potential Noxious Weed Infestation

Affected Lands / Noxious Weed Names	Acres Affected in Oregon		Potential Acres That May Be Affected in Oregon	Estimated Economic Impact of Present Infestation				Potential Economic Impact of Identified Species				ODA Annual Weed Control Budget	
	Gross	Net		Sector Sales	Total Personal Income	FTE Jobs	Net Economic Value	Sector Sales	Total Personal Income	FTE Jobs	Net Economic Value	Specific Programs	Total Agency
A. Rangeland													
(2) Yellow Starthistle (Centaurea solstitialis)	1,873,407	947,068	--	$4,245,878	$2,359,666	94	$3,416,849	--	--	--	--	--	
(3) Distaff Thistle (Carthamus lanatus)	2,174	10	2,500,000	N/A	N/A	N/A	N/A	$7,642,581	$4,247,398	170	$6,150,328	$41,564	
(5) Knapweeds	3,622,380	1,815,591	--	$7,672,737	$4,271,514	171	$6,083,434	--	--	--	--	--	
Diffuse Knapweed (Centaurea diffusa)													
Spotted Knapweed (Centaurea maculosa)													
Russian Knapweed (Centaurea repens)													
Squarrose Knapweed (Centaurea virgata)													
(7) Leafy Spurge (Euphorbia esula)	12,700	7,324	3,600,000	$88,553	$49,271	2	$44,328	$1,771,062	$985,421	39	$886,552	$31,372	
(10) White Top and Perennial Pepperweed (Cardaria draba and Lepidium latifolium)	2,322,187	1,184,326	--	$20,927,514	$11,606,035	464	$9,457,672	--	--	--	--	--	
(11) Scotch Thistle (Onopordum acanthium)	1,011,134	526,800	--	$2,357,719	$1,310,376	52	$1,896,577	--	--	--	--	--	
(12) Mediterranean Sage (Salvia aethiopis)	1,275,077	250,000	--	$1,056,507	$588,171	24	$837,666	--	--	--	--	--	
(13) Purple Starthistle (Centaurea calcitrapa)	80	1	2,000,000	N/A	N/A	N/A	N/A	$15,285,162	$8,494,797	340	$12,300,655	$3,558	
(14) Hawkweeds	600	100	1,500,000	$1,526	$824	0	$575	$22,890,750	$12,359,625	494	$8,625,000	--	
Orange Hawkweed (Hieracium aurantiacum)													
Yellow Hawkweed (Hieracium floribundum)													
B. Rangeland and Farmland													
(1) Tansy Ragwort (Senecio jacobaea)	3,260,000	163,000	391,200	$7,537,796	$4,186,865	167	$5,826,638	$18,090,710	$10,048,475	402	$13,983,932	$14,668	
(8) Rush Skeletonweed (Chondrilla juncea)	2,000,000	60,000	--	$4,853,100	$3,244,350	130	$4,605,000	--	--	--	--	--	
C. Forestland													
(4) Scotch Broom (Cytisus scoparius)	16,000,000	1,500,000	--	$58,443,750	$47,690,475	1,908	$14,221,200	--	--	--	--	--	
(6) Gorse (Ulex europaeus)	300,000	31,354	--	$1,221,630	$996,858	40	$297,261	--	--	--	--	--	
D. Wetlands													
(9) Purple Loosestrife (Lythrum salicaria)	3,646	2,230	--	$4,299,440	$2,838,790	114	$1,482,695	--	--	--	--	--	
(15) Spartina (Spartina SPP.)	5	0	12,800	N/A	N/A	N/A	N/A	$25,448,400	$17,434,000	697	$8,525,584	$35,000	
(16) Brazilian Elodea (Egeria densa)	90,000	9,074	--	$6,178,033	$4,077,856	163	$3,538,860	--	--	--	--	--	
Total - All Species	31,773,390	6,496,878	10,004,000	$118,884,183	$83,221,050	3,329	$51,708,753	$91,128,664	$53,569,717	2,143	$50,472,051	$126,162	$921,519

Notes: 1. Defiitions:
Sales = Total output affected.
Personal income = Total personal income (direct, indirect, and induced) affected.
Jobs = Estimated full time equivalent jobs, at $25,000 per year, affected.
Economic value = Total loss to society by affected lands. This may be value of goods produced for the market or for non-traded goods.
2. The total annual 2000 budget was $921,519. Of this amount $392,930 came from the General Fund, $229,589 from Lottery Fund, and $299,000 from contracts. Some funds are spcifically directed to specific spcies programs.
3. Acres affected in Oregon from personal communication with ODA Staff.

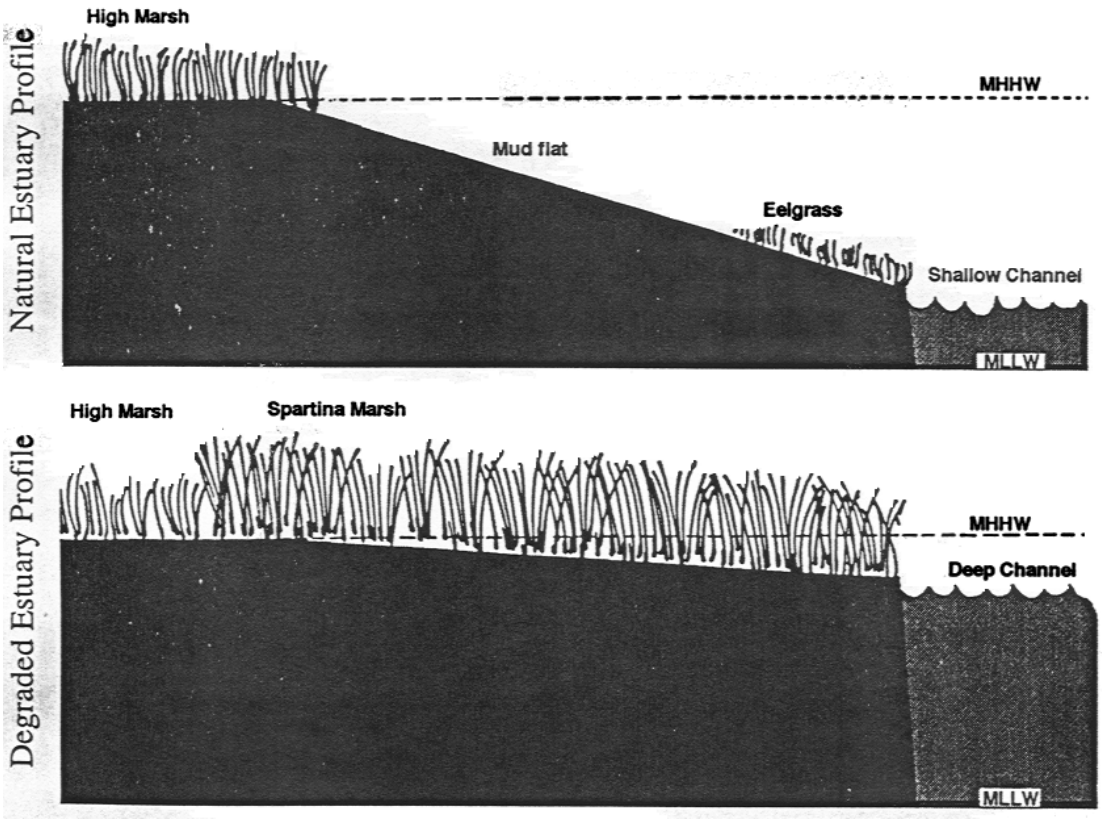
Source: Oregon Department of Agriculture (ODA) staff. Personal communication. July 2000.

Figure 3
Economic Impact of Existing and Potential Noxious Weed Infestation



kco D:\Data\Excel\NoxWeed-Links.xls Figure 3

Figure 4
Impacts of Spartina on Pacific Estuaries



Notes: 1. Mudflat intertidal area before (top) and after (bottom) Spartina infestation. Note higher elevation in Spartina marsh due to siltation. Redrawn from Spartina Workshop Record, pg. 27.
2. Source used with permission from Washington State Sea Grant program. University of Washington.

Source: Pfauth and Sytsma (1998).

V. RISK AND UNCERTAINTY

"A plant population goes through certain phases as it increases in numbers - it is introduced to a new site, it establishes and becomes naturalized, it increases in numbers slowly and, after a period of time, its rate of increase becomes higher until some factor in the environment limits further increase. This limiting factor may be imposed either naturally or as a result of human intervention, some form of management, after which the rate of population increase slows (Figure 5) (Groves 1999)." A few naturalized plant species increase exponentially almost immediately after arrival and become major weeds.

In biological systems economic effects derive from bio-physical effects. Projecting the economic effects incurred must begin with projection of an infestation expansion path. However lack of sufficient data is the major factor limiting analysis and estimation of infestation growth patterns. Smith et al. (1999) used a database of 35 observation on the expansion of invasive weed infestations in the West to conclude that effects on resources, ecosystems, and biodiversity accelerate typically when measures to eradicate an infestation are delayed (Table 3) (Smith et al. 1999). "This analysis supports the contention that an early and rigorous approach to the eradication of new invasive weed infestations is expedient, for both environmental and economic reasons. It also supports policy recommendations that we implement programs to manage large well-established infestations in ways that can minimize enormous annual increases in infested acreage that will otherwise occur (Smith et al. 1999)." Early detection and preventive programs should be viewed to be in the left hand corner of Figure 5. Many treatment programs are initiated in the range of the exponentially increasing phase. Biological control programs tend to be noticed and effective during the top end of the growth phase. However, it may also be utilized at the low end of the growth phase, if enough of the host plant is available to support the biological agent.

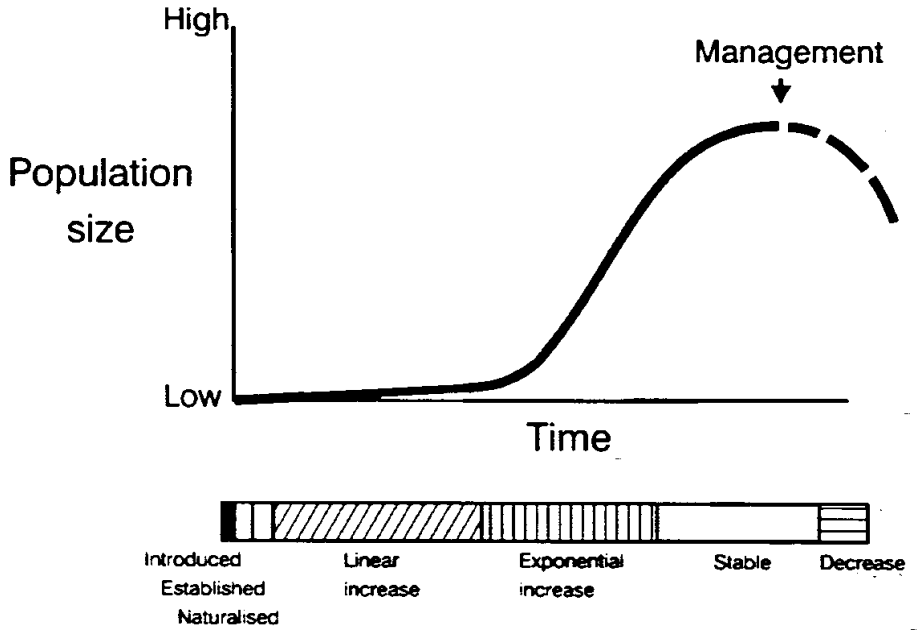
A. Data

The data supplied by the ODA on the geographic scope are part of a state policy to rate and classify weeds at the state level (Table 1). These data identify the target weed, provide a current status of the weed, and identify ODA management goals for that weed.[1] Included in these management goals are yearly surveys of identified species to describe the severity of the infestation. These surveys are the basis for the identification of gross and net acres affected. These surveys and knowledge of neighboring state's noxious weed problems form the background for identifying potential problems.

The uncertainty in identifying potential growth is in the estimation of the stage of growth of the weed. The establishment and spread of gorse in western Oregon has followed almost a classic growth curve (Figure 6). Its position on the growth curve represents a real economic threat to Oregon. The present status of distaff thistle is fairly minimal in Oregon (2,174 gross acres, 10 net acres). Its position on the low end of the growth curve represents a large potential threat to

1. ODA Noxious Weed Control Summary. Various Weeds. Updated periodically. Oregon Department of Agriculture.

Figure 5
Phases in the Population Increase of a Weed



Note: Phases in the population increase of a weed. Sleeper weeds are those invasive plants showing a low rate of increase in population, i.e. they occupy the time period between naturalization and the start of a high rate of increase in population size.
Source: Groves 1999.

Oregon (Figure 7). Based on evidence in other states, ODA staff has concluded that the potential of distaff thistle may follow the lead of yellow starthistle in its growth cycle.

Yellow starthistle is probably near 35 to 40 percent of its total potential at 1,873,407 acres. At its high population level it may invest 4,675 thousand acres. A robust infestation period of distaff thistle that reaches 60 percent of its population potential may infect as many as 2.5 million acres in Oregon (Table 2).

Similar decisions on growth potentials are made regarding other identified noxious/invasive species. There is no absolute certainty in the identified growth path; however as Smith et al. (1999) concludes, "the analysis demonstrates the need for better data and further analysis."

B. Economic Data

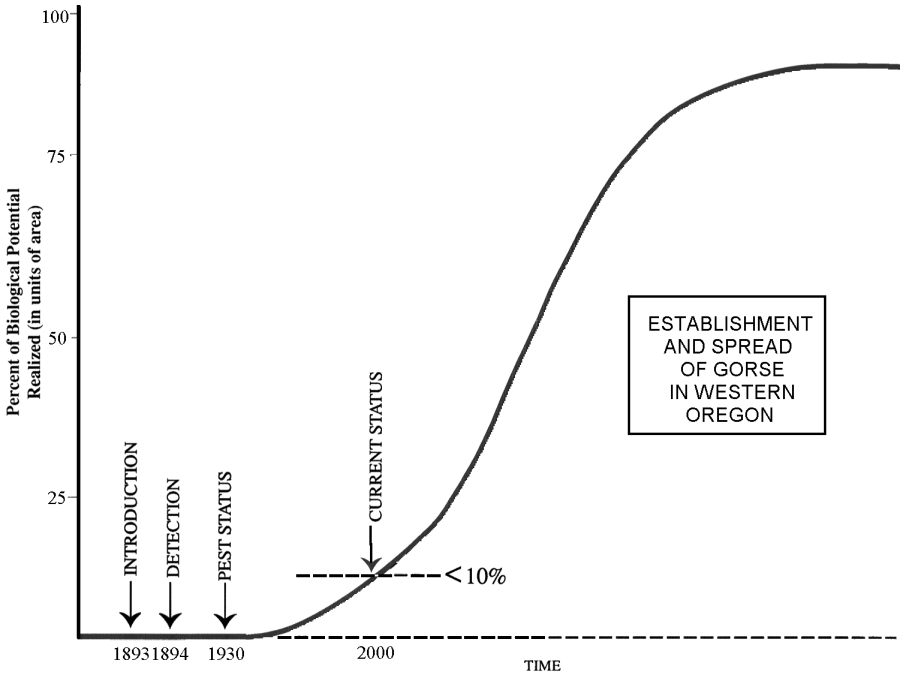
Control of undesirable plants, especially noxious/invasive plants requires knowledge of the alternative control measures and their related costs. Previous work on economic evaluation of noxious weed management in the U.S. has centered around individual landowner evaluations (Griffith 1999 and Frandsen and Boe 1991). Such studies and the general availability of information on costs land returns to private agriculture provide a basis for evaluating private benefits of controlling noxious weeds. It is more difficult to estimate the impacts of noxious

Table 3
Observations on Initial and Final Weed Infestation Sizes

Weed Species	Initial Size	Final Size	Time
	---------ha---------		yr
Common crupina (Crupina vulgaris Cass. CJNVU)	Unknown	9,308	16
	239	24,282	30
Dyers woad (Isatis tinctoria L. ISATI)	4,856	60,704	8
	Unknown	9,713	51
	14.2	718	16
Diffuse knapweed (Centaurea diffusa Lam. CENDI)	61	526	8
Spotted knapweed (Centaurea maculosa L. CENMA)	Unknown	1,821,125	76
	121	648	8
	Unknown	203,561	44
	Unknown	688	12
	152	1,760	16
Squareose knapweed (Centaurea virgata Lam. CENVS)	0.4	60,704	46
	16,188	40,496	8
Yellow starthistle (Centaurea solstitialis L. CENSO)	Unknown	121,408	30
	405	56,657	42
	404,695	4,046,945	19
	Unknown	74,868	32
	Unknown	848	25
	16.2	202,347	42
Canada thistle (Cirsium arvense Scop. CIRAR)	Unknown	930,797	100
Musk thistle (Carduus mutans L.. CRUNU)	10,927	173,209	8
	162	1,862	16
Scotch thistle (Onopordum acanthium L. ONRAC)	6,070	14,164	8
Leafy spurge (Euphorbia esula L. EPHES)	Unknown	404,695	30
	Unknown	617	52
	263	1,255	16
Medusahead (Taeniatherum caput-medusae L. ELYCM)	Unknown	1,821,125	52
	Unknown	607	8
	Unknown	1,821,125	46
Rush skeletonweed (Chondrilla juncea L. CHOJU)	16.2	1,618,778	33
	Unknown	1,416,431	23
	202	202,347	36
	21,246	50,992	16
Tall whitetop (Lepidium latifolium L. LEPPE)	2,833	6,880	8
Purple loosetrife (Lythrum salicara L. LYSTA)	0.8	20,235	16

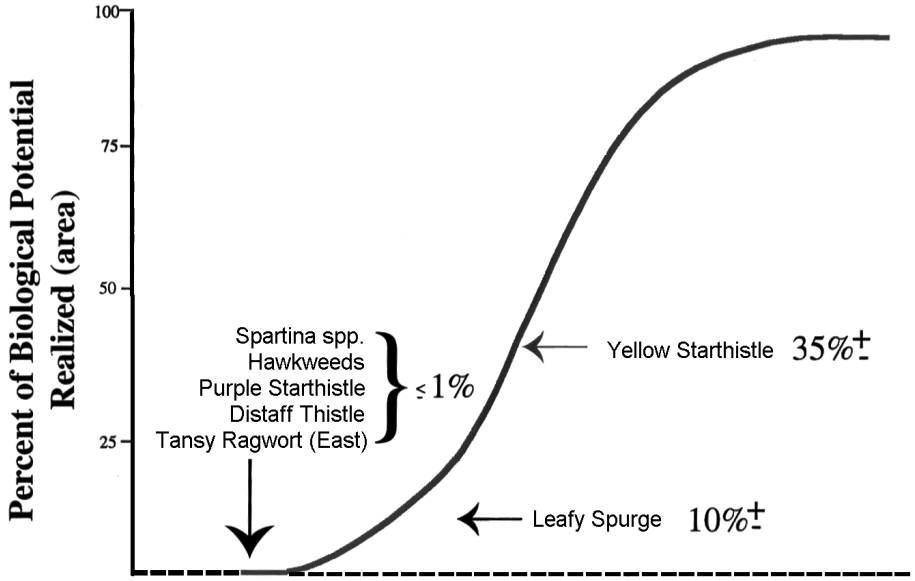
Note: Time refers to the number of years between the initial and final observations.
Source: Smith et al. 1999.

Figure 6
Establishment and Spread of Gorse in Western Oregon



Source: ODA 2000(c).

Figure 7
Status of Six Oregon Noxious Weeds Selected for
Evaluation of Potential Economic Impact



Source: ODA 1999.

weeds on other natural resource values, such as wildlife, habitat, outdoor recreation use, soil productivity, and watershed productivity.

There are only a few economic studies available that address the economic implications of noxious/invasive weed control programs. Some of these have been completed in New Zealand (Grundy 1989a; Green and Sheppard 1990; and Hill 1986). In the U.S. economic studies on leafy spurge and knapweeds (Leitch et al. 1994; Leistritz et al. 1992; and Hirsch and Leitch 1996) in Montana, Wyoming, North Dakota, and South Dakota provide some guidance on per unit economic impacts to use in these evaluations. General valuation of environmental benefits for other public programs such as the Conservation Reserve Program (CRP) (Feather et al. 1999) also provide very general guidance on economic values of wildlife habitat.

An overview analysis of the ODA program may use such guidelines with the understanding that the per unit impacts and values used may not be totally representative of the conditions found in Oregon. For example, the leafy spurge analysis on wildlife develops a species/land coefficient that represents the relative importance of different land uses in supporting current wildlife (Leitch et al. 1994). A species/land coefficient of 0.40 for North Dakota means that 10 percent of the states area wildland supports 40 percent of the state's wildlife. For the ODA analysis no estimates of infested lands to wildlife producing lands are used. It was assumed to be the same as in other Western States.

For some species that invade critical habitat in Oregon such general criteria may understate the impacts. For economic net value wildlife values, the CRP study provided estimates for wildlife recreation for all of the U.S. (Feather et al. 1999). In Oregon where population are lower and resource lands more abundant the average value per wildlife producing acre may not be as high as the national average.

The general transfer of impacts and values in a general overview process is probably adequate. However, for specific benefit-cost calculations or allocation of resources toward specific programs more detailed analysis is required. The ODA analysis of the Tansy Ragwort Program provided such an analysis (Radtke 1993). This evaluation showed that the biological control program provides a return on investment of 83 percent (or a benefit-cost ratio of at least 13:1).

It is especially important to develop data and unit of measurements for the potential infestation of noxious/invasive plants in eastern Oregon rangelands and Oregon wetlands (estuaries). Many of these lands are in the public domain. Establishment of criteria to evaluate the uses of these lands is critical in developing containment and eradication programs.

The need for specific research to provide better evaluation is summarized by,

> "Review of the literature discloses that: (1) very little research has been focuses on the economics of noxious weed control; (2) what research that has been conducted is largely oriented to the impacts incurred by the western states' livestock industry; (3) while many tax dollars are spent each year to eradicate or control weeds, the general public is either unaware or apathetic to the issue; and (4) a significant data base is needed to identify and define the

multiple resource relationships involved and the joint costs and benefits of noxious weed management (Frandsen and Boe 1991)."

VI. POLICY IMPLICATIONS

Noxious weeds have become so thoroughly established and are spreading so rapidly on state, count, and federally-owned lands, as well as private land, that they have been declared by ORS 570.505 to be a menace to public welfare. Steps leading to eradication, where possible, are necessary. It is further recognized that the responsibility for such eradication and/or intensive control rests not only on the private landowner and operator, but also on the county, state, and federal government.

A. Oregon State Weed Control Policy

"Weed Control Policy

Therefore, it shall be the policy of the Oregon Department of Agriculture (ODA) to:

1. Rate and classify weeds at the state level.
2. Prevent the establishment and spread of noxious weeds.
3. Encourage and implement the control or containment of infestations of designated weed species and, when possible, eradicate them.
4. Develop and manage a program of biological weed control.
5. Increase awareness of potential economic losses and other undesirable effects of existing and new invading noxious weeds, and to act as a resource center for the dissemination of information.
6. Encourage and assist in the organization and operation of noxious weed control programs of other government units.
7. Cooperate with county weed control officers, Oregon State University, and other in developing weed control methods.
8. Conduct statewide noxious weed surveys and weed control efficacy studies (ODA 2000a)."

The control and spread of noxious/invasive weeds are of public concern because the private market may not be able to address the problem of externalities (spillover effects) and public goods (e.g. vistas and biodiversity). The private market will underproduce public goods, due to the free rider problem. Eradication and control of unwanted and noxious weeds is an example of a public good. The background research and maintenance costs can be prohibitive for any single individual or even single industry. Once the control has been established, people cannot be excluded from benefiting from the program. The benefits of such a program may be shared by a variety of agricultural producers and the public at large.

Oregon enjoys the benefits of two highly effective biological control programs. The first was the control of St. Johnswort (also called Klamath weed) in the late 1940's and 1950's. There are insufficient data to estimate benefits from control of this weed, but accumulated net benefits would be at least in the tens of millions of dollars.

The other was the program to control and reduce the growth of tansy ragwort (a noxious weed) in Oregon. In the early 1970's, the spread of tansy ragwort was identified as a very serious problem. In order to address this problem, the ODA initiated an intensive integrated tansy ragwort program that included biological control as well as chemical, cultural, physical, and other preventative methods of weed control. An economic analysis evaluated this program from the point of the start of the program. The purpose was to evaluate the specific tansy ragwort biological control program. The results of this study, based on the assumptions of avoided costs, show that the biological control of tansy ragwort has given the State of Oregon a stream of benefits of about $5 million per year. This provides a return on investment of 83 percent annually (or a benefit-cost ratio of at least 13:1). The problem facing Oregon's decision makers is to decide what is the "critical mass" required to keep a biological control program functional. The recent trends observed in western Oregon show a large decrease in tansy ragwort biomass and the maintenance of high insect populations without the volatility of insect-plant fluctuations observed in England. It could be that the plant population has been permanently stabilized by the insect and that long term biological control will have been achieved. It may also be prudent to continue to monitor this program so as to be able to respond to any new areas of outbreak. This is especially important in areas such as eastern Oregon, where the density of vegetation may make it difficult to initiate and to continue a control program based solely on biological agents. The tansy ragwort analysis dealt specifically with biological control of tansy ragwort. One question certainly should be whether it is appropriate to apportion all cost of the ODA biological control program toward tansy ragwort, especially since there are many other needs of "concern" that are being addressed by the program. Given the large internal rate of return and the high benefit-cost ratio, these would be interesting exercises, but would not change the direction of results. The result is that the State is receiving a high rate of return on a program with relatively low annual investment.

B. Exploring Options for Adjustments to Weed Control Policy

During the 70th Oregon Legislative Assembly in 1999 House Bill 2118 was passed. This bill instructed the ODA and the Oregon State Weed Board to assemble a working group to develop a strategic plan to address the growing problem of invasive noxious weeds. A working group representing interests from agriculture, forestry, counties, state and federal agencies, conservation groups, and members of the public contributed input and provided direction to the strategic planning process. As part of the legislative directive and the strategic planning process, the ODA and OSU through the Oregon Agriculture Research Foundation, developed and implemented this economic study to assess the impacts of 21 of the 99 Oregon State listed noxious weeds. This economic study quantifies the impacts of these identified noxious weeds to the State's resources and demonstrates the need to mitigate the impacts associated with the invasion and proliferation of exotic noxious weeds and the need to prevent the introduction of additional invasive plant species. The identified noxious weeds that were analyzed in this study presently reduce Oregon's total annual personal income by about $83 million, or about 3,329 annual jobs. More is at stake if all 99 ODA listed noxious weeds were to be evaluated. This is a substantial loss in jobs for Oregon's economy.

The foregone economic value of the existing identified noxious weed infestation was calculated to be $52 million (Table 2). The potential for an aggressive infestation of six identified weeds (distaff thistle, leafy spurge, purple starthistle, hawkweeds, eastern Oregon tansy ragwort, and spartina) is for another $51 million of economic value to be lost.

Net economic value may be used to estimate the "worth" of an asset or the foregone value of not having such an asset. The asset value of this lost production may be estimated by utilizing the principles of capital budgeting. In other words, what is the total value of this lost production if the losses reoccur every year? This approach basically can be summarized by the following formula:

$$\sum_{j=1}^{N} R_j \big/ (1+i)^j$$

where R_j = net returns in period j, i = the discount rate, and N = length of the planning horizon or period over which the returns are to be recovered.

For example, if a rancher could lease a piece of property to his neighbor for 30 years with a payment of $8 per acre, the value of that stream of income would be $122.98

$$\sum_{j=1}^{30} \frac{8}{(1+i)^j}$$

if a discount rate of five percent was used (Godfrey and Rimbey 1988). The value at 10 percent would be much lower.

The net annual value of present foregone production is estimated to be $52 million (Table 2). The lost asset value, to the citizens of Oregon, of the present loss of production (at five percent interest) is estimated to be $795 million at five percent discount rate and $480 million at a 10 percent rate. The present value of avoiding the loss of potential invaders is estimated to be about the same level.

Noxious/invasive plants interfere with agricultural production and have negative impacts on wildlife and general natural biodiversity of natural habitat. Individuals as well as public agencies have a role in controlling the spread of these weeds. The budget of the ODA is not the only ongoing program. The U.S. Bureau of Land Management's (BLM) strategic plan overall goal is to present a strategy that will facilitate restoration/maintenance of desirable plant communities and health ecosystems (U.S Bureau of Land Management 1994).

C. Benefit-Cost Analyses of Oregon Weed Control Programs

In Oregon the ODA's annual weed control budget for the year 2000 was $921,519. Of this amount $126,162 was earmarked for specific programs such as leafy spurge control (Table 2).

In order to derive a benefit-cost analysis of the effectiveness of these programs the production foregone level without a program would have to be compared to the present or future program. Such an analysis was performed on the tansy ragwort program. Species that lend themselves to early detection and integrated management programs that include education and biological control should be evaluated on a time series basis. In other cases chemical or manual control in the early stages of invasion may also result in favorable and high benefit-cost ratios. Programs for existing invasive weeds that are expensive to eradicate with manual or chemical means and that have no potential biological control agents may not evaluate favorable on a benefit-cost analysis. In such cases education for containment may be the best option.

Managing noxious/invasive plants is a capital investment. Both benefits and costs of weed management occur through time. Because of the time element, economic evaluation requires the use of net present value analysis. Such an analysis adjusts all costs and benefits to current dollars.

The Oregon tansy ragwort biological control program was evaluated on the basis of "what if the policy makers in 1974 speculated on an 18 year stream of benefits and costs of this program (Table 4)." The evaluation of this program showed that the State of Oregon received benefits of about $13 for every $1 invested (Table 5).

D. Evaluation of Three Possible Programs

The information needed to evaluate specific species program is not readily available. However, an overview of some ongoing and potential preventive programs may provide information on the returns to the public of these programs. The annual cost of the Oregon Tansy Ragwort Biological Control Program has averaged $300 thousand during the 1970's, 1980's, and early 1990's (Radtke 1999). Using this program as an example, other programs may be evaluated on their prospective returns to the State.

1. Biological Control

Possible biological control agents are being identified for knapweeds that may reduce infestation by 50 percent within 20 years. The annual NEV of lost production from knapweeds is $6.1 million (Table 2). The net present value of programs that reduce infestation on an even flow basis at 5 percent per year for eighteen years is $12.1 million (Table 6). A 7.8:1 benefit-cost ratio means that the State of Oregon would be prudent to invest in such a program.

2. Future Threats

Six noxious weeds have been identified as posing a real future threat to Oregon's natural resources. These are distaff thistle, leafy spurge, purple starthistle, and hawkweeds into rangelands; tansy ragwort into eastern Oregon; and spartina into Oregon estuaries and wetlands. Prevention program lands are the key to excluding these weeds from Oregon's lands. Potential costs of these weeds to the state in terms of net value foregone have been identified as $50.5 million (Table 2). A possible scenario of expansion based on phases of population increase in

Table 4
Biological Control of Tansy Ragwort in Western Oregon,
1974-1992 Cumulative Discounted Costs and Benefits by Year

	Cumulative Present Value of Benefits and Costs					
	7%			10%		
	Cumulative Costs	Cumulative Benefits	Cumulative Net Benefits	Cumulative Costs	Cumulative Benefits	Cumulative Net Benefits
Year	1974 Dollars	1974 Dollars	1974 Dollars	1974 Dollars	1974 Dollars	1974 Dollars
1974	38,496	0	-38,496	37,446	0	-37,446
1975	75,210	0	-75,210	72,185	0	-72,185
1976	241,635	0	-241,635	225,361	0	-225,361
1977	354,238	0	-354,238	326,174	0	-326,174
1978	555,474	0	-555,474	501,425	0	-501,425
1979	710,652	973,117	262,465	632,880	824,350	191,470
1980	841,778	1,882,573	1,040,795	740,930	1,573,760	832,829
1981	954,752	3,072,515	2,117,763	831,484	2,527,553	1,696,069
1982	1,047,792	4,184,610	3,136,818	904,026	3,394,638	2,490,612
1983	1,131,583	6,114,815	4,983,232	967,575	4,858,548	3,890,973
1984	1,200,395	7,918,745	6,718,349	1,018,341	6,189,376	5,171,035
1985	1,263,445	10,304,964	9,041,519	1,063,586	7,901,769	6,838,183
1986	1,323,399	12,535,076	11,211,677	1,105,437	9,458,490	8,353,053
1987	1,378,264	14,619,292	13,241,028	1,142,690	10,873,691	9,731,000
1988	1,419,528	16,567,158	15,147,630	1,169,945	12,160,237	10,990,292
1989	1,457,236	18,387,593	16,930,357	1,194,172	13,329,825	12,135,653
1990	1,489,147	20,088,935	18,599,788	1,214,114	14,393,086	13,178,972
1991	1,517,550	21,678,973	20,161,424	1,231,381	15,359,687	14,128,307
1992	1,543,431	23,164,991	21,621,560	1,246,685	16,238,416	14,991,731

Note: All crop and livestock impacts, cattle mortality = 2%.
Source: Radtke 1993.

weeds usually follows a logistic growth curve. The initial stages have slow growth but this rate increases at higher rates over time if not controlled (Figure 7 and Table 7).

The net present value of the eastern Oregon Tansy Ragwort Prevention Program on an eighteen year period was calculated to be $1.5 million. A similar program at a cost of about $300 thousand per year that is successful in excluding these weeds from entering Oregon or from expanding into Oregon may have a benefit-cost ratio of 34:1. If this threat is as real as identified by ODA staff, then it would be prudent for Oregon to invest at several times the $300 thousand amount in these weed control and exclusion programs.

3. Scotch Broom

A third example is the threat of Scotch broom infestation reduction through biological agents. Scotch broom affects mainly marginal rangelands and timberlands in western Oregon. Once established, Scotch broom eradication by chemical and/or manual methods is expensive. There is potential for a biological agent to reduce Scotch broom by a total of about 10 percent. A 10 percent reduction may result in an increase of $1.4 million in net value (Table 2). On an annual

Table 5
Biological Control of Tansy Ragwort in Western Oregon, 1974-1992: Benefit-Cost Evaluation

Discount Rate (percent)	Percent Value		
	Program Cost	Benefits	Benefit-Cost Ratio
Seven	$1.5	$23.2	15.0:1
Ten	$1.2	$16.2	13.0:1

Notes: 1. Values in millions of 1974 dollars.
2. Internal Rate of Return = 83.0%
Source: Radtke 1993.

Table 6
Potential Benefit-Cost Ratio of a Biological Control Program for Knapweeds in Oregon

Years	Cost Reduction	Potential Annual Benefits	Annual Costs of Tansy Ragwort Program	Net Present Value of Cummulative Costs	Benefit/Cost Ratio
1	$6,083,434	$0	$41,191		
2	$5,904,509	$178,925	$46,191		
3	$5,725,585	$357,849	$234,341		
4	$5,546,660	$536,774	$180,000		
5	$5,367,736	$715,698	$366,550		
6	$5,188,811	$894,623	$328,000		
7	$5,009,887	$1,073,547	$329,000		
8	$4,830,962	$1,252,472	$329,000		
9	$4,652,038	$1,431,396	$311,000		
10	$4,473,113	$1,610,321	$311,000		
11	$4,294,189	$1,789,245	$284,000		
12	$4,115,264	$1,968,170	$284,000		
13	$3,936,340	$2,147,094	$301,000		
14	$3,757,415	$2,326,019	$301,000		
15	$3,578,491	$2,504,943	$253,000		
16	$3,399,566	$2,683,868	$253,000		
17	$3,220,642	$2,862,792	$240,000		
18	$3,041,717	$3,041,717	$240,000		
Net Present Value	$49,094,566	$12,099,226		$1,543,431	7.8

Notes: 1. Net Present Value is at 7 percent.
2. Eighteen years is chosen as a time frame to make this comparable to the tansy ragwort study.
3. Cumulative costs in constant dollars. See Table 4.
Source: Study.

Table 7
Potential Costs to the State of Oregon in Damage to Oregon's
Natural Resources of Identified Noxious Weeds

Years	Potential Annual Benefits	Growth Rates
1	$999,998	50.1%
2	$1,496,143	49.6%
3	$2,227,760	48.9%
4	$3,293,945	47.9%
5	$4,821,272	46.4%
6	$6,956,271	44.3%
7	$9,840,776	41.5%
8	$13,563,636	37.8%
9	$18,094,760	33.4%
10	$23,231,885	28.4%
11	$28,607,879	23.1%
12	$33,782,407	18.1%
13	$38,377,177	13.6%
14	$42,174,034	9.9%
15	$45,129,438	7.0%
16	$47,324,589	4.9%
17	$48,898,971	3.3%
18	$50,000,000	2.3%
NPV	$163,102,386	

Notes: 1. Net Present Value is at 7 percent.
2. Eighteen years is chosen as a time frame to make this comparable to the tansy ragwort study.

Source: Study.

basis, a program that may cost about $300,000 per year would produce a positive benefit-cost ratio of about 4.7 annually.

The above examples are based on information and data that may be speculative. However, the results do indicate that investment in programs of early detection, containment, and control of noxious weeds is Oregon do make economic sense.

This analysis should be viewed as a reconnaissance study that identifies the scope of the problem of noxious/invasive weeds in Oregon. The study may be used to educate the public of the seriousness of the noxious/invasive weed problem to Oregon's resource production potential and to Oregon's wildlife habitat. More detailed information is required in order to evaluate the most cost effective means of a specific species program. Foregone benefits of invaded (or potentially invaded) areas with the cost of specific programs should be evaluated. Such an analysis may provide targeting areas or programs that provide the highest ratio of environmental benefits to the program costs. A similar approach has been proposed for targeting resource conservation expenditures by Wu et al. (2000) and selecting biological reserves cost-effectively. As Ando et al. (1998) summarizes, "future work should attempt to incorporate the biological and economic

consequences of alternative land management to capture more of the important, but complex, reality inherent in conservation decision-making."

Such analysis is especially important for rangelands where knapweeds and leafy spurge are present. These weeds are expanding as much as 10 percent and 25 percent per year in Montana and in other western states. In Oregon's wetlands and estuaries, spartina is of special concern in that very productive habitat may be altered by this weed that is causing severe problems in the Willapa Bay estuary in Washington and in the San Francisco Bay area in California.

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