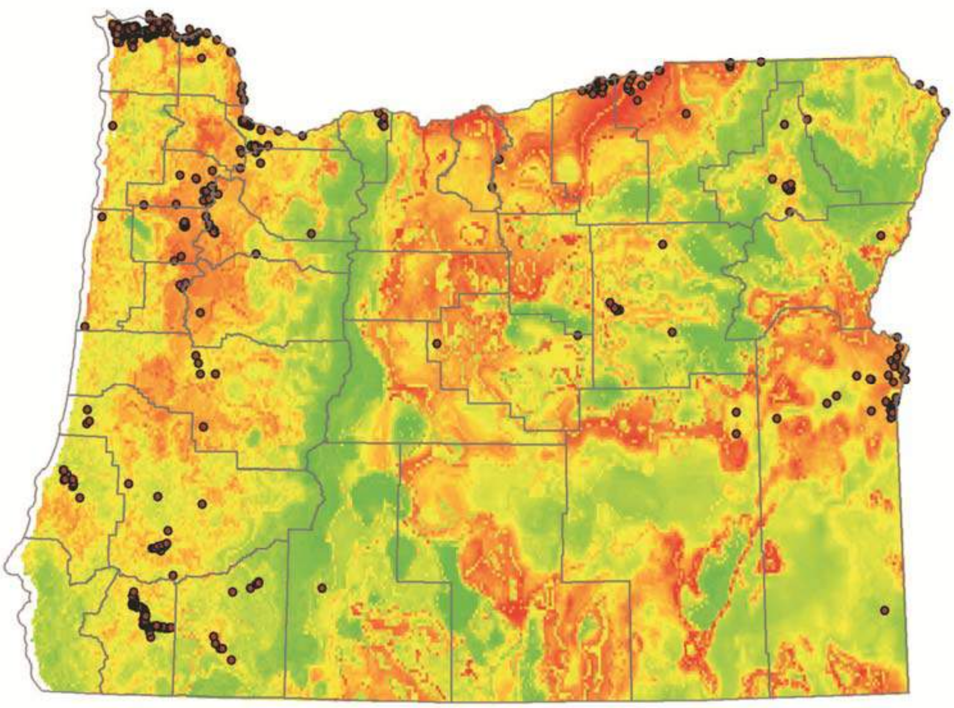
Economic Impact From Selected Noxious Weeds in Oregon



Photos from left to right:

1. Leaf beetle Galerucella calmariensis *feeding on purple loosestrife leaves*
2. Aerial survey for yellowtuft in Curry County
3. Woolly distaff thistle flower head
4. Paterson's curse treatment in Douglas County
Map: Purple loosestrife distribution and habitat suitability in Oregon

Oregon Department of Agriculture

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prepared by

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prepared for

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Noxious Weed Control Program

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PREFACE

The Oregon Department of Agriculture Noxious Weed Control Program (ODA) commissioned an update for the economic analysis study of noxious weeds completed in a previous study with a report dated November 2000. The update work was assigned to the same economic consulting firm who prepared the previous study. The update consultant was The Research Group, LLC, Corvallis, Oregon (TRG). There were four primary authors for the update study report. Shannon Davis was the principal investigator and was greatly assisted by Kari Olsen. Hans Radtke, Ph.D., Consulting Natural Resource Economist, Yachats, Oregon was the study coordinator in addition to having authorship duties. Ed Waters, Ph.D., Professional Economist Consultant, Beaverton, Oregon provided IMPLAN system information for the input-output modeling used in the economic analysis.

For reading convenience, the authors have adopted a less technical writing style in this report. The narrative is not extensively interrupted with citations to material/communications from others. It is also assumed that the reader is somewhat familiar with plant ecology and economic base modeling. A glossary is included, but not all biological and economic analysis terms are defined nor explained. Some narrative in this report is captured or paraphrased from the previous study report when relevant and applicable.

The authors are primarily responsible for updating the economic activity model. The model's output is factors for noxious weed specific marginal economic impact per infestation area. The factors show changes to the state's economy using measurement units for business sales and household income, personal income, and jobs. The ODA has provided results from a separate modeling exercise for estimating the current and potential infestation areal extent. A time dimension for the invasion growth into the susceptible areas is assumed to be immediate and without economy structural adjustment.

The authors' interpretations and conclusions should prove valuable for this study's purpose, but no absolute assurances can be given that the described results will be realized. Government legislation and policies, market circumstances, plant ecology, climate and other influences can affect the basis of modeling assumptions in unpredictable ways and lead to unanticipated changes. The information should not be used for investment or operational decision-making. The authors do not assume any liability for the information and shall not be responsible for any direct, indirect, special, incidental, or consequential damages in connection with the use of the information.

ACKNOWLEDGEMENTS

There are many update study participants to be acknowledged. At the Oregon Department of Agriculture Noxious Weed Control Program (ODA), Tim Butler, Program Manager; Tom Forney, Projects Coordinator; Eric Coombs, Biocontrol Entomologist; and Glenn Miller and Carri Pirosko, Integrated Weed Management Coordinators all provided a wealth of knowledge about noxious weeds and control programs. Alex Park, GIS Specialist provided the spatial modeling information for the invasive species infestations current and susceptible areas and analysis of impacts on natural resources. Tim, Tom, Eric, and Alex at the ODA authored case study write-ups. Dennis Isaacson, ODA retired staff also contributed case study write-up material. Tom Nordblom, Principal Economist, New South Wales Department of Trade and Investment provided information about Australian control programs. Gary Lettman, Economist, Oregon Department of Forestry provided information about invasive species considerations within the context of forestland management. The Cascade Pacific Resource Conservation and Development was the fiscal agent for the update study contracting. Kirk Shimeall was the fiscal sponsorship coordinator. Information was received from Oregon county noxious weed coordinators and other technicians in academia and industry. Permission for revealing their names was not sought, so they will have to be thanked anonymously.

The authors made certain independent examination of this report was carried out in accordance with accustomed procedures and that review comments were carefully considered. While all of these acknowledged contributors and reviewers provided material and comments that assisted in making the update study results as sound as possible, they were not asked to endorse study findings and results. And as such, the authors are solely responsible for content.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT.)

LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS (CONT.)

APPENDICES

GLOSSARY

AUM	An animal unit month (AUM) is the amount of forage needed by an animal unit (AU) grazing for one month. The quantity of forage needed is based on the cow's metabolic weight. The measure for an AU is defined to be one mature 1,000-pound cow and her suckling calf. The average consumption rate is 26 pounds of forage dry matter per day (Society for Range Management Glossary). That makes an AUM equal to 31 days x 26 pounds per day or about 800 pounds of air-dried forage. More conservative or liberal values are also used, for example 600 to 1,000 pounds of forage per AUM are common values.
BCA	Benefit-cost analysis (BCA) (see "net economic benefits")
CEA	Cost effectiveness analysis (CEA) is a method to assess how to get the biggest "bang for the buck." CEA can be used to compare two or more alternatives when the projects have the same type of outcome. For example, what alternative noxious weed control technique might achieve the least cost long-term for agricultural production. In the case of comparisons for projects that will have ongoing costs versus one-off costs, equivalency annualized costing procedures are first applied.
CWMA	Cooperative weed management areas (CWMA)
Economic consequences	An economic contribution metric that relates to a short-term perspective for how an industry is represented in the local economy. If there is a change in the economy's industry activity, there may very well be adjustments in the longer term that may cause increased or decreased economic contributions. For example, a tourism business start-up may replace a fishing industry business closure.
Economic metric	The economic contribution measurement selected for this study is business sales, personal income, and a jobs metric. It could just as well been other metrics that would describe the same economic direct and secondary effects, but in a different dimension. Other example metrics are business output (analogous but different than sales), value added, generated government taxes, and job equivalents. The jobs metric is different than the jobs equivalent metric. The former includes full-time and part-time employees, and proprietors. The latter would be a measure for a full-time position at an assumed compensation level.
EDRR	Early detection and rapid response (EDRR) is an approach that focuses on surveying and monitoring at-risk areas to find infestations at their earliest stages of invasion. After initial introduction of a new invasive plant, there is a short period of opportunity for eradication or containment. Once permanently established, a new invader becomes a long-term management problem.
ESA	Endangered Species Act (ESA)

FEAM	Fishery Economic Assessment Model (FEAM) was used to calculate fishing industry economic contributions. The FEAM is a derivative model of the IMPLAN system.
IMPLAN®	The IMpact Analysis for PLANning (IMPLAN) is a software and dataset system for input-out models applicable to the nation, states, and counties. Datasets for U.S. zip codes are also available.
Input-output (I/O)	The relationships between suppliers and producers and the economic impact of import or export of producer goods to meet consumer demand. The relationship is the extent that the outputs of one industry become the inputs to another.
IWM	Integrated Weed Management (IWM)
KRESS	The Kinetic Resource and Environmental Spatial System (KRESS) is software used to define areal extent of habitat suitability for noxious weed invasions.
Marginal changes	The change in economic value associated with a unit change in output, consumption, or other economic indicator.
MCDA	Multi-Criteria Decision Analysis (MCDA)
Multiplier effect	The economic effects from subsequent rounds of spending (indirect and induced effects) that occur before money has leaked from the economy. For example when personal income is the economic metric, it includes the net earnings from jobs and business owner income where commercial businesses and recreational users purchase goods and services. It also includes the net earnings gained from businesses receiving the share of household spending that can be attributed to income from the affected industries.
Net economic benefits	The sum of positive and negative net economic values (NEV) typically used in benefit-cost analysis (BCA) framework. NEV is measured by the most someone is willing to give up in other goods and services less the actual costs in order to obtain a good, service, or state of the environment. The accounting of benefits in a BCA would include valuations for not only extracting or disturbing natural resources like fish, but also appreciating their non-use. The accounting for costs in a BCA would include opportunity costs, such as for the next best use of the investment being studied. One summary statistic for the BCA is net present value (NPV), which is the sum of discounted net between benefits and costs over the period being analyzed. The BCA has the advantage for including economic effects from decisions made in a current year that are staged over future years. It is important to declare an accounting stance when applying a BCA to understand which user and non-user groups are being included. A national economy accounting stance is generally declared for an analysis when decision actions affect non-users.
NEV	Net economic value (NEV) (see "net economic benefits")

Oregon Noxious Weed Rating System	"A" listed weed - a weed of known economic importance which occurs in the State in small enough infestations to make eradication or 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 eradication or intensive control when and where found. "B" listed weed - a weed of economic importance which is regionally abundant, but which may have limited distribution in some counties. Recommended action: Limited to intensive control at the state, county, or regional level as determined on a site specific, case-by-case basis. Where implementation of a fully integrated statewide management plan is not feasible, biological control (when available) shall be the primary control method. "T" listed weed – annually, a target list of weed species is selected that will be the focus for prevention and control by the Noxious Weed Control Program. Action against these weeds will receive priority. T listed noxious weeds are designated by the Oregon State Weed Board and directs ODA to develop and implement a statewide management plan. T listed noxious weeds are species selected from either the A or B list.
ODA	Oregon Department of Agriculture Noxious Weed Control Program (ODA)
ODF	Oregon Department of Forestry (ODF)
ODFW	Oregon Department of Fish and Wildlife (ODFW)
OSU	Oregon State University (OSU)
Personal income	Income accruing to households in the form of net earnings from wages, salaries, and proprietorship income. Total household personal income includes transfer payments (such as social security payments) and investment income (such as stock dividends, rental property income, and interest payments).
PRISM (Chapter II)	Parameter-elevation Regressions on Independent Slopes Model (PRISM)
PRISM (Chapter III)	Partnerships for Regional Invasive Species Management (PRISM)
Public good	An activity may cause additional effects on uninvolved parties. The externality effects may be negative (public cost) or positive (public benefit). Those who suffer from external costs do so involuntarily, whereas those who enjoy external benefits do so at no cost. Eradication or control of unwanted and noxious weeds with biological agents is an example of a public good. Private parties may be required to pay for the eradication costs where culpability can be established, but the public enjoys the benefits. In turn, the public may solely be the payee for eradication and private parties have a "free ride" in absorbing the benefits.

Regional economic impact (REI)	Economic contribution and REI are different concepts, but in this report the two terms are used interchangeably. A stricter use of the term "contribution" would be for an economic activity that exists. The use of the term "impact" would be when an economic activity is to be subtracted or added. It is the share of the regional economy supported by the expenditures made by the industry being analyzed. It can be expressed in terms of a variety of economic metrics.
Resource rent	The term resource rent (or just the one word rent) introduces opportunity and expectation costs to a business operation profit equation. There would be subtractions from the production revenues from not only the operation costs, but also from using the capital investment and labor investment in a next best substitute manner, and the subtraction for the perceived amount of normal profit to be made in the business operation. Resource rent calculations typically do not include external effects outside the operation, such as ecosystem effects.
Response coefficient	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.
Success rate	A recreational effort (usually measured in a visitor day) per taking unit (for example one retained fish or one killed deer). The inverse of success rate for fishing is sometimes titled "catch per unit effort."
WSM	Weighted Sum Model (WSM)
WTP	Willingness to pay (WTP) is the maximum amount an individual is willing to sacrifice to procure a good or service minus the actual cost of the good or service.

EXECUTIVE SUMMARY

Noxious weeds are depriving Oregon agriculture and other natural resource industries of significant revenues. This causes adverse economic impacts to Oregon's economy. The Oregon Department of Agriculture Noxious Weed Control Program (ODA) contracted with The Research Group, LLC (TRG) in Corvallis to conduct an economic impact study for current and potential infestations of specific noxious weeds on Oregon rangelands, farmlands, forestlands, and wildlands. The study is distinctive in that it incorporates Oregon WeedMapper software program results for existing invasions, which was analyzed along with other environmental variables using a unique geospatial analysis model to provide noxious weed habitat suitability data for potential infestations.

The study found there is an estimated annual loss of almost $83.5 million personal income to the State's economy from 25 selected weed species. (All referenced values in the study are adjusted to 2012 dollars.) That is the equivalent to the loss of about 1,900 jobs in the private sector. If left unchecked, there is a potential annual loss of $1.8 billion personal income and 40,800 jobs. Two of the 25 selected weeds, Armenian blackberry and Scotch broom, are widespread and contribute $79.6 million to the current overall economic impact. The remaining 23 species are limited in distribution and are under intensive management thus contributing to less than five percent of total current impacts.

The purpose of this current study is to update a previous similar study of noxious weeds found in Oregon. Case descriptions for several individual species are documented to bring clarity for how different prevention and control programs are utilized and have demonstrated success. Government policy implications for providing noxious weed research and control program services are discussed. In particular, the current study provides an opportunity for ODA to look at the impacts of two widespread invasive weeds (Armenian blackberry and Scotch broom) and address the potential economic impact of up and coming noxious weeds. The study reveals the benefits of having safeguards such as biological, prevention, and other control programs in place to minimize impacts.

The noxious weeds selected for the analysis contain all but one of the previous study's weeds, two grouped together, and six additional species for a total of 25 weeds. This economic analysis is limited to measurements of regional economic impacts (REI) using the metrics for business sales, personal income, and jobs. This economic analysis distilled the selected weeds into 15 unique economic model groupings. The marginal REI calculations for the groupings can be used to calculate a new weed's economic impacts.

The economic impact information is supplemented with explanations and estimated unit costs for different control approaches including none; prevention; early detection and rapid response (EDRR); and, long-term maintenance. The cost discussions when related to the economic impact results provide illuminating information about the importance of control programs. However, the provided economic impact information in the current study is not from a formal benefit-cost analysis (BCA). The REI measure tells us an immediate with or without change in economic activity. A BCA deals with the time value of money where sometimes one-time costs are incurred today, but net economic benefits accrue far into the future. A BCA can include externality effects or changed societal values, and a BCA can account for the positive benefits as well as the foregone economic activity. The disadvantage of a BCA is that the measurement can lack tangibility and authenticity. The public and decision makers are generally only provided simple benefit-to-cost ratios and other summary indexes without knowing assumptions and methods.

A properly conducted BCA will show whether the net economic benefits for a single weed control project make it worth undertaking a control program given commercial and recreational production to be recovered or preserved. For example, the previous study found that biological control of tansy ragwort has a $13 return for every $1 investment and prevention programs have a benefit to cost ratio of 34 to one.

The assumed affected economic activities for the analyzed weed species were associated with the previous study four land types:

1. Rangelands: livestock loss, reduced cattle foraging, and reduced wildlife grazing.
2. Farmlands: seed loss, decreased other agriculture, and reduced aquaculture.
3. Forestland: reduced timber production.
4. Wildlands: wildlife and fish stressor that lowers hunting, fishing, and boating recreational uses.

Economic model parameters specific to the analyzed weeds include the following:

1. Plant coverage factor. The share of the infested areas that affects a particular economic activity.
2. Degradation factor of the economic activity. This factor can have various interpretations depending on the economic activity. For example, it could be interpreted as a cow mortality rate for the livestock economic activity. The assigned degradation factors are different for an economic activity affected for a particular analyzed noxious weed located on a particular land type. The factors are normalized to apply to an economic activity and are usually expressed as a percent.
3. Land production factors. The factors are an assignment based on the land use for livestock, other agriculture, timber, or wildlife management.

The geospatial analysis model developed to show current and potential area infestations is titled Kinetic Resource and Environmental Spatial System (KRESS). Its output was the potential range across Oregon for the 25 selected weeds. The modeling was based on the weeds' currently known locations, and their relationship with environmental and elevation variables. A post KRESS outcome factor was applied to forestry susceptible areas to account for land management set asides for non-timber production. The KRESS models utilized the Oregon WeedMapper dataset, which is comprised of 300,000 known weed infestations across the state. The KRESS input data is collected through partnerships with non-profit, local, county and federal agencies. The KRESS determined mean predicted area was bounded with confidence intervals of one standard deviation to provide a statistical measure of precision. Potential weed ranges were compared against different land uses capable of being degraded by noxious weeds. The eight land types in the KRESS model were mapped to the four land types used in the economic activity modeling.

Of the estimated foregone economic activity from current levels of noxious weed infestations ($83.5 million personal income and about 1.9 thousand jobs), the economic impact shares from the analyzed species three largest contributors (in order) are: Armenian blackberry 48 percent, Scotch broom 47 percent, and rush skeletonweed two percent. The current study economic impacts without the six additional analyzed species are $43.1 million, which compares to the previous study $101.5 million. The decrease would be an indicator of success in the containment efforts for the previous study's analyzed species.

The estimated economic impact of the analyzed species would be between $1.5 billion and $2.4 billion personal income if infestation moved into the susceptible areas. The point estimate for mean within this range would represent 40.8 thousand jobs. The three analyzed species with the largest contributions for susceptible areas are: Armenian blackberry 15 percent, rush skeletonweed 12 percent, and gorse 11 percent. For the six species analyzed for susceptible areas in the previous study (tansy ragwort, distaff thistle, leafy spurge, purple starthistle, hawkweeds, and spartina), the current study economic impacts from susceptible areas is $305.0 million as compared to the previous study $68.7 million. While methods differ between the two studies on the estimation of susceptible habitat, an inference is that there is a growing threat from the six species.

The results are from complex methodological calculations that have high uncertainty. For example, the species with the second highest economic loss threat of the 25 analyzed species is Scotch broom. The current infestation share of lost economic activity for this species is $39.5 million personal income. The important lost economic activity associated with this species is from timber production degradation following invasion. An uncertainty analysis shows a 42 percent increase in the degradation factor and susceptible area would about double the lost income over the current study estimate.

There are five case studies that provide examples of control projects conducted by ODA. Biological control and prevention programs are shown to be beneficial and can have a high return on the investment from these types of activities.

The unintended spread of introduced species such as Scotch broom can turn them into undesirable plants in a very short time. 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 insects or microorganisms that adversely affect the unwanted plant. While more emphasis is being placed on biological controls, chemical or manual control in the early stages of invasion may also result in favorable cost effectiveness. Programs for existing noxious weeds that are expensive to eradicate with manual or chemical means, and that have no potential biological control agents, may not evaluate financially favorable. In such cases, education about containment may be the only option.

The control and spread of noxious weeds are of public concern because of a private market externality problem. The background research and maintenance costs can be prohibitive for any single individual or even single industry. A public agency may need to be involved when private party culpability and enforcement processes are not adequate for controlling invasions. Once control programs have been established, the private businesses will become a free rider to the benefits of the program in the case the weed is deleterious to commercial production. Depending on harm caused by particular weeds, the public will also benefit from control programs through greater recreational use opportunity. In either case, there is a gain in social values from knowing ecosystems are being restored.

ODA serves as a leader in protecting natural and agricultural resources from the introduction and spread of noxious weeds. ODA approaches noxious weed control with an integrated, multidisciplinary approach. Integrated Weed Management (IWM) is a decision making process based on the best available science and experience of weed managers. Control options depend on site-specific information and the best strategy or combinations of strategies for effective management decisions. IWM uses all available methods and techniques for noxious weed control including prevention, mechanical, cultural, chemical and biological control.

There are many entities involved in noxious weed management in Oregon including state and federal agencies, county weed control programs, cooperative weed management areas, and universities. The Oregon Invasive Species Council serves to protect Oregon's natural resources from invasive species thorough coordination efforts. Other regional and national groups are engaged to increase awareness, address policy needs, and direct resources toward invasive plant control. Government agencies and universities contribute through research services, sponsored prevention and control operations, financial incentive grants, and punitive regulations.

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I. INTRODUCTION

A. Purpose

The purpose of this current study is to update the economic analysis found in a November 2000 publication sponsored by the Oregon Department of Agriculture Noxious Weed Control Program (ODA). The publication was titled "Economic Analysis of Containment Programs, Damages, and Production Losses From Noxious Weeds in Oregon" and was authored by The Research Group, LLC (TRG). The publication described the economic analysis results for a reconnaissance level study of 21 weeds listed in Oregon as noxious.[1,2] The previous study analysis was for both the existing infestation and the potential spread of the noxious weeds.

Almost 15 years later, there is more detailed information about harm caused by noxious weeds; useful prevention and control programs; and, changes in the type and extent of economic activity that is affected by noxious weeds. There are improved methods available to determine infestation susceptible areas using environmental and landscape variables to determine habitat suitability. The current study's noxious weed list contains the previous study's weeds sans one weed, two grouped into one, and six new weeds added for a total of 25 weeds (Table I.1). The current study economic analysis is limited to be for measurements of regional economic impacts (REI) using the metrics for business sales, personal income, and jobs.[3]

The current study economic analysis descriptions are supplemented with explanations and estimated costs for different control approaches including none; prevention; early detection and rapid response (EDRR); and, long-term maintenance. Sometimes the three control approaches are additive and other times singular, but all will have future costs and benefits for reduced environmental impacts and increased water and land productivity.

Economic modeling that shows the REI with and without prevention and controls becomes a tool to run scenarios for informing policy and management decision-making about best use of noxious weed management funds. Case descriptions for several individual species are documented to bring clarity for how different prevention and control programs are utilized and have demonstrated success. Government policy implications for providing noxious weed research and control program services are discussed.

B. Problem

Noxious weeds in Oregon are a subset of both plant and animal invasive species that threaten ecosystems, commercial land and water production, and human health. An economic analysis of even the noxious weed subset of the overall invasive species problem can be useful for educating and informing about necessary regulations and making control program funding decisions.

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1. The Oregon State Weed Board adopted lists of noxious weeds assists in setting control program priorities as authorized by Oregon Revised Statutes Chapter 569.
2. TRG (November 2000) assessed 14 species primarily affecting rangelands, two species primarily affecting both rangeland and farmland, two species primarily affecting forests, and three species primarily affecting wildlands.
3. This report contains a glossary of economic analysis terms. There is also a chapter that describes methods and assumptions used in the economic analysis.

Economic analysis is complex when done correctly. There are social as well as economic consequences, and while economics does have the tools to deal with the broad effects, results can be abstract and lose tangibility in informing. This current study attempts to limit the economic analysis to determining the most understandable measurements. While the analysis results will be highly qualified, there are narrative explanations about the assumptions and exclusions so that the reader has an understanding about where results fit into other economic studies about invasive species. There is a growing body of noxious weed economic study literature that is in addition to the already mentioned TRG (2000) report. There is national (for example Pimentel et al. 2001) and worldwide (for example Emerton and Howard 2008) orientation to the studies. A report prepared by PNWER (2012) summarized several state level, national, and worldwide economic studies.

Other studies have provided economic evaluations of certain noxious weed species in certain areas. For example, the estimated total direct cost for all Idaho lands is $300 million annually based on information from private lands, and federal, state, and county organizations (Idaho State Department of Agriculture 1999). A dollar value for the loss of plant diversity, wildlife habitat, watershed health, recreation and tourism, human life and property was not completed for the Idaho study.

An economic study of leafy spurge's competition with desirable plants was completed for areas in Montana, Wyoming, and both Dakotas. The study found reduced carrying capacity and therefore reduced ranchers' economic contribution to the regional economy estimated to be nearly $129 million personal income (Federal Interagency Weed Committee 1999). The same study reported that, if spotted knapweed were allowed to continue to spread to the fullest extent of its range, it would 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, spotted knapweed has spread from three areas in 1982 to throughout the state by 1999. Without a containment program, it has the potential to have a similar negative effect on Oregon's economy as what has happened in Montana.

The estimated annual loss of productivity caused by invasive species in the U.S. is $120 billion (Pimentel et al. 2004). The loss in production in the agricultural sector alone has been estimated to be $20 billion (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.

C. Analytical Framework

The following workflow is used to complete the current study economic analysis.

1. The Oregon State Weed Board has designated 118 weeds as noxious as of the date of this publication. ODA staff selected 25 of the most worrisome for economic harm and infestation

potential for inclusion in this current study. Appendix A contains a summarized description of the analyzed species status. Appendix B contains descriptions of the harm that can be caused by the species and includes affected area maps for the species.

2. The areal extent of the analyzed noxious weeds existing and potential infestation was determined using a geospatial habitat suitability model. Infestation existing and susceptible area and stream lengths of anadromous fish habitat were the model outcomes. The statistical lower bound, mean, and upper bound were calculated for the susceptible habitat. Appendix D shows model outcomes by species and by classifications for eight land types (agriculture, rangeland, urban, riparian, pasture, forestry, estuarine, and wildlife). Table I.2 depicts the crosswalk between the current study eight land types, the previous study four land types (rangeland, farmland, forestland, wildland), and the associated economic activity model type (livestock, agriculture, timber, recreation).

   The habitat suitability model is titled Kinetic Resource and Environmental Spatial System (KRESS). KRESS inputs are environmental variables for precipitation, elevation, wet/freeze days, growing degree days, and other temperature data. The variables are combined to generate a gradient from low to high probability of suitability based on where the plant grows today to predict where it could grow in the future. There are other limiting factors to plant growth such as soil characteristics and land management practices that were not included in the habitat suitability model's design. A post model outcome factor was applied to forestry susceptible areas to account for land management set asides for non-timber production.

3. The previous study's economic model for direct effects and REI was updated. Only market valuation of harm is applied in this current study. Other valuations would have to be assessed if rigorous benefit-cost analysis (BCA) was desired, such as for considerations where the noxious weed threatens endangered species. The direct effect's economic indicators are commercial production sales and recreational expenditures foregone due to noxious weed infestation (Figure I.1). Decreased commercial production and shrinking recreational use will decrease business sales and attendant labor and proprietor income. The decreases have multiplier effects throughout regional and state economies.

   The current study economic assessment model includes new production prices, recreational use spending, and carrying capacity assumptions. A marginal per area economic metric for sales and personal income was calculated for each model type and previous study noxious weeds. Biophysical information for the new six weeds in the current study was used to decide which combination of previous study economic production model type and land type was to be associated with the new weeds. The marginal economic impact factors were then applied to the infestation current and susceptible areas provided by the geospatial habitat suitability model.

4. Prevention and control programs and their costs are described for the analyzed noxious weeds. Programs must be tailored to the invasive progression status and consideration for harm being done to an ecosystem. The management approach for invasives must have an ecosystem perspective because there can be benefits from noxious weeds as well as negative impacts to land/water cultivation production and recreation. The ecosystem perspective is

important in economic analysis discussions because decisions about best use of limited management funds need to consider broad objectives for cost effectiveness in management spending. It is necessary to know the status, biological development, effects on human use of land, and effects on biodiversity so that the end goal for management will justify the means and cost to get there.

When the economic assessment information was complete, it was then referenced in discussions about the benefits of prevention and control programs. Economic assessments of noxious weeds or invasives of any flora or fauna will show massive economic damage numbers if the species are allowed to flourish. The numbers are generated in this current study to not only underscore the importance of prevention and control programs, but also at the same time identify the economic sectors most impacted by the direct and secondary effects.

D. Report Contents

This report begins with an introduction chapter that summarizes the purpose and analytical framework for the updated economic analysis. Chapter II describes the economic and geospatial analysis methods and assumptions used in the economic assessment model. Oregon noxious weed prevention and control programs are described in Chapter III. Discussion about modeling results is contained in Chapter IV. The discussions include comparing prevention and control costs and the foregone benefits for several Oregon noxious weeds. Extensive use of appendices is made to provide noxious weed inventory and management descriptions. Appendix A summarizes in a table format the bio-economic characteristics of the current study's analyzed noxious weeds. Appendix B describes in detail the analyzed noxious weed presence in Oregon. The appendix offers additional economic information about production losses and control cost for five case study noxious weeds. Appendix C shows the economic assessment model assumptions, algorithms, and dependencies. The noxious weeds current and susceptible area determinations are shown in Appendix D.

Table I.1
Noxious Weeds in Current and Previous Study

Species in Current and Previous Study

Current Study	Previous Study
Cordgrass	Spartina
Gorse	
Leafy spurge	
Hawkweeds (meadow and orange)	Yellow, orange hawkweed
Mediterranean sage	
Perennial pepperweed	White top and perennial pepperweed
Purple loosestrife	
Purple starthistle	
Rush skeletonweed	
Scotch broom	
Scotch thistle	
Tansy ragwort	
White top (hoary cress)	White top and perennial pepperweed
Woolly distaff thistle	Distaff thistle
Yellow starthistle	
Knapweeds - Diffuse	
Knapweeds - Meadow	Russian knapweed
Knapweeds -Spotted	
Knapweeds -Squarrose	

Species in Current Study and Not in Previous Study

Armenian blackberry (Himalayan)
Dalmatian toadflax
Giant hogweed
Japanese knotweed
Kudzu
Paterson's curse

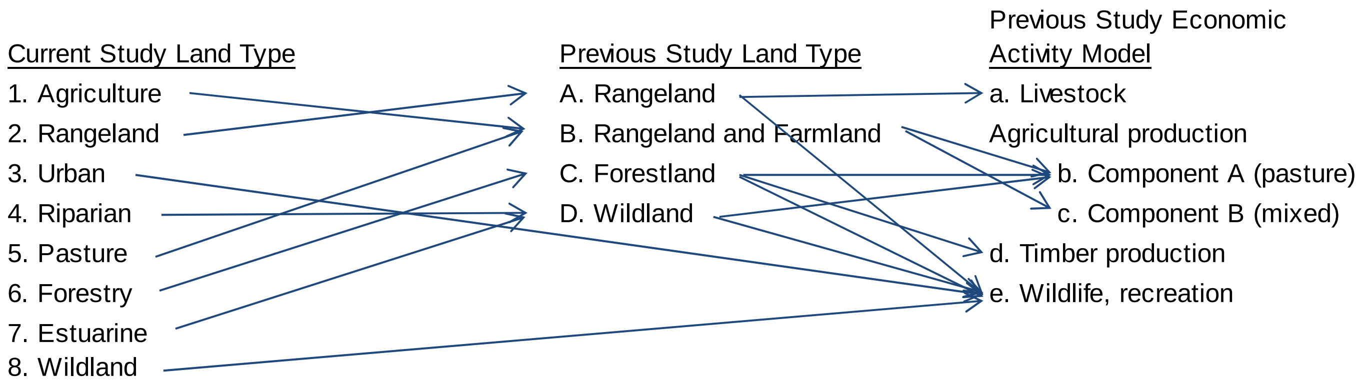
Species in Previous Study and Not in Current Study

Brazilian elodea

Notes: 1. The table's species list uses generally known common names (less known are in parenthesis). See Appendix A weed profiles for taxonomy of genus names and the species name.

Source: Study.

Table I.2
Crosswalk of Current Study and Previous Study Land Types
and Associations With Economic Activity Models

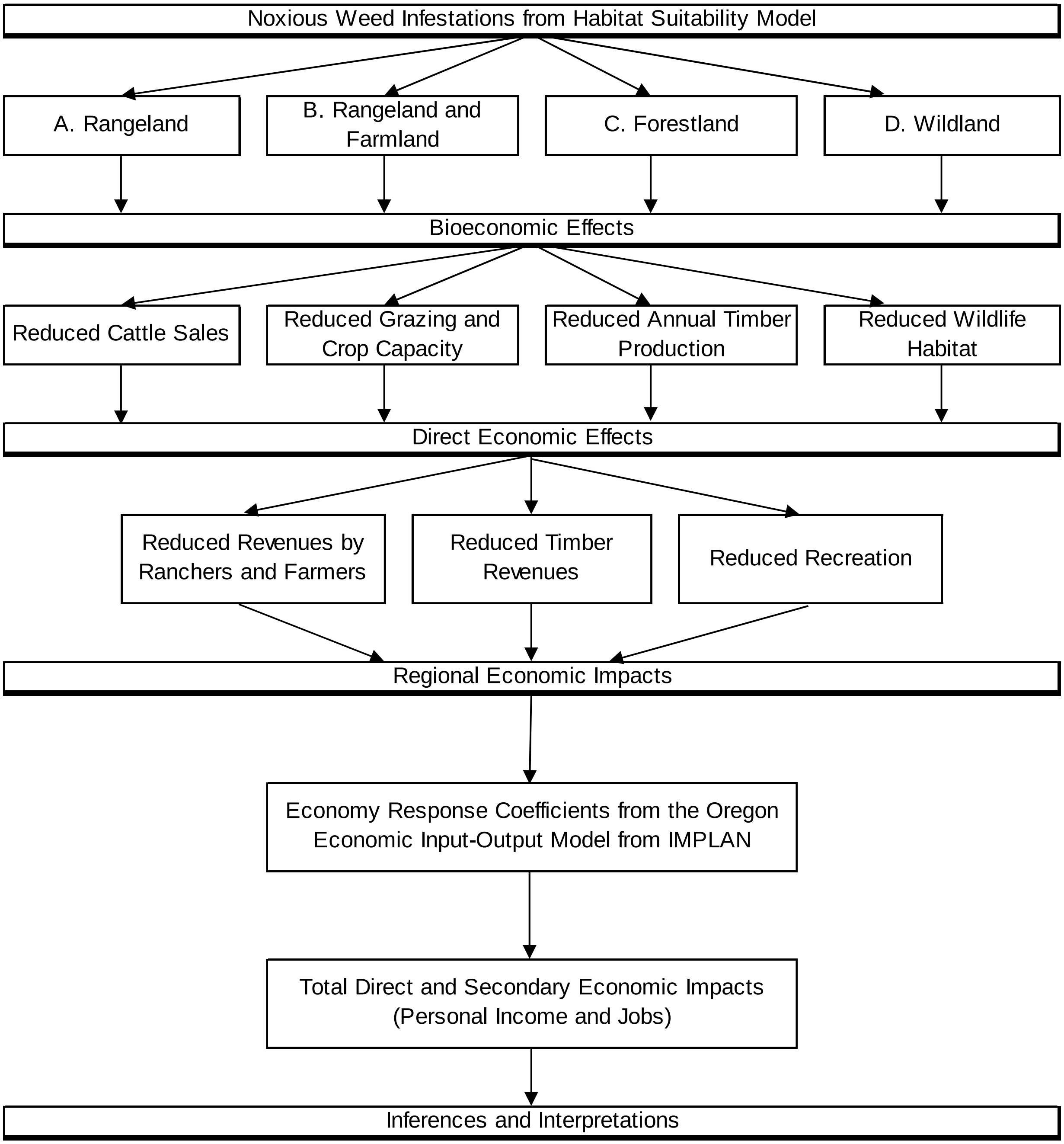


Current Study and Previous Study Infestation Land Types and Association With Economic Model

Current Study		Previous Study	
Species	Land Type	Land Type	Economic Model
Armenian blackberry (Himalayan)	1, 3, 4, 5, 6	***C***	***b, d, e***
Cordgrass	7	D	c, e
Dalmatian toadflax	2, 3, 4, 8	***A***	***a, b, e***
Giant hogweed	3	***B***	***b, c***
Gorse	3, 5, 6, 8	C	b, d, e
Japanese knotweed	3, 4	***A***	***a, b, e***
Kudzu	3	***A***	***b, e***
Leafy spurge	2, 4, 5, 8	A	a, b, e
Hawkweeds (meadow and orange)	3, 4, 8	A	b, e
Mediterranean sage	2	A	b, e
Paterson's curse	1, 2	***A***	***a, b, e***
Perennial pepperweed	2, 4, 5	A	a, b, e
Purple loosestrife	4, 8	D	e
Purple starthistle	2	A	none
Rush skeletonweed	1, 2	B	b, c
Scotch broom	3, 6	C	b, d, e
Scotch thistle	2, 3	A	a, b, e
Tansy ragwort	5, 8	B	a, b, c, e
White top (hoary cress)	1, 2, 5	A	a, b, e
Woolly distaff thistle	2	A	a, b, e
Yellow starthistle	2, 3, 5	A	a, b, e
Knapweeds - Diffuse	2, 3, 5	A	b, e
Knapweeds - Meadow	3, 5, 8	A	b, e
Knapweeds -Spotted	2, 3, 5	A	b, e
Knapweeds -Squarrose	2	A	b, e

Notes: 1. Species in the current study and not the previous study show bold and italic font for the assigned previous study land types and economic activity model.
Source: Study.

Figure I.1
Economic Assessment Model System



Notes: 1. IMPLAN is a software and data system for creating multiplier and other useable economic analysis factors from input-output models of the national, state, and county economies in the U.S. The system allows for multi-state and multi-county regional economies to be developed.
Source: Study.

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II. ECONOMIC AND GEOSPATIAL MODELING PROCEDURES

A. Economic Measurement Concepts

Economics provides tools to inform managers and policymakers about the economic impacts of existing and potential infestations and the benefits that can come from different noxious weeds prevention and control programs. Cusack et al. (2009) points out that economic studies have been particularly focused on forest or agricultural potential infestation production losses and damage to natural resources which lowers both market and social values. The economic impacts on ecosystem functioning and human health have been less well studied. Invasive species management is also a "weakest link" public good, meaning incentives exist to take a "free ride" on the efforts of others and shoulder less than a fair share of the costs of prevention and control. Economics can be used to provide before-the-fact evaluation, prioritization, and selection of prevention and control programs (ex-ante). After-the-fact evaluation of management measures assesses their efficiency and effectiveness (ex-post).

Economic analysis generally uses two measures. The first measure is typically referred to as REI modeling because the impacts are the effects from changed spending within an area for goods and services. The measures for the effects can be business sales, personal income, and jobs. The first measure's calculation is accomplished through the use of input-output (I/O) modeling. I/O models are mathematical representations of the economy that describe how different economic sectors are linked to one another. The models trace how spending associated with an activity such as agricultural operations and recreation circulates through a regional economy. The initial direct expenditures start a flow of spending in the region. For example, farmers make purchases at local businesses. These businesses in turn pay suppliers for goods and also pay workers for their labor. The dollars from the initial expenditures are "multiplied" through rounds of spending but leak out of the local and state economy over time.

The second measure is net economic value (NEV) and is typically used in a BCA. A BCA accounting stance is usually at the national level. Program costs can be compared to program benefits using discounted streams of future net economic benefits.[1] NEV measures:

- Deal with the time value of money where sometimes one-time costs are incurred today, but net economic benefits accrue far into the future.
- Will show if program or policy ultimately has an investment index (net economic benefits in numerator and costs in denominator) greater than one or an acceptable return on investment (usually measured as an internal rate of return that is compared to the adopted discount rate).
- Useful for comparing one program or policy to another to see which is better.
- Advantages are that it can include externality effects or changed societal values.

1. Net economic benefits are value received minus the dollar amount paid. The two main types of net economic benefits are producer surplus (revenues minus costs), and consumer surplus (willingness to pay (WTP) minus the amount actually paid). Several types of societal values (e.g., existence value, option value and bequeathal value) can also be defined to be included net economic benefit calculations.

Other studies' BCA measurements are referenced, but calculations are not included in the current study. The reason is that the measurement can lack tangibility and authenticity. The public and decision makers are provided simple benefit-to-cost ratios without knowing methods. For example, what is the accounting stance (regional, national, etc.), and are opportunity and social costs included? BCA is difficult because in many cases total costs for prevention and control programs are unknown. There may be many private land owners and agencies involved, all operating independently and at different operational levels. Further, land management operations that have controlling effects will have taken place anyway. It would be impossible to track the beneficial uses arising from the costs of those operations. For example, reforestation of timberlands is required the Oregon's Forest Practices Act. The reforestation design may be partially influenced by the control of noxious weed spread. Lastly, noxious weeds are mostly present because of their beneficial uses. The BCA should necessarily account for the positive benefits as well as the foregone economic activity.

Other economic analysis can be completed such as cost effectiveness analysis (CEA) which finds relative costs for generating a desired outcome or objective like eradicated weed infested acreage, increased grazing production, or saved fish smolts. The advantage for using CEA is that benefits do not have to be calculated.

Sometimes a suite of metrics is used for the economic measurements. The suite of metrics offers a description of the same economic effects, but in different dimensions. The choice of one metric or another is related to a person's familiarity with a particular measure, and how the measure will be used in providing information for possible tradeoff decisions. All too often a metric is chosen simply because it is larger (such as business sales) than another (such as personal income) in order to impress and justify issue positions. The meaning and usefulness of economic measurements can be lost in this choice of metrics.

The analytical framework described in Chapter I explains the direct effects and REI methodological approach and measurements to be used for this current study's economic analysis. The chosen valuation metrics for this current study (business sales, personal income, and jobs) all have qualities for being understandable and comparable. This chapter first explains the methods and assumptions used to develop the economic assessment model. Second, the specifications for the economic assessment model are explained. Third, economic analysis results are shown. Discussion about the results is contained in Chapter IV.

B. Regional Economic Impact Modeling

Developing an REI measurement for producers starts with determining the actual or potential expenditures made in a defined geographical region. For example, a farmer will purchase herbicides at a local supplier. If the herbicide is manufactured outside of the region, then a portion of the farmer's payment will leak to the economy where it is manufactured. A portion of this purchase will be retained in the local economy for transportation services and wholesale and retail trade operations. Some of the money will make its way to pay for wages and salaries of those who work for 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 gross profits is the economic impact from the purchase. The measurement units can be business sales, personal income, or jobs. Business sales are the total purchases created by the affected industries. When personal income is estimated, a job metric can be calculated by dividing the total personal income created from the purchases by the annual average earnings received across all affected occupations in the geographical area.

The REI is calculated via an I/O model. An I/O model approximates an economy 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. The annual dollar amounts of these transactions are organized into a table called a transaction matrix. The transaction matrix table generated by an I/O 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 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]

The I/O model used in the previous and this current study is the IMPLAN system.[3] The IMPLAN system was designed for the construction of regional I/O 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, nation) relevant to the analysis. Over time, researchers, analysts, and managers have adapted IMPLAN to a wide array of resource planning applications.

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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. There are different multipliers for the different modeled outcomes.
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.
3. The IMpact Analysis for PLANning (IMPLAN) system 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. 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. Operation of the IMPLAN model and database was subsequently transferred to the University of Minnesota, where it was administered by the Minnesota IMPLAN Group, Inc. (Alward et al. 1989). The system is now owned and administered by IMPLAN Group LLC located in Huntersville, N.C.

It is important for an analyst to understand the industry being studied. If the industry is well represented by a sector already contained in IMPLAN, then a derivative model need not be constructed. If it is not represented (commercial fishing is a good example of not having representation), then the multipliers and response coefficients must be derived from IMPLAN. The derivative process includes disaggregating as well as aggregating sectors. The analyst must be careful to marginalize transportation services and wholesale and retail trade so as not to duplicate total business sales when undertaking the derivative model building. The process allows for the targeted industries to be further specified 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 in this current study. The most important reason for using this derivation approach is that it provides the user with a detailed analysis of specific industry operations, and a thorough evaluation of resulting economic impacts on the affected region.

C. Habitat Suitability Geospatial Modeling Methods

Working with Oregon State University (OSU) beginning in 2011, ODA quantified the potential distribution of invasive plant species by utilizing topographic and climatic data in Oregon in a Multi-Criteria Decision Analysis (MCDA) Weighted Sum Model (WSM) inside the KRESS developed at OSU (Johnson et al. 2005). Seven climatic variables and a digital elevation model GTOPO30 were scaled to 256 levels and re-sampled to 1.25 arc-minute resolution for analysis in KRESS. Relative probabilities were extracted from where a condition is met, such as the presence of a weed and used as the relative weight in the WSM (Johnson et al. 2005). Each variable was weighted based on expert knowledge and the potential risk of invasion was assigned in proportion to the distribution curve for that variable based on intersections between weed locations and environmental variables. Those areas most climatically and elevationally similar to current infestations were assumed to have the highest risk of infestation within the WSM (Johnson et al. 2005).

The environmental variables being utilized in the model consist of (1) GTOP030 Digital Elevation Model, (2) freeze free days, (3) growing degree days over 10 degrees C, (4) precipitation, (5) average temperature maximums, (6) temperature means, (7) average temperature minimums and (8) number of wet days. Climatic data was obtained from The Climate Source, Inc., whom developed the datasets using the Parameter-elevation Regressions on Independent Slopes Model (PRISM). PRISM utilizes point measurements of environmental data, digital elevation models, and other geospatial data to generate annual and monthly climate data. The datasets utilized in KRESS were generated from data between 1971-2000 (Daly and Taylor 2001). Elevation data was obtained from the U.S. Geological Service, EROS Data Center and was comprised of the GTOPO30 data set.

The modeling process for plant habitat suitability modeling consists of the following steps:

1. Define the area in which the plant currently exists through use of Global Positioning System (GPS), expert knowledge, and Geographic Information System (GIS).
2. Identify the factors of importance (these being environmental and landscape variables).

3. Build the GIS layers of factors that are needed as ASCII Raster Maps.
4. Scale each of the factors so that they can be treated similarly between 0-256.
5. Determine or estimate of the "importance" or the weight of each of those factors for mathematical analysis.
6. Determine the spatial and temporal relationships between the factors.
7. Build the model in the KRESS modeling interface.
8. Process the weighted factors mathematically using a Weighted Sum Algorithm.
9. Each cell in the area being modeled will be evaluated for suitability.
10. View the spatial pattern of the model.
11. Evaluate the model using statistical methods or in-field verification.

The KRESS multiple factor analysis is used to simultaneously take into account a series of factors that affect the preference of plants for a particular position on the landscape based on a deterministic application of rules (Johnson et al. 2005). A scientist or resource manager can conceptualize linear, non-linear, or mixed models, and if spatial data exists for the parameters chosen, apply them to the landscape. The user can then incorporate information about the system to build a model that seems reasonable and generate the suitability for each cell on the landscape (Johnson et al. 2005). The KRESS model will be used in this research to quantify and convey the potential area protected from continued, unfettered expansion of weed populations if not for the control programs implemented by ODA.

A statewide land cover grid created by the Oregon Natural Heritage Information Center was utilized in analyzing intersections between the habitat suitability model of the modeled weeds (OBIC 2010), and particular resources that are susceptible to invasion. These land use types were chosen by the ODA (ODA 2013). The land cover grid was altered from its original 156 separate land use elements, and concatenated into resource categories based on their vegetation type or land use. For this study, the appropriate elements were combined to display the general distribution of agriculture, rangeland, urban zones (including right-of-way and parks), pasture, riparian zones, forestry, estuarine zones, and wildlife zones (publicly owned land) (ODA 2013). ArcGIS was used to overlay the mean, plus and minus one standard deviation of the habitat suitability model onto these particular resource categories to generate acreages of potential impact if these weeds were to reach these ecological amplitudes in each resource area. The mean of the model was chosen as to improve precision across all models analyzed, while negating the natural inclination of fitting models to data, thereby reducing human error. Additional analysis using standard deviations was generated to create confidence intervals. It is important to note that because vegetation categories were used to generate these acreages, it does not reflect the political boundaries that define these lands utility i.e., areas considered rangeland with available forage may not be grazed by the land manager.

Impacts from riparian invaders to anadromous fish runs were also analyzed. Using Oregon Department of Fish and Wildlife's (ODFW's) Fish Distribution Data (ODFW 2014), the predicted suitability area (including standard deviations and means) were extracted onto existing runs of coho, steelhead, Chinook, and chum. Historical runs were removed from analysis. River miles of impacted habitat were captured for economic analysis.

The data collated to comprise the weed location dataset was created from 25 different management agencies, with different collection protocols between and within the agencies. Disparate protocols create gross errors in both quality of observations, GPS precision, and quality control. Additionally, each data point can represent one to and unknown quantity of a weed, neither indicating density of infestation or size. The datasets that were retrieved from the agencies also came in different geographic projections, which were subsequently transformed into WGS84 when conducting the standardization of the dataset, which will also generate spatial error.

Point data in the weed location dataset did not consistently contain attribute indicating the size and density of the infestation, thus each presence was treated equally where the whole cell was converted to a one to indicate presence. Each cell is approximately 394 hectares (973 acres), and thus the conversion to raster is a gross over-estimation of actual area infested by the weeds analyzed, but as each cell needed to be of exact size and dimension, this was necessary to implement the model and analysis.

The resampling and scaling process introduces error through scaling the continuous environmental data, whereby a single value in the scaled dataset can represent a range of data from the original environmental dataset. Depending on the size of the continuous environmental dataset, the amount of values combined into a scaled value can vary. This makes analysis less precise as the scaled data represents one or more real-world values. The GTOPO30 data set was resampled to match the cell size of the PRISM dataset by averaging approximately 4 GTOPO30 cells to fit the 1.25 arc minute resolution of the PRISM data.

D. Economic Assessment Model Specification

The focus of this current study economic analysis is on the primary economic activity being decreased due to noxious weeds. There is additional information about other ecosystem harm caused by the analyzed invasive terrestrial and aquatic species in Appendix A and B. Given the serious intrusions that some species make into ecosystem alterations, it would not be possible to include all of the primary and secondary harm caused to production systems and biodiversity in this current study. The intent is to at least capture some of the directly affected production systems (such as livestock losses, agriculture carrying capacity, timber harvests, and recreational uses) while acknowledging there are other direct impact systems not being captured (such as water supply and quality, infrastructure maintenance, energy production, human health, etc.). There are also indirect and tertiary effects not being measured (such as commodity market prices, decreased tax revenue, compromised investment spending, increased community economic vulnerability, and increased fire and flood risk). In addition to market related effects, there are also non-market impacts such as diminished cultural values associated with pristine ecosystems.

Another limitation in this economic analysis is that there is not an economic assessment of noxious weeds' benefits. Noxious weeds may have production positive valuations, some of which are associated with why they became introduced (weeds such as spartina for erosion control, Armenian blackberry for berries and honey, and other species for ornamental nursery stocks). Scotch broom was found to be useful for controlling sand dune movement after being introduced for its ornamental qualities. Armenian blackberry is enjoyed for its fruit and provides the nectar for a wild blackberry honey commercial product. Another positive economic impact not being considered is from the control programs themselves. Often there are federal funds available that when expended within the region becomes an infusion of new money into the economy. Outside sourced money will always have a positive economic impact unless the money has to be repaid. Despite the limited circumscribed comprehensiveness of the economic model, there is a need for even a limited economic analysis to show some quantitative measure of economic damages. It provides information about the comparable importance of the problem so as to improve control program funding tradeoff decision making, demonstrate the relative hazard for not providing prevention and control programs, and lead to greater understandings of economic sectors being affected.

The economic assessment model is production driven, based upon the physical flows of goods and services. For example, business sales are measured in terms of the cattle and wheat sold, or recreational use expenditures. Total business 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 personal income. To convert sales 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, business sales revenues are divided into cash flows (expenditure) on the basis of industry accounting models. The cash flows are then multiplied by response coefficients from the I/O model to determine the estimated contribution in regional income resulting from the stated production. A follow-on statistic for jobs is calculated using average net earnings in the region.

The economic assessment model examines marginal changes - the change in economic value associated with a unit change in output, consumption, or other economic indicators. The results will only hold for relatively small changes within the region being considered. Any infestation that is large enough to change the underlying structure and trade relationships of the economy will necessarily change the relationships quantified in the response coefficients. These adjustments are not reflected in the marginal statistics developed for this current study.

There are distributional issues that are not reflected in the economic assessment model. The considered effects to certain commercial production and recreational use will assist in understanding economic sectors being affected, but there can be concerns that different business establishments and social groups within sectors will be affected at dissimilar scales and times.

The adopted production functions assume that average damages per area is equal to marginal damages per area for commercial production changes and recreational use degradation due to plant coverage. The marginal ratio estimator for economic impacts per acre was developed using the net acres affected from the previous study. Because it was those infestation area amounts that the degradation factors were applicable, it becomes an assumption that the marginal economic impact ratio estimator still applies to the new infestation area estimates. It could be the degradation factors may be different depending on the growth trajectory of a particular weed and its continued effect on commercial production and recreational use. Moreover, the other inputs for production such as labor may be different at other levels of plant coverage. For example, the economic impacts could actually increase if control costs increase. The higher 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. The effects from temporally changed inputs were not included in the economic assessment model.

There is a great amount of data specificity in the current study economic analysis. The accompanying data variability is carried through in the economic activity modeling parameters. The infestation area estimates are accompanied with a variability range; a +/- one standard deviation in bio-physical filters are used for determining upper and lower bounds. The dynamic response of the ecosystem or land cultivation may cause what appears to be susceptible habitat to reject the spread. Production degradation may not be a linear response as the weed spreads into habitat that is less hospitable to weed growth. Risk and uncertainty for spread and production degradation is discussed more in Chapter IV. The current study economic assessment model answers the question for "what-if" the spread occurs within the lower and upper bound range of susceptible areas and assumptions about production degradation.

The general economic assessment production function for calculating foregone economic activity is as follows.

$H = f(Y,T)$ Function Eq. 1

where: H is economic harm
Y is commercial production sales foregone
T is decreased expenditures from diminished recreational use

The function inputs for commercial production in algebraic notation are as follows.

$Y_j = \sum_i A_j * B_j * L1_{i,j} * W1_i$ Production Eq. 2

where: Y is sales foregone for a particular economic activity
A is price
B is normal production per area
$L1$ is factor of production degradation due to noxious weed
$W1$ is noxious weed infested area
i is noxious weed
j is economic activity affected

$I_p = \sum_j Y_j * R_j$ Production Eq. 3

where: I_p is personal income impact from production
R is the I/O model response coefficients

For the commercial production function, A and B are constants for each economic activity and W and L depend on the land type for the analyzed noxious weed bioeconomic and biophysical characteristics.

The recreation economic assessment model inputs are based on per area participation and valuations from pertinent studies found in literature searches. The input estimators are for hunting, fishing, and boating.

$$T_u = \sum_i F_u * L2_{i,u} * W2_i \qquad \text{Recreation Eq. 4}$$

where: T is expenditures for a recreational use economic activity
F is expenditures per area
$L2$ is a recreational use degradation factor
$W2$ is noxious weed infestation area
u is recreational use affected
i is noxious weed

$$I_u = \sum_u T_u * R_u \qquad \text{Recreation Eq. 5}$$

where: I_u is personal income impact from recreation use
R is the I/O model response coefficients

The calculated personal income from commercial production losses and diminished recreational use can be translated to jobs.

$$J = (I_p + I_u) / N \qquad \text{Jobs Eq. 6}$$

where: J is jobs for full-time and part-time employee and proprietor in the regional economy.
N is average net earnings in the regional economy

The selected economy level for calculating total effects (including multiplier effects) is the State.

E. Economic Assessment Model Calibration

The economic assessment model is distilled to 15 unique model groupings according to the analyzed noxious weeds for which they are applicable. The model groupings' current study and previous study applicable noxious weeds are shown in Table II.1. The Appendix Table C.1a and C.1b show the model's input values for variables independent of analyzed species and input values that are associated with a particular analyzed species. The table shows intermediate calculations for the marginal economic impacts. The marginal calculations could be used for a new weed that has similar effects on economic activity as one or more of the analyzed species groupings. The Appendix Table C.2 contains a table showing the economic assessment model algorithms for each of the analyzed species groupings. The Appendix C.3 contains another table that summarizes the degradation and plant coverage factor assumptions.

The basic assumptions (see Table C.1a for sources) for input variables independent of the analyzed species for the previous study four land types are as follows:

1. Rangelands: livestock loss, reduced cattle foraging, and reduced wildlife grazing. Livestock loss and reduced cattle foraging is based on animal unit month (AUM) supported by a particular land type. An AUM is usually defined to be what a cow and calf consumes on grazing grounds in one month. Price of range land will usually be appraised on the AUM carrying capacity of the land. For example, a ranch of 2,000 acres, with carrying capacity of two acres per AUM, and no additional features such as meadows, could expect to produce a total of 1,000 AUM's. At an assumed 2014 AUM lease rates of $13.50 (average between public and private lands as described in the cited study showing on Table C.1a), the grazing value of that land would be about $13,500. The end product of a ranch operation is the annual sales of the calf production. The weaning rate (sale of calves per cow) is generally about 82 to 85 percent. Also it takes at least one bull per 20 cows to produce calves. Therefore including these considerations, it takes the nutrition of about 15 AUM's to produce one calf for sale. On a per calf sale that averages over $600, and the sale per AUM would be $38.13.
2. Farmlands: seed loss and reduced aquaculture. Seed production from bentgrass and wheat are the examples of diminished cultivated land production. Many other agricultural crops could have been included in the agriculture Component A model. The noxious weed profile descriptions in Appendix A mention other agriculture impacts. The calculated economic activity should be considered highly conservative for the analyzed species. The example aquaculture production is oysters.
3. Forestland: reduced timber production. It is assumed an average annual growth across western and eastern Oregon forests is 0.25 thousand board feet per year. The foregone sales is a "pond value" for the Table C.1a shown price. (Pond value is the timber stumpage value after consideration of hauling transportation costs.)
4. Wildlands: wildlife and fish stressor that lowers hunting, fishing, and boating demand.
    a) Wildlife (hunting) is based on agriculture Component A plant cover and degradation and cow-deer equivalency of 4.5 and with 7.3 acres per AUM grazing. The deer hunting expenditures per day are assumed to be $73.66, with success rate of 15.2 days per deer, and 30 percent harvest rate.
    b) Wildlife (fishing) is based on 2.5 salmon adults per mile of anadromous fish habitat for invasive species removal. The assumed harvest rate for the adults is 50 percent. It is further assumed that half of the harvests are caught in commercial fisheries and half are caught in recreation fisheries. Fall Chinook salmon is the assumed species to translate harvests into economic activity. Fall Chinook are included in a fall fishery and are caught coincident with other salmon species in many ocean and inriver locations, therefore the calculated economic activity will include the presence of other salmon species recovered through the invasive species removal. The assumed ex-vessel value per fish and assumed angler expenditures per day are $100. The recreational success rate is assumed to be four days per fish. The recreational economic activity is based on trip only expenditures since the desired parameter is marginal changes. This assumes economic activity for equipment expenditures

would have occurred with or without the increased production due to invasive species removal.

c) Wildlife (boating) economic impacts assume the presence of the noxious weed species cordgrass will eliminate boating activity. The boating use days are for "bays" and include all trip purposes except fishing since fishing economic impacts are included in another wildlife category. The calculated economic impacts are probably liberal due to the average includes water types that are not conducive to cordgrass growth. It is also assumed cordgrass will eliminate oyster aquaculture in its presence. The reduced oyster production and economic activity parameters are shown as an agriculture Component B on Table C.1a.

Parameters specific to the analyzed weeds used as inputs for the economic activity model include the following:

1. Plant coverage factor. The share of the infested areas that affects a particular economic activity.
2. Degradation factor of the economic activity. This factor can have various interpretations depending on the economic activity. For example, it could be interpreted as a cow mortality rate for the livestock economic activity. The assigned degradation factors will be different for an economic activity affected for a particular analyzed noxious weed located on a particular land type. The factors are normalized to apply to an economic activity and are usually expressed as a percent.
3. Grazing production factor. The factor is an assignment based on the land forage qualities affected by a particular weed.
4. Land management factors. Forestland managed for other than wood production and lands in reserve (such as for old growth protection, wilderness designation, and other conservation purposes) and multiple uses (saved for recreation, water production, etc.) is estimated to be 47.5 percent (OFRI 2013).[1] These lands vegetation succession will not provide soil conditions in disturbed site status for Scotch broom invasion. If there are invasions, there would purportedly not be a loss in timber production due to the management restrictions. A post habitat suitability model outcome factor of 52.5 percent was applied to forestry susceptible areas.

F. Economic Assessment Model Results

The current and previous study infestation areas are shown on Table II.2. The calculated economic impacts for infestation areas are shown on Table II.3 and Figure II.1 (direct effects are depicted on Table II.3a and REI are depicted on II.3b). The estimated foregone economic activity from current levels of noxious weed infestations is $83.5 million personal income which would represent 1.9 thousand jobs. The economic impact share from the analyzed species three

1. The share of timberland managed for wood production is 36 percent and the share managed for multiple uses is 33 percent. The balance is managed for reserve status. It was assumed half of the multiple use land would be for wood production.

largest contributors (in order) are: Armenian blackberry 48 percent, Scotch broom 47 percent, and rush skeletonweed two percent. The current study economic impacts without the six additional analyzed species are $43.1 million, which compares to the previous study $101.5 million (adjusted 2012 dollars). The decrease would be an indicator of success in the containment efforts for the previous study's analyzed species.

The estimated economic impact of the analyzed species would be between $1.5 billion and $2.4 billion personal income if infestation moved into all of the susceptible areas. The point estimate for mean within this range would represent 40.8 thousand jobs. The three analyzed species with the largest contributions for susceptible areas are: Armenian blackberry 15 percent, rush skeletonweed 12 percent, and gorse 11 percent. For the six species analyzed for susceptible areas in the previous study (tansy ragwort, distaff thistle, leafy spurge, purple starthistle, hawkweeds, and spartina), the current study economic impacts from susceptible areas is $305.0 million as compared to the previous study $68.7 million (adjusted 2012 dollars). While methods differ between the two studies on the estimation of susceptible habitat, an inference is that there is a growing threat from the six species.

An analyst might be interested in performing an ex-ante analysis to find economic impacts of a weed not analyzed in this report. The ex-ante analysis might be useful for comparing the foregone economic contribution due to the weed presence to the costs of a control program. The first step would be to select an economic activity grouping most applicable to the new plant's characteristics from the 15 groupings showing in Table C.1b. The next step is to apply the ratio estimator "economic impacts per net acre" to the new weeds plant coverage. Figure II.2 conveniently shows where this factor is displayed on Table C.1b. For example, if the new weed's characteristics fit the tansy ragwort economic activity grouping, then the economic impacts per net acre for reduced cattle foraging on rangelands is $8.57 personal income per acre (includes multiplier effect). A more thorough ex-ante analysis might be needed when control costs are high and span many years for implementation. In such cases, the simple ratio estimator approach may not be a sufficient economic measurement to fully describe the benefits from a control program.

Table II.1
Current Study and Previous Study Analyzed Noxious Weeds
Associated With Unique Economic Assessment Model Groupings

Economic Assessment Model Group	Previous Study	Current Study
1	Tansy ragwort	Tansy ragwort
2	Yellow starthistle	Yellow starthistle Japanese knotweed
3	Distaff thistle	Woolly distaff thistle Paterson's curse
4	Scotch broom	Scotch broom
5	Knapweeds	Knapweeds - Diffuse Knapweeds - Meadow Knapweeds -Spotted Knapweeds -Squarrose Kudzu
6	Gorse	Gorse Armenian blackberry (Himalayan)
7	Leafy spurge	Leafy spurge
8	Rush skeletonweed	Rush skeletonweed Giant hogweed
9	Purple loosestrife	Purple loosestrife
10	White top and perennial pepperweed	White top (hoary cress) Perennial pepperweed Dalmatian toadflax
11	Scotch thistle	Scotch thistle
12	Mediterranean sage	Mediterranean sage
13	Purple starthistle	Purple starthistle
14	Hawkweeds	Hawkweeds (meadow and orange)
15	Spartina	Cordgrass

Source: Study.

Table II.2
Comparison of Current Study and Previous Study Infestation Area

	Infestation Area (thousands of acres)						
	Current Study						
	Mean		Susceptible Variance		Previous Study		
Current Study	Current	Susceptible	Upper Bound	Lower Bound	Net	Gross	
Armenian blackberry (Himalayan)	1,638	10,106	+36%	-25%			
Cordgrass	T	40	0%	0%			
Dalmatian toadflax	345	31,724	+35%	-33%			
Giant hogweed	T	2,077	+31%	-26%			
Gorse	28	16,580	+52%	-13%	31	300	
Japanese knotweed	42	1,799	+30%	-23%			
Kudzu	T	7,313	+31%	-13%			
Leafy spurge	8	37,277	+20%	-34%	7	13	
Hawkweeds (meadow and orange)	1	17,888	+32%	-25%	T	1	
Mediterranean sage	90	15,410	+20%	-30%	250	1,275	
Paterson's curse	T	19,737	+86%	-37%			
Perennial pepperweed	89	15,992	+25%	-17%	1,184	2,322	
Purple loosestrife	7	15,276	+49%	-41%	2	4	
Purple starthistle	T	4,017	+95%	-45%	T	T	
Rush skeletonweed	110	15,365	+33%	-31%	60	2,000	(combined)
Scotch broom	1,528	7,601	+15%	-17%	1,500	16,000	
Scotch thistle	102	19,241	+4%	-45%	527	1,011	
Tansy ragwort	125	11,384	+31%	-19%	163	3,260	
White top (hoary cress)	191	15,558	+20%	-31%	0	0	
Woolly distaff thistle	T	18,627	+55%	-36%	T	2	
Yellow starthistle	376	18,596	+33%	-19%	947	1,873	
Knapweeds - Diffuse	275	16,191	+16%	-28%	1,816	3,622	
Knapweeds - Meadow	125	12,443	+35%	-21%	0	0	(combined)
Knapweeds -Spotted	168	37,297	+25%	-31%	0	0	
Knapweeds -Squarrose	T	14,003	+44%	-10%	0	0	

Notes:
1. Acres are shown in thousands, and non-zero amounts less than 500 are shown with a "T" for "trace."
2. Previous study gross acres are areas where a species is an immediate potential threat for infestation or has been detected which has caused some level of productivity degradation. Net acres are areas spatially located within the gross acres where productivity has been wholly displaced.
3. Species that were not in the previous study are blank in the previous study columns. Species that were in the previous study but not the current study are excluded. The previous study combines white top and perennial pepperweed, and knapweeds, so the combined acres are shown in only one row of each, and the other rows show zero.
4. The infestation susceptible area upper bound and lower bound correspond to area calculations for minus one standard deviation and plus one standard deviation, respectively.

Source: Study.

Table II.3a
Noxious Weeds Regional Economic Impacts of Current
and Susceptible Areas Measured by Direct Sales

		Susceptible			Previous	
Current Study	Current	Mean	Upper Bound	Lower Bound	Study	
Armenian blackberry (Himalayan)	46,815	358,811	504,416	238,288		
Cordgrass	1	52,238	52,238	52,238	N/A	
Dalmatian toadflax	341	27,219	36,176	19,100		
Giant hogweed	0	1,434	1,883	1,055		
Gorse	531	255,546	343,006	223,457	1,566	
Japanese knotweed	42	1,801	2,345	1,386		
Kudzu	0	197,478	264,160	169,802		
Leafy spurge	29	104,328	119,441	62,935	114	
Hawkweeds (meadow and orange)	1	24,692	32,476	18,545	2	
Mediterranean sage	0	1,964	2,181	1,500	1,355	
Paterson's curse	0	275,691	357,596	229,473		
Perennial pepperweed	182	8,831	10,145	6,743	26,834	
Purple loosestrife	20	45,810	68,076	26,923	5,513	
Purple starthistle	0	8,207	8,584	7,960	N/A	
Rush skeletonweed	2,177	355,493	490,068	301,610	6,223	(combined)
Scotch broom	44,853	204,428	233,615	166,922	74,939	
Scotch thistle	8	3,185	3,389	1,216	3,023	
Tansy ragwort	185	20,710	23,466	19,480	9,665	
White top (hoary cress)	882	86,819	116,970	53,608		
Woolly distaff thistle	0	253,092	293,926	201,586	N/A	
Yellow starthistle	1,320	45,463	72,034	31,496	5,444	
Knapweeds - Diffuse	55	2,302	2,544	1,984	9,838	
Knapweeds - Meadow	205	21,522	28,163	17,790		(combined)
Knapweeds -Spotted	49	161,322	199,257	118,395		
Knapweeds -Squarrose	0	3,389	9,242	2,257		
Total	97,696	2,521,774	3,275,398	1,975,750	144,517	

Notes: 1. Direct sales is expressed in thousands of 2012 dollars.
2. The infestation susceptible area upper bound and lower bound correspond to area calculations for minus one standard deviation and plus one standard deviation, respectively.
3. Species that were not in the previous study are blank in the previous study columns. Species that were in the previous study but not the current study are excluded. The previous study combines white top and perennial pepperweed, and knapweeds, so the combined direct sales are shown in only one row of each, and the other rows show zero.

Source: Study.

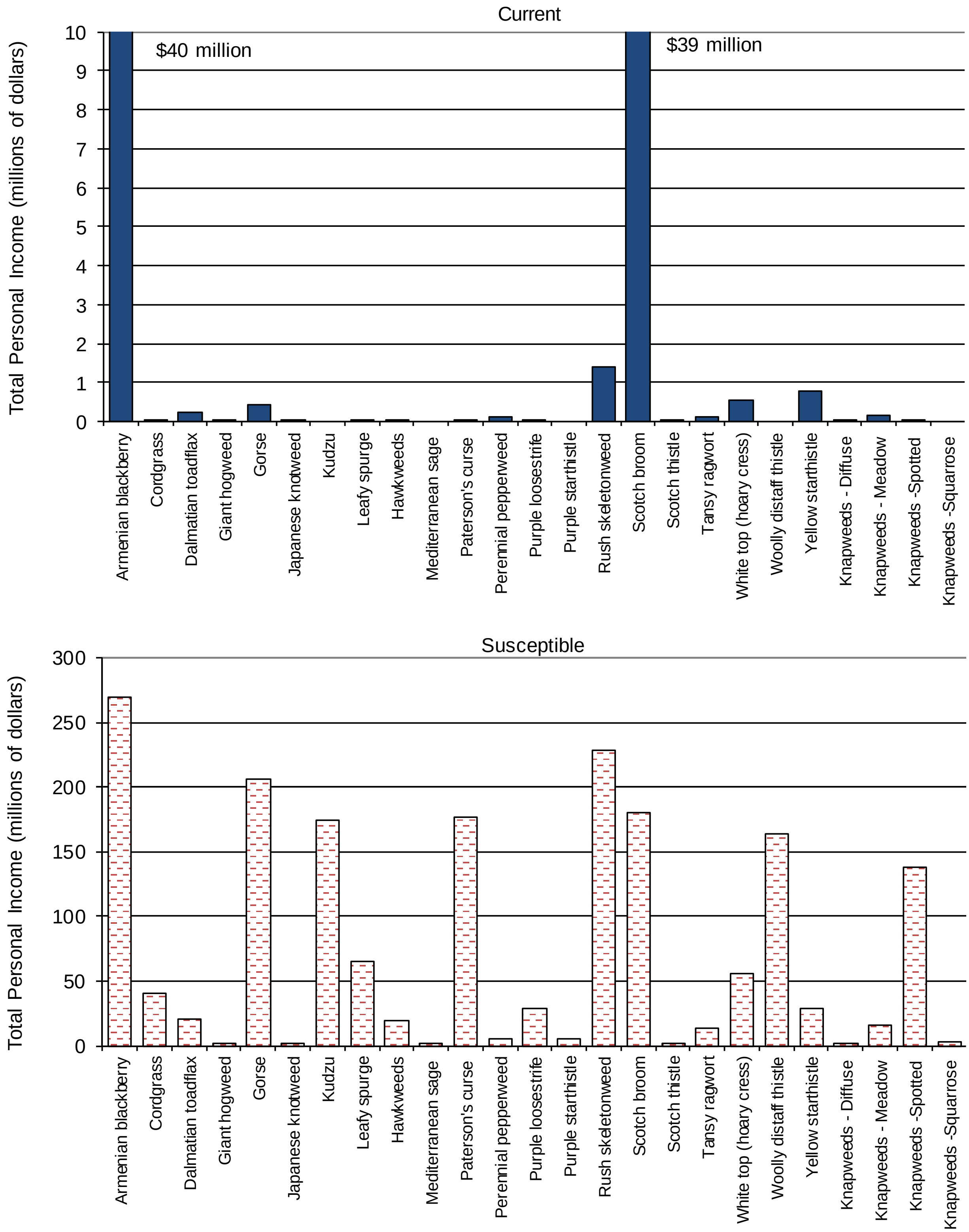
Table II.3b
Noxious Weeds Regional Economic Impacts of Current
and Susceptible Areas Measured by Personal Income

		Susceptible			Previous	
Current Study	Current	Mean	Upper Bound	Lower Bound	Study	
Armenian blackberry (Himalayan)	40,133	268,382	373,402	185,799		
Cordgrass	1	40,223	40,223	40,223	N/A	
Dalmatian toadflax	254	20,335	27,027	14,269		
Giant hogweed	0	1,071	1,407	789		
Gorse	441	205,576	269,215	179,952	1,278	
Japanese knotweed	31	1,338	1,742	1,029		
Kudzu	0	173,590	232,247	149,254		
Leafy spurge	17	65,174	75,340	40,063	63	
Hawkweeds (meadow and orange)	1	18,448	24,263	13,855	1	
Mediterranean sage	0	1,132	1,257	865	754	
Paterson's curse	0	176,765	229,070	147,045		
Perennial pepperweed	110	5,329	6,152	4,063	14,882	
Purple loosestrife	12	28,444	42,270	16,717	3,640	
Purple starthistle	0	4,729	4,946	4,587	N/A	
Rush skeletonweed	1,397	228,219	314,613	193,627	4,160	(combined)
Scotch broom	39,465	179,838	205,513	146,839	61,151	
Scotch thistle	6	1,923	2,052	741	1,680	
Tansy ragwort	115	12,661	14,491	11,798	5,369	
White top (hoary cress)	559	55,263	74,533	34,020		
Woolly distaff thistle	0	163,800	191,031	130,126	N/A	
Yellow starthistle	774	27,911	43,229	19,814	3,026	
Knapweeds - Diffuse	36	1,379	1,532	1,182	5,477	
Knapweeds - Meadow	146	15,070	19,898	12,315		(combined)
Knapweeds -Spotted	33	138,064	170,243	101,479		
Knapweeds -Squarrose	0	2,057	5,560	1,358		
Total	83,532	1,836,719	2,371,255	1,451,812	101,481	
Jobs	1,855	40,797	52,670	32,247	2,254	
Total w/o 6 new	43,114	1,195,239	1,506,361	953,626	101,481	

Notes: 1. Personal income is expressed in thousands of 2012 dollars. Personal income includes the "multiplier effect."
2. The infestation susceptible area upper bound and lower bound correspond to area calculations for minus one standard deviation and plus one standard deviation, respectively.
3. Species that were not in the previous study are blank in the previous study columns. Species that were in the previous study but not the current study are excluded. The previous study combines white top and perennial pepperweed, and knapweeds, so the combined personal income is shown in only one row of each, and the other rows show zero.

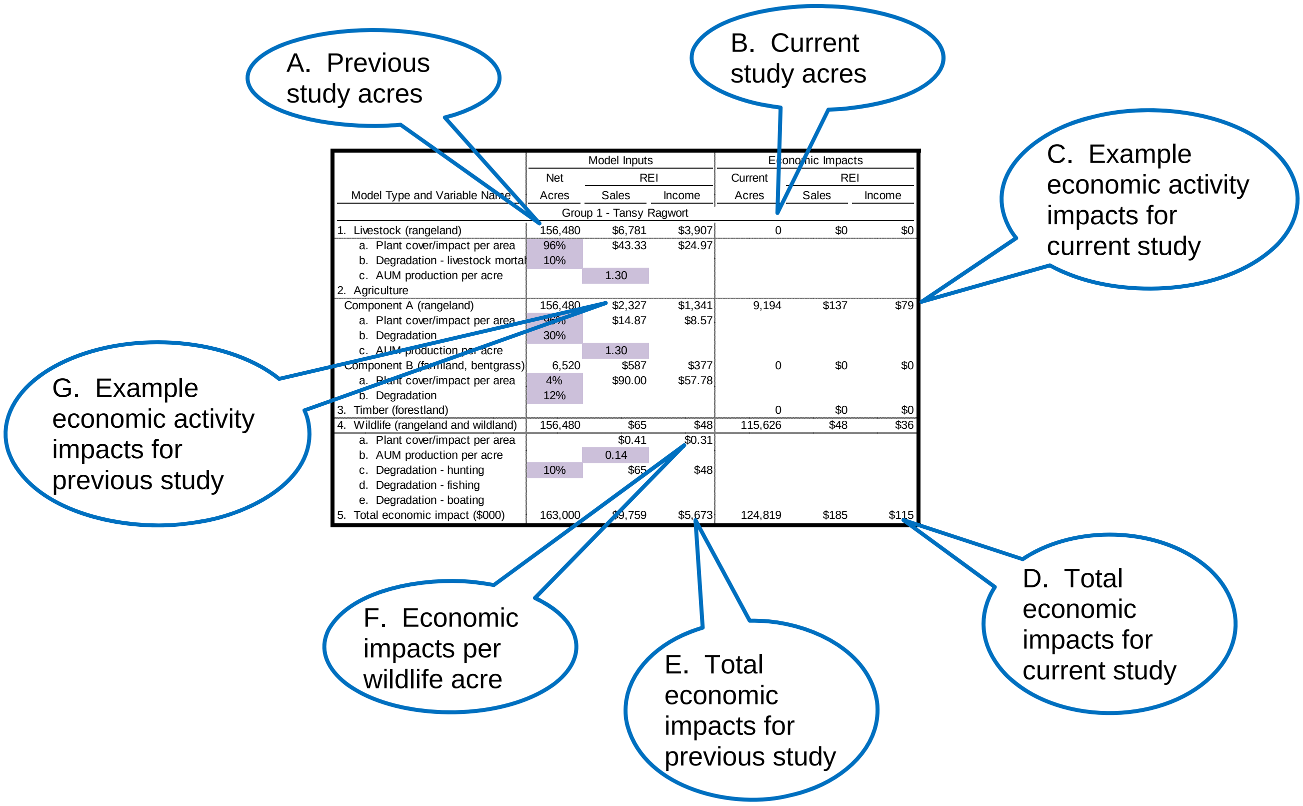
Source: Study.

Figure II.1
Noxious Weeds Regional Economic Impacts of Current
and Susceptible Areas Measured by Personal Income



Source: Study.

Figure II.2
Factors to Use in Ex-Ante Analysis



Model Type and Variable Name	Model Inputs: Net Acres	Model Inputs: REI Sales	Model Inputs: REI Income	Economic Impacts: Current Acres	Economic Impacts: REI Sales	Economic Impacts: REI Income
Group 1 - Tansy Ragwort						
1. Livestock (rangeland)	156,480	$6,781	$3,907	0	$0	$0
a. Plant cover/impact per area	96%	$43.33	$24.97			
b. Degradation - livestock mortal	10%					
c. AUM production per acre		1.30				
2. Agriculture						
Component A (rangeland)	156,480	$2,327	$1,341	9,194	$137	$79
a. Plant cover/impact per area	96%	$14.87	$8.57			
b. Degradation	30%					
c. AUM production per acre		1.30				
Component B (farmland, bentgrass)	6,520	$587	$377	0	$0	$0
a. Plant cover/impact per area	4%	$90.00	$57.78			
b. Degradation	12%					
3. Timber (forestland)				0	$0	$0
4. Wildlife (rangeland and wildland)	156,480	$65	$48	115,626	$48	$36
a. Plant cover/impact per area		$0.41	$0.31			
b. AUM production per acre		0.14				
c. Degradation - hunting	10%	$65	$48			
d. Degradation - fishing						
e. Degradation - boating						
5. Total economic impact ($000)	163,000	$9,759	$5,673	124,819	$185	$115

Source: Study.

III. DETERMINING ECONOMIC EFFECTS AND MANAGEMENT COSTS

A. Economic Effects

The underlying goal of the previous study was to quantify the economic impacts of particular noxious weeds in such a way that a general economic analysis model was developed to show the importance for improving and implementing both control and research programs. Modeling is difficult because it is necessary to build-up a catalog of information about the analyzed species in a standardized manner. The catalog has to contain the bio-physical properties, economic activities affected, existing/potential growth status of the species being analyzed, and control programs available or underway. The problem with cataloging is the unpredictability for where a species might be on its growth curve.

The previous study cited Groves (1999) about a noxious weed's growth.

> "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 III.1 depicts the ODA's staff estimated status of example noxious weeds as of the date of the previous study's publication.

Given the growth curve's non-linear shape, it may <u>not</u> be appropriate to rely on the current study's ratio estimators to predict economic impacts for new analyzed noxious weeds nor new plants. The modeled estimates may be for a status that is highly transitory and what occurs in one measurement year may be quite different the next year. There may be relationships with ecosystems and climate that naturally limit or encourage growth. A cross sectional approach such as used in this current study may under or over estimate the economic impacts depending on where the analyzed species might be on the growth curve and how the species might react to a designed control program. There is a typical lag between marshaling budget resources and carrying out implementation for management projects, and the foregone economic activity justification estimates may not apply when the management project starts.

Smith et al. (1999) compiled a database of noxious weeds and concluded that effects on resources, ecosystems, and biodiversity typically accelerate when measures to eradicate an infestation are delayed.

> "The contention is 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."

Sytsma (2009) discussed the status of invasive species related to the Columbia River in terms of vector strength (pathways for introductions) and management. A stylized management framework overlaid on the pathway and growth potential of invasive species is shown on Figure III.2.

There are three basic reasons why a public agency may be involved in control and preventative programs for noxious weeds. The first reason has to do with localized control programs causing hybridizations which make weeds immune to existing control methods (CAST 2012; Roush 2013). Additional research and development costs are incurred to overcome the hybridization effects (Figure III.3). The second is to preserve the economic development that comes from private landowners and public resource managers land uses. The third has to do with 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 adversely 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 (WTP), 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 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. Duncan et al. (2004) found in a literature search that environmental and societal costs were not included in most invasive species economic analyses. The study concluded that additional research is needed to quantify economic and environmental losses of invasive species. This conclusion is a continuation of earlier observations by Frandsen and Boe (1991). While the issue is discussed, the current study's limited economic analysis does not improve upon the literature noted shortcomings.

B. Management Costs and Approaches

The ODA approaches noxious weed control with an integrated, multidisciplinary approach (ODA 2001). Integrated Weed Management (IWM) is a decision making process based on the best available science and experience of weed managers. Control options depend on site specific information and the best strategy or combinations of strategies for effective management decisions. IWM uses all available methods and techniques for noxious weed control including prevention, mechanical, cultural, chemical and biological control.

> <u>Prevention:</u> 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.
>
> <u>Biological Control</u>: 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. 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.
>
> <u>Mechanical</u>: 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.
>
> <u>Cultural Control</u>: 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. 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.
>
> <u>Chemical</u>: 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.

The ODA policy on IWM can be summarized as both a preventative program and treatment program. The preventative program includes tracking information from surrounding states on new threats. This program includes surveying potential sites for new invader species within Oregon. Early detection and preventive projects 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 (Rejmánek and Pitcairn 2002).

Table III.1 outlines treatment program costs for different land types and means. The chemical, aerial, manual, and mechanical treatment means generally have large initial costs followed by ongoing maintenance costs. Once biocontrol agents become abundant, the costs per release after five to 10 years can be as low as $50 per release. The biocontrols adapt and spread on their own, and reapplication in infested areas and application in nearby newly infested areas become effectively treated without the intervention treatment costs.

Biocontrol programs can have effectiveness lag times between initial implementation until there is a regional success (Syrett et al. 2000). For example, it took nearly 20 years for the tansy ragwort biocontrol project to become regionally successful in western Oregon (Coombs et al. 1996).[1] Figure III.4 shows the delay between when weeds were first identified and a biocontrol agent was developed and deployed for five western states (Rice 2014).

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 and the public is 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 (Coombs et al. 1996).

Economic analysis efficiency ranking of invasive species prevention and control programs would show (Smith et al. 1999):

- EDRR and prevention are among the most cost-efficient and cost-effective ways of reducing the adverse economic impacts of invasive species.
- Biological controls when shown to not have indirect adverse effects are usually preferable to herbicide and insecticide control programs.

Smith et al. (1999) noted what is needed to reduce risk of catastrophic economic losses:

- Enhanced EDRR capabilities
- Vulnerability assessments of suitable habitat using new satellite imagery inventorying methods
- Research on management techniques
- Resolution of approval and permit issues for control programs
- Coordinated state level programs
    - Localized control programs need statewide approach that anticipates hybridizations which can cause immune weeds and insects

1. Comprehensive information for western states including Oregon about the lag from weed appearance to when it was targeted for biocontrol can be found in the Invaders Database System (Rice 2014).

- There are economies of scale for prevention and control
- State government can overcome free rider problem

The State's IWM is coordinated at the local and federal government level. At the local level, county government will generally have assigned weed management contacts and responsibilities. Special districts can be established in Oregon with taxing authority to pay for control programs. There are cooperative weed management areas (CWMA's) that can have multi-county and intra-county boundaries. They are a partnership of federal, state, and local government agencies, tribes, individuals, and interest groups that manage noxious weeds in defined areas.[1]

In other areas in the U.S., the Partnerships for Regional Invasive Species Management (PRISM) may take the place of CWMA's. PRISM's simply expand the goal of CWMA's across broader defined areas. In Oregon the Oregon Invasive Species Council addresses all invasive species: plants, animals, pathogens, aquatic, and terrestrial. There is more than one state agency in Oregon with staff and programs devoted to control of invasive species. The ODFW is active with projects to control aquatic plants and animal invasive species. The Oregon Department of Forestry (ODF) includes noxious weed management considerations when approving timber management plans. ODF undertakes operations control projects for forest lands they manage. The ODA with oversight on weed classification and control program priorities provided by the Oregon State Weed Board concentrates on all plant species.

Other states and federal government agencies work with ODA via financial incentives (i.e. grant programs), contracts, memorandums of understanding, or regulation. There is less consistency and coordination between state-to-state programs than in intra-state programs (Ederington and Minier 2003). This is despite federal programs being unbiased in financial support of prevention and control programs and through legislation imposed prohibitions on interstate and international trade of plants designated as noxious weeds and products containing noxious weeds.[2] There are several interstate coordinating bodies in the Pacific Northwest, including Pacific Northwest Invasive Plant Council, 100th Meridian Initiative, and the Pacific Northwest Economic Region Invasive Species Working Group.

1. CWMA partners develop a comprehensive weed management plan for their area. Locally-driven CWMA's are especially effective at generating public interest in weed management and organizing community groups to support on-the-ground programs. There are 27 cooperative weed management areas in Oregon that occupy 85 percent of the land base. The first was formed in 1994. The structure in Oregon varies from small landowner groups focusing on a specific project to multi-agency organizations. There is an Oregon Cooperative Weed Management Association (ORCWMA) whose membership is all of the CWMA's.
2. The interstate transfer legislation is the Plant Protection Act of 2000 and the Federal Seed Act of 1939. There are many other federal laws and regulations addressing invasive species flora and fauna, including the Noxious Weed Control and Eradication Act of 2004. The federal Executive Order 13112 directs all federal agencies to address invasive species concerns and preparation of a national invasive species management plan.

Table III.1
Estimated Oregon Noxious Weed Control Costs

Pasture/Range and Forest:

- Chemical - Spot: $165 per acre; Broadcast: $65 per acre; Aerial: $50 per acre
- Manual - $1,000 per acre
- Mechanical - $250 per acre
- Biological - $650 per release or about $130 per acre

Riparian:

- Chemical - Spot: $500 per acre; Broadcast: NA
- Manual - $1,000 per acre
- Biological - $650 per release or about $130 per acre

Right-of-Ways:

- Chemical - Spot: $80 per acre; Broadcast: $65 per acre
- Mechanical - $250 per acre
- Manual - $1,000 per acre
- Biological - $650 per release or about $130 per acre

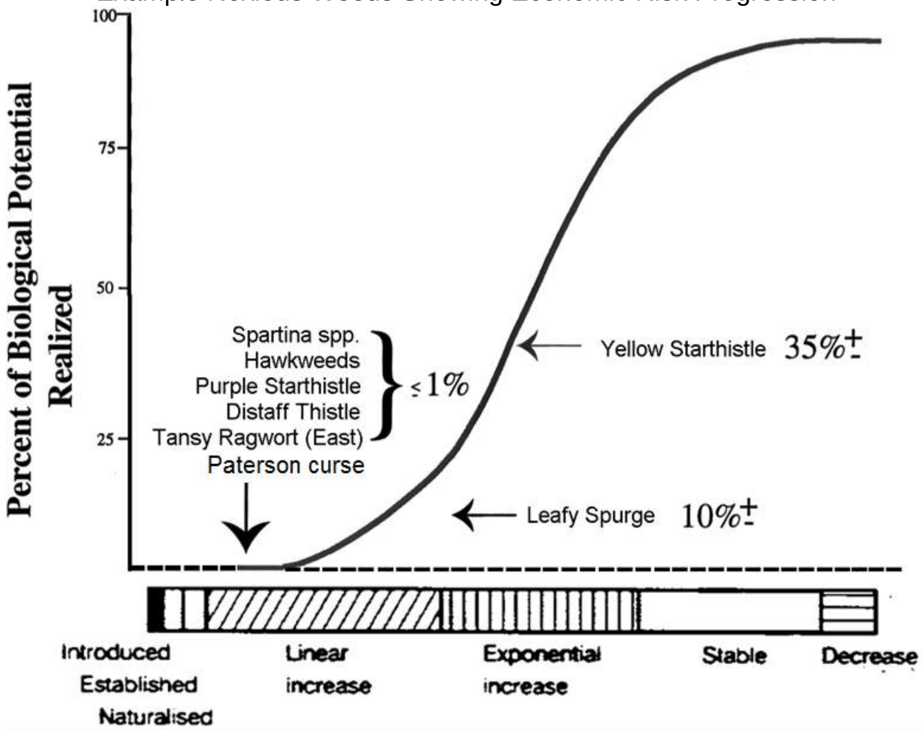
Estuary:

- Chemical - Spot: $500 per acre; Broadcast: NA
- Manual - $1,500 per acre

Notes:
1. Estimated average costs based on information from the ODA and cooperators contracting costs. There are many variables that can cause control costs to increase such as terrain and accessibility.
2. There is very little difference in the cost of control between different weed species. The major cost differences are from increases in labor costs due to the type of site and terrain and the method of treatment.

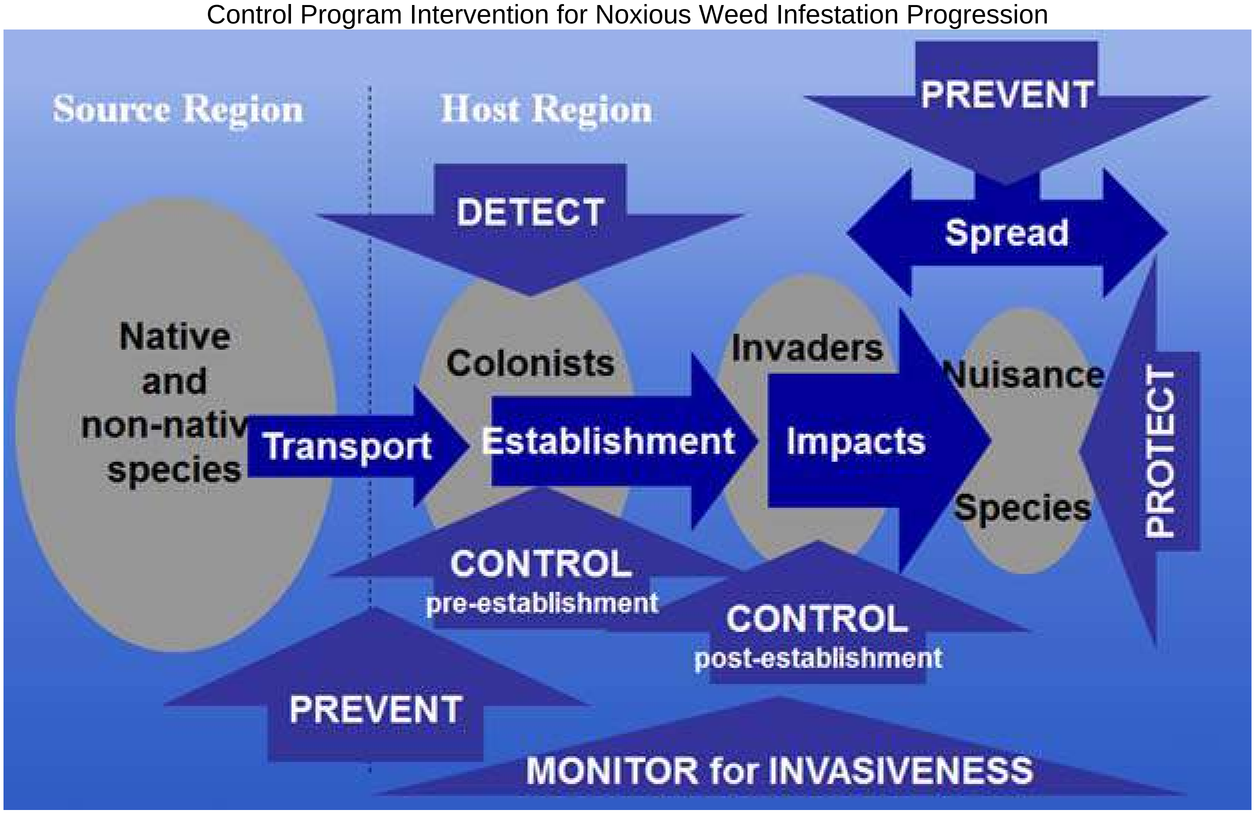
Source: ODA personal communication (April 2014).

Figure III.1
Example Noxious Weeds Showing Economic Risk Progression



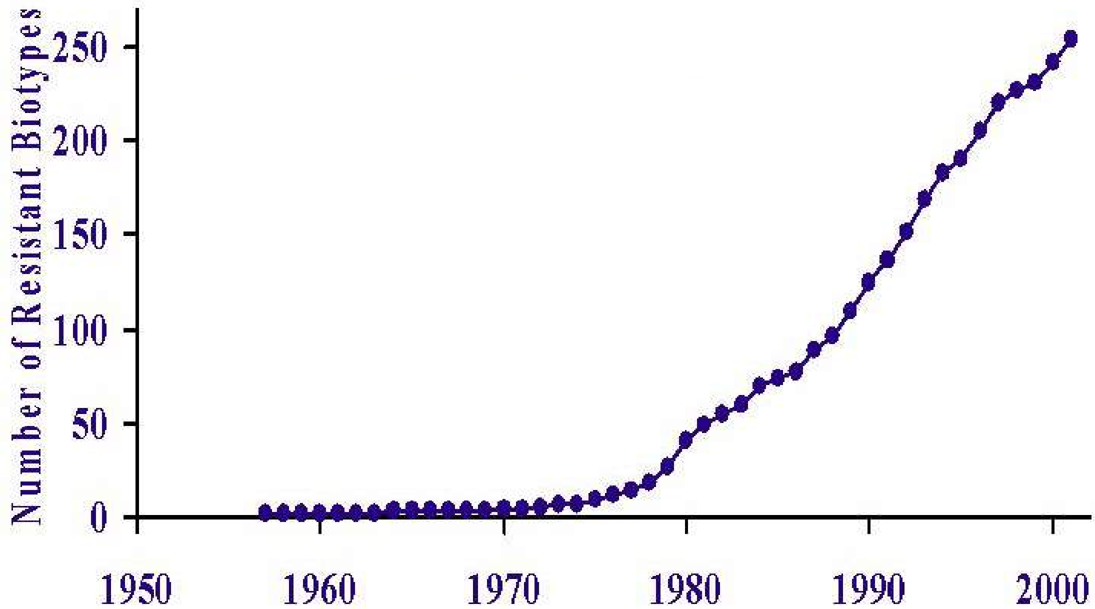
Source: TRG (November 2000).

Figure III.2
Control Program Intervention for Noxious Weed Infestation Progression



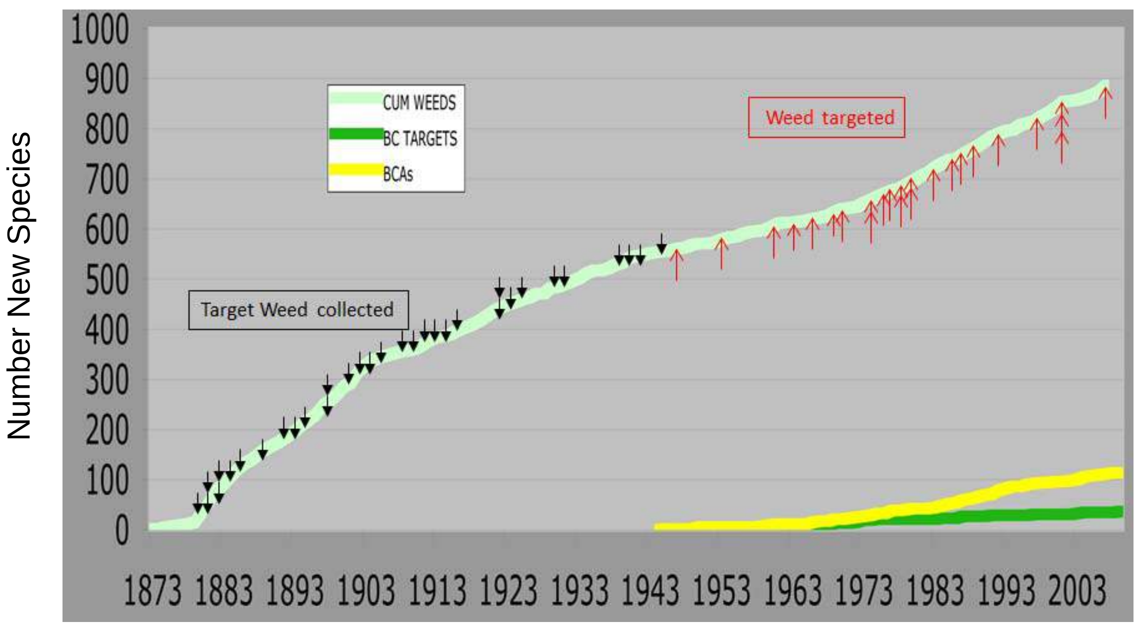
Source: Sytsma (2009).

Figure III.3
The Chronological Increase in Unique Cases of Herbicide-Resistant Weeds Worldwide



Source: Roush (2013).

Figure III.4
Weed Identification and Biocontrol Agent Development and Deployment Timeline Through 2007



Notes: 1. CUM - cumulative; BC - biocontrol; BCA - biocontrol agent.
2. Timeline shows lag between when weeds are identified and biocontrol agents are developed and deployed.
3. Compilations are for five western states: Oregon, Idaho, Washington, Montana, and Wyoming.

Source: Rice (2014).

IV. DISCUSSION

A. Benefits From Prevention and Control Programs

1. Foregone Economic Activity

This current study updates one of the more comprehensive state level economic analyses of noxious weeds that exists (Duncan et al. 2004). Despite the limited economic analysis methods applied (i.e. no net economic evaluation that would include societal losses) and limited economic activity included (i.e. no water quantity/quality losses), the results are still purposeful for informing decision makers about the scale and range of economic effects from current infestations and how bad it can get if prevention and control programs are not implemented.

Current study results show for the 25 weeds chosen by ODA to be particularly harmful with high risk for additional spreading have $83.5 million personal income (includes multiplier effect) lost to the State's economy. This is equivalent to about 1,855 jobs. While this impact is overwhelming, it is insignificant if the infestations spread to susceptible areas. The mean estimate in lost personal income would be $1.8 billion which represents about 41 thousand jobs. This enormous loss of production and diminished recreational activity from the 25 analyzed species can be compared to the total REI for the Oregon commercial forestry sector at $5.2 billion personal income in 2011 (FSEAT 2012) and the total REI for the Oregon agriculture sector at $9.8 billion personal income in 2009 (OSUES 2011).[1]

The economic analysis results are from complex methodological calculations that have high uncertainty. A following section in this chapter describes result sensitivities to model parameters using Scotch broom for an example.

2. Control Program

In order to evaluate the economic effectiveness of prevention and control programs, the cost of programs needs to be developed. Such an analysis was performed on the tansy ragwort program.[2] 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." The evaluation of this control program showed that the State received net economic benefits of about $13 for every $1 invested for biological control program (Table IV.1). The prevention program for this type of control program has a benefit to cost ratio of 34 to one. If the threat of tansy ragwort is as real as identified by ODA staff, then it would be prudent for Oregon to invest several times the $300 thousand amount in these types of control programs.

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1. The OSUES (2011) reports offer an economic impact measurement for jobs (full and part-time) to be 2.2 million (includes the multiplier effect). This calculates to the $9.8 billion net earnings component of personal income using an Oregon average $37,660 per all job estimate in 2009 as reported from the U.S. Bureau of Economic Analysis.
2. Managing noxious 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 a BCA that would generate summary statistics like net present value and benefit-cost ratios. Such an analysis adjusts all costs and benefits to current dollars. The annual cost of the Oregon Tansy Ragwort Biological Control Program averaged $300 thousand during the 1970's (Radtke 1999).

The cost information needed to evaluate other 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.

a. Biocontrol Programs

An example of success for a biocontrol program is its use 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.

Evaluation of biocontrol programs 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 biocontrol program. For gorse in New Zealand, a BCA showed that a high degree of control would result in a ratio of benefits to costs of at least 12:1.7 (Hill 1986). There is promise from biocontrol for Scotch broom using the seed beetle, *B. villosus* (Syrett et al. 1999). The biocontrol of gorse and Scotch broom is especially significant to Oregon agriculture and timber production in that the two weeds have become troubling invaders.

b. Calamitous Threat Species

ODA staff has identified five noxious weeds as posing particularly harmful future threats to commercial production and recreation. These are Paterson's curse invading agricultural and rangelands; purple loosestrife invading riparian and wildlands; cordgrass (spartina) invading Oregon estuaries and wetlands; woolly distaff thistle invading rangelands; and tansy ragwort invading pasture and wildlands. The Appendix B case study section describes existing control programs for these species. Foregone benefits of these weeds to the State are estimated to be $128 thousand current and $421.9 million susceptible personal income (Table II.3b).

B. Economic Analysis Model Parameter Sensitivity

Making public policy decisions about noxious weed control programs is sobering because it pertains to the use of public funds, involves many existing interest groups, impacts private property owners, and has long-term effects to the environment. The economic activity models offer point estimates without bounds for what might occur if data and relationships had uncertainty. The infestation susceptible area determinations are offered for +/- one standard deviation of the combined predictive parameters. Other data descriptions and modeling assumptions were stated, but the complex interactions among the natural environment, social and economic, and political systems cannot be perfectly defined. As such, policy decisions informed by economic analysis results rely on the best available information.

This section presents additional information about economic effects if there was a different analytical model specification or more was known about data limitations. In offering this information, it assists decision makers to realize there is a range of possible outcomes with only probabilities that the described effects and implications will occur. While study resources did not allow for a formal analysis of data error propagation and introduction and/or refinement of the model specification, economic results are shown if different values and modeling factors for key variables are changed. Uncertainty and risk analysis is its own discipline and much more research could be undertaken. The National Research Council in 1983 (NRC 1983) and again in 1996 (NRC 1996) describes procedures for how risk assessment and management can have relevance to policy decisions.

Sensitivity tests are made for degradation and infestation area variables. Scotch broom is used as an example for the sensitivity analysis. The threat of Scotch broom infestation damage is enormous in Oregon. The current infestation share of lost economic activity for this species is 47 percent of all analyzed species or $39.5 million personal income. This rises to $179.8 million (10 percent of all analyzed species) if the species invades all of the susceptible habitat. Scotch broom affects mainly marginal rangelands and timberlands in western Oregon. Once established, Scotch broom eradication by chemical and/or manual methods is expensive. The $1,000 per acre (Table III.1) control costs for eradication plus the annual maintenance would exceed expected future production returns from the land. Private land owners may simply decide to not manage the lands for production and divest ownership rather than undertake control programs.[1]

The important economic activity associated with this species is from timber production degradation following invasion. Figure IV.1 shows the incremental change to lost income for forestland susceptible area and timber production degradation. A 42 percent increase in the two factors would about double the lost income over the current study estimate. The uncertainty for the two variables has more than just statistical range interpretation:

- The previous study model used a 50 percent timber production degradation based on investigation of the existing situation in coastal Oregon counties for forestland private land ownership. Timber management in such situation has relatively short rotations and

1. An example ranch being abandoned in Klamath County due to leafy spurge invasion is described by Marks (1997).

the infestation is on disturbed soils with high weed climate and habitat suitability. The current study model uses a 25 percent degradation factor. The different factor was adopted based on personal communication with ODF (2014) timber management specialists who suggested statewide degradation with longer management rotation would be high at 25 percent. Conifer growth eventually wins out over noxious weeds, especially when the invasive species are at limits of their habitat suitability.

- The habitat suitability model provided susceptible area calculations based on elevation and climate information. Other limiting factors for plant growth, such as soil characteristics, were not a habitat suitability model input. Also, land management was not a habitat suitability model input characteristic. A post habitat suitability model outcome factor for 52.5 percent was applied to the forestry susceptible area calculation based on estimated non-timber management areas provided by OFRI (2013).

There could be higher factual interpretations for the two variables used in the economic assessment model. If the degradation factor was 50 percent and the calculation of susceptible area did not consider land management, then the REI for Scotch broom potential invasion into susceptible areas becomes $684.2 million. The Scotch broom economic activity model's specification is used to calculate REI for gorse, Armenian blackberry, and knapweeds, so the parameter change would substantially increase the total for all the analyzed species.

A similar sensitivity analysis could be applied for the other analyzed species assumptions and data inputs. Any change in the parameters could create significant bias in the economic analysis results. The high uncertainty in the estimates should be considered when relying on the utility of the results for program or policy decision making.

C. Program Policy Implications

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 decreased economic activity as well as increased costs for prevention and control programs. The damages (animal mortality, productivity decreases, loss of environmental quality) can be estimated in terms of economic effects. The problem is assessing who should pay for the prevention and control programs.

Most alien plants now established in the United States were introduced for food, fiber, or ornamental purposes. The rate of introductions and risks associated with invasive species has increased enormously because of human population growth, rapid movement of people, and alteration of the environment (Pimentel et al. 2004).

Scotch broom, as an example introduction for beneficial purposes, was brought into Oregon as an ornamental plant and a stabilizer of beaches. The Siuslaw Oar (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."

The unintended spread of introduced species such as Scotch broom can turn them into undesirable plants in a very short time. The main negative impacts include interference with forest land regeneration, reduced sight distance when it grows on highway right-of-way, interaction with physical and biotic characteristics of the natural landscape, and harm to nursery businesses when its sales are prohibited (Isaacson 2000).

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 insects or microorganisms that adversely affect the unwanted plant. While more emphasis is being placed on biological controls, chemical or manual control in the early stages of invasion may also result in favorable cost effectiveness. Programs for existing noxious weeds that are expensive to eradicate with manual or chemical means and that have no potential biological control agents may not evaluate financially favorable. In such cases education about containment may be the only option.

Noxious weeds have become so thoroughly established and are spreading so rapidly on state and federally-owned lands, as well as private land, that they have been declared by Oregon Revised Statutes Chapter 569 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.

> "<u>Weed Control Policy</u>
>
> 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 listed noxious weeds.
> 3. Encourage and implement the control or containment of infestations of listed weed species and, if possible, eradicate them.
> 4. Develop and manage a biological weed control program.
> 5. Increase awareness of potential economic losses and other undesirable effects of existing and newly 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 with government agencies and other weed management entities.

7. Develop partnerships with county weed control officers, universities, and other cooperators in the development of control methods.
8. Conduct statewide noxious weed surveys and weed control efficacy studies.

The previous and current study may be used to educate the public of the seriousness of the noxious weed problem to Oregon's commercial production and recreation potential as well as conservation of natural resources. 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 when making management program priority funding decisions. Such an analysis will provide decision makers with comparative information about economic benefits and 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."

The control and spread of noxious weeds are of public concern because of a private market externality problem. The background research and maintenance costs can be prohibitive for any single individual or even single industry. Once control programs have been established, the private businesses will become a free rider to the benefits of the program in the case the weed is deleterious to commercial production. Depending on harm caused by particular weeds, the public will also benefit from control programs through greater recreational use opportunity. In either case, there is a gain in social values from knowing ecosystems are being recovered.

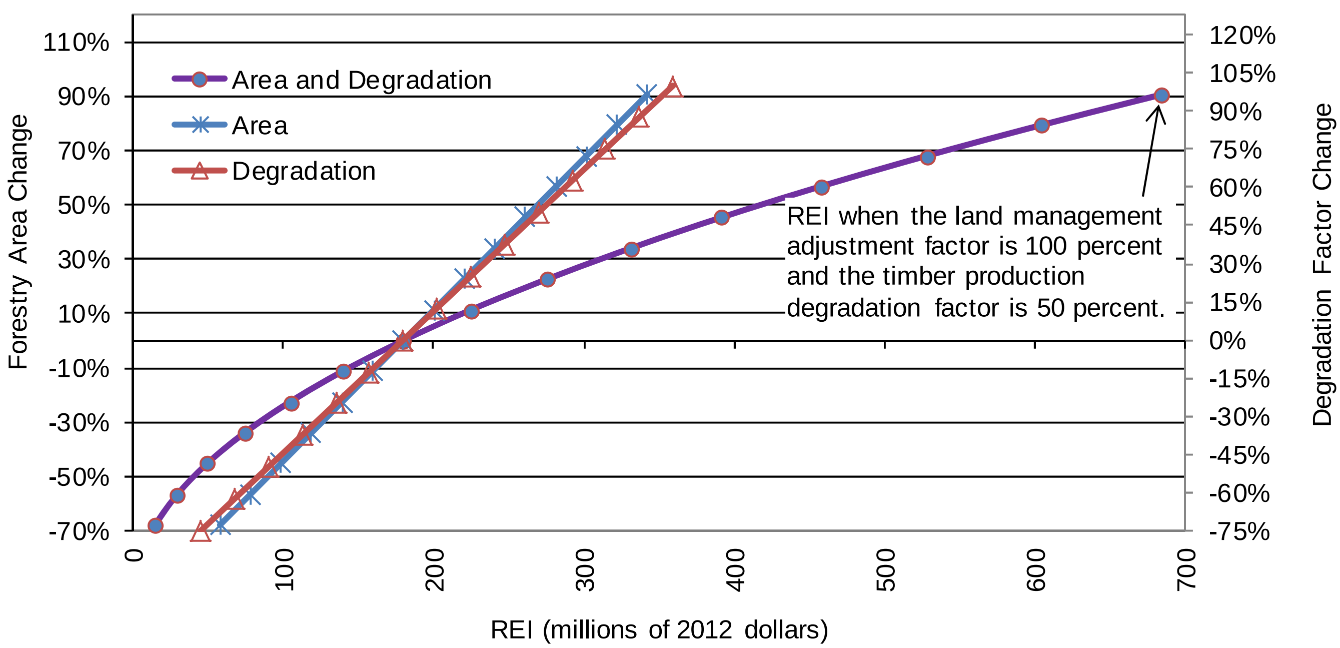
Table IV.1
Biological Control of Tansy Ragwort in Western Oregon, 1974-1992: Benefit-Cost Evaluation

Discount Rate (percent)	Percent Value: Program Cost	Percent Value: Benefits	Percent Value: 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).

Figure IV.1
Sensitivity of Scotch Broom Regional Economic Impacts to
Forestry Susceptible Areas and Timber Production Degradation



Notes: 1. REI is measured by personal income and includes the "multiplier effect."
2. The current study assumes the timber production degradation factor is 25 percent and the land management adjustment factor for forestry susceptible areas is 52.5% percent.
3. The *y*-axis change is the positive and negative percent change of the study assumed timber degradation factor and study assumed forestry land management adjustment factor.

Source: Study.

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APPENDIX A

Analyzed Oregon Noxious Weeds Status

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Analyzed Oregon Noxious Weeds Status

Noxious Weed Names /1	Rating Class /2	Present Status /3	Estimated Affected Acres in U.S. /6	Species is Native From /4	Management Policy /5	Method of Control /5	Resource and Industry Affected /5	Negative Impacts /7	Potential Future Impacts /7	Beneficial Use /7	Geographic Distribution in Oregon /5
Armenian blackberry (Himalayan) *(Rubus armeniacus)*	B	Found throughout the U.S.	No estimate	Central Asia	Containment	Chemical, mechanical, biological control	Agricultural, urban, riparian, pasture, forestry	Ecosystem domination due to fast expansion rate by caning, and seed dispersal by birds. Removal is expensive and energy intensive.	Continued expansion into most of Oregon's temperate landscape, where its presence results in competition with native plants and agriculture	Produces consumable fruit	Established widely in western Oregon, expanding into NE Oregon. Interruption of agricultural and ecological systems if not removed quickly. Total domination of sites possible. Outcompetes native vegetation along anadromous fish bearing waterways.
(15) Cordgrass* *(Spartina spp.)*	A, T	Expanding in the Pacific Northwest in Washington and California	No estimate	East Coast North America	Eradication	Chemical and manual	Estuarine areas; shellfish production	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.	Used in coarse paper production.	One site in Siuslaw estuary eradicated. Monitoring and detection efforts in other Oregon estuaries.
Dalmatian toadflax *(Linaria dalmatica)*	B	Found throughout the U.S.	844	Western Asia	Containment, local eradication	Chemical, biological control	Range, urban, riparian, wildlands	Dalmatian toadflax most successfully invades areas of cultivation and/or soil disturbance in dry climates where competition from other perennial plants is reduced.	Potential future impact into disturbed rangelands where competition is largely reduced. Successful biological control has reduced large scale infestations across state.	None	Established mainly in central and eastern Oregon, with spotty infestations on the west side of the Cascades.
Giant hogweed *(Heracleum mantegazzianum)*	A, T	Oregon, Washington, and eastern U.S. states.	No estimate	Southwest Asia	Eradication	Biological control	Urban	Threat to human health due to toxic sap. Readily invades riparian habitat and can ecological dominate said systems with high seed production rates.	Movement throughout urban areas poses a growing threat to human health. Active management has limited this spread.	None	Established mainly in the Portland metro area with scattered infestations on the Oregon Coast. Limitations to access of recreational areas, and if left to expand, limiting areas for fishing.
(6) Gorse *(Ulex europaeus)*	B, T	Isolated in Pacific Coast	No estimate	Europe	Biocontrol and containment.	Biocontrol, chemical, manual	Urban, pasture, forestry, 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	None known.	Concentrated in Coos, Curry, Douglas, and Lane Counties. Small infestation in Clackamas, Tillamook, Clatsop, Lincoln, and Columbia Counties.
Japanese knotweed *(Polygonum cuspidalum)*	B	Found throughout the U.S.	No estimate	Asia	Containment, local eradication	Chemical and manual	Urban, riparian	Plants grow vigorously along roadsides, waste areas, streams and ditch banks and create dense colonies that exclude native vegetation and greatly alter natural tree regeneration. Established populations are extremely persistent and do not respond to mowing/cutting.	Riparian areas across the state are susceptible to this plant.	None	Heavy infestations occur in northwestern Oregon, but scattered infestations are present in most of the counties of the State. Large infestations can be eliminated with approved herbicides, but treatments are costly and time consuming. Reduction of native plant cover can impact salmonid species and reduce fishing access.

Noxious Weed Names /1	Rating Class /2	Present Status /3	Estimated Affected Acres in U.S. /6	Species is Native From /4	Management Policy /5	Method of Control /5	Resource and Industry Affected /5	Negative Impacts /7	Potential Future Impacts /7	Beneficial Use /7	Geographic Distribution in Oregon /5
Kudzu *(Pueraria lobata)*	A, T	Oregon, Washington, central and eastern U.S. states.	7 million	Asia	Eradication	Chemical and manual	Urban	Kudzu kills or degrades native and desirable plants by smothering them under a solid blanket of leaves, by girdling woody stems and tree trunks, and by the sheer force of its weight breaking branches or uprooting entire trees and shrubs. Trees covered by kudzu become damaged by its weight during ice events or die from insufficient light.	Kudzu grows best where winters are mild, summer temperature are above 80 degrees and annual rainfall is 40 inches or more, thus much of the western portion of the State is at risk.	None	One small infestation in Portland remains. Once established kudzu grows at a rapid rate extending as much as 60 feet per season at a rate of about one foot per day, thus urban and forestry areas impacted would see large control costs.
(7) Leafy spurge *(Euphorbia esula)*	B, T	Western U.S.	3 million	Europe and Asia	Biocontrol and containment.	Biocontrol, chemical, manual, cultural (sheep and goats)	Rangeland, riparian, pasture, 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.
(14) Hawkweeds Orange hawkweed *(Hieracium aurantiacum)* Yellow hawkweed *(Hieracium floribundum)*	A, T	Expanding in the Pacific Northwest	No estimate	Europe	Eradication	Chemical and manual	Urban, riparian, 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.
(12) Mediterranean sage *(Salvia aethiopis)*	B	Expanding in western states	1.3 million	Northern and Eastern Mediterranean Area	Limited biocontrol/ control	Biocontrol, chemical, manual	Rangeland	Reduces forage production on rangeland and pasture. Unpalatable to grazing animals.	Potential for additional spread in Eastern Oregon.	None known.	Eastern Oregon
Paterson's curse* *(Echium plantagieum)*	A, T	Oregon, California, and some eastern U.S. states	No estimate	Europe	Eradication	Chemical and manual	Agriculture, rangeland	Paterson's curse is poisonous to grazing animals and a threat to natural areas. Paterson's curse is a prolific seed producer enabling rapid spread and displacement of pasture, range and desirable plants.	It is a threat to native habitat with the potential to invade oak woodland, native prairie, and dry upland slopes. The plant contains pyrrolizidine alkaloids that cause chronic liver damage and death to susceptible animals.	None	Infestations occur in Linn and Douglas Counties.
(10) White top and perennial pepperweed *(Cardaria draba* and *Lepidium latifolium)*	B, T (p.p. only)	Expanding in the West	No estimate	Asia	Containment/ control	Chemical and manual	Ag., range, pasture (white top); range, riparian, pasture (p. pepperweed)	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
(9) Purple loosestrife* *(Lythrum salicaria)*	B	Found throughout the U.S.	No estimate	Europe	Biocontrol and containment.	Biocontrol, chemical, manual	Recreation areas, riparian wetland; 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.
(13) Purple starthistle *(Centaurea calcitrapa)*	A, T	Expanding in the West, especially in California	No estimate	Mediterranean area	Eradication	Chemical and manual	Rangeland	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.	None known.	One site in Clackamas County declining under eradication program. One site eradicated in Sherman County in 1991.

Noxious Weed Names /1	Rating Class /2	Present Status /3	Estimated Affected Acres in U.S. /6	Species is Native From /4	Management Policy /5	Method of Control /5	Resource and Industry Affected /5	Negative Impacts /7	Potential Future Impacts /7	Beneficial Use /7	Geographic Distribution in Oregon /5
(8) Rush skeletonweed *(Chondrilla juncea)*	B, T	Expanding in the West	6.2 million	Asia and Mediterranean Region	Biocontrol	Biocontrol, chemical, manual	Agriculture, rangeland	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 Columbia Basin and northeastern Oregon.
(4) Scotch broom *(Cytisus scoparius)*	B	Pacific Coast		Europe	Biocontrol	Biocontrol, chemical, manual	Urban, forestry	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.
(11) Scotch thistle *(Onopordum acanthium)*	B	Western U.S.	No estimate	Europe and Asia	Containment/ control	Chemical and manual	Rangeland, urban	Competes with and decreases desirable forage. Sharp spines deter livestock and wildlife from grazing.	Potential for wider distribution in the state.	None known.	Eastern and central Oregon.
(1) Tansy ragwort* *(Senecio jacobaea)*	B, T	Pacific Northwest	3 million	Europe and Asia	Biocontrol in western Oregon and eradication in eastern Oregon	Biocontrol, chemical, manual	Pasture and wildlife	Livestock injury (liver damage); rangeland and habitat degradation; and displacement of desirable species	Potential to spread in eastern Oregon.	None known.	Widespread in western Oregon. Limited in eastern Oregon.
(3) Woolly distaff thistle* *(Carthamus lanatus)*	A, T	California	No estimate	Mediterranean area.	Eradication and containment	Chemical, manual	Rangeland	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.	None known.	Southern Oregon (Douglas and Josephine Counties)
(2) Yellow starthistle *(Centaurea solstitialis)*	B	Western states	8 million	Mediterranean Region of Europe	Biocontrol and containment	Biocontrol, chemical, manual	Rangeland, urban, pasture	Livestock injury (chewing disease) especially horses; range and habitat degradation; and displacement of desirable species.	Potential to spread in southeast 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.
(5) Knapweeds		U.S.	8 million	Mediterranean Region of Europe and Africa, Central Europe and Asia	Biocontrol and control/contain ment. Squarrose: eradication and containment	Biocontrol, chemical, manual	Rangeland, urban, pasture, 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 County. Spotted, diffuse, and Russian limited distribution in western Oregon and are widely distributed in central and eastern Oregon.
Diffuse knapweed *(Centaurea diffusa)*	B										
Spotted knapweed *(Centaurea maculosa)*	B, T										
Russian knapweed *(Centaurea repens)*	B										
Squarrose knapweed *(Centaurea virgata)*	A, T										

Notes: 1. The weeds identified with numbers in parentheses are the 15 for which unique economic models are developed. The weeds identified with an asterisk have case study descriptions in Appendix B.

2. Refer to "Noxious Weed Policy and Classification System" Oregon Department of Agriculture - Noxious Weed Control Program. 2014. Noxious Weed Control Rating System.

3. Council for Agricultural Science and Technology. Invasive Plant Species. Issue Paper Number 13. February 2000. http://www.cast-science.org/download.cfm?PublicationID=2864&File=f030a5f2afb66480223c4b233e6767307816

4. Various sources that include monographs and specialized weed publications.

5. ODA staff.

6. 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.
Westbrooks, R. Invasive plants, changing the landscape of America: Fact book. Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW), Washington, D.C. 109 pp. 1998. http://www.weedcenter.org/resource_guide/Invasive%20Plants%20Factbook.pdf

7. ODA staff and various Oregon State University Extension publications.

Source: Study.

APPENDIX B

Analyzed Noxious Weeds Profiles and Case Studies

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Analyzed Species Profiles

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Armenian Blackberry, *Rubus armeniacus*

Description

Perennial; blooms June to August. Root buds produce trailing reddish stems with sharp spines that can grow more than 20 feet per season. Leaves alternate, palmate and compound with serrate margins. Flowers five pedaled, white to light pink. Fruits aggregate.

Impacts

Armenian blackberry (another common name is Himalayan blackberry) is the most widespread and economically disruptive of all the noxious weeds in western Oregon. It aggressively displaces native plant species, dominates most riparian habitats, and has a significant economic impact on right-of-way maintenance, agriculture, park maintenance and forest production. It is a significant cost in riparian restoration projects and physically inhibits access to recreational activities. It reproduces at cane apices (tips) and by seeds, which are carried by birds and animals. This strategy allows it to expand across a landscape or to jump great distances and create new infestations. Any control strategy can be considered short-lived unless projects are planned and funded for the long-term.

Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
1,638,000	$40,133,000	10,106,000	$268,382,000

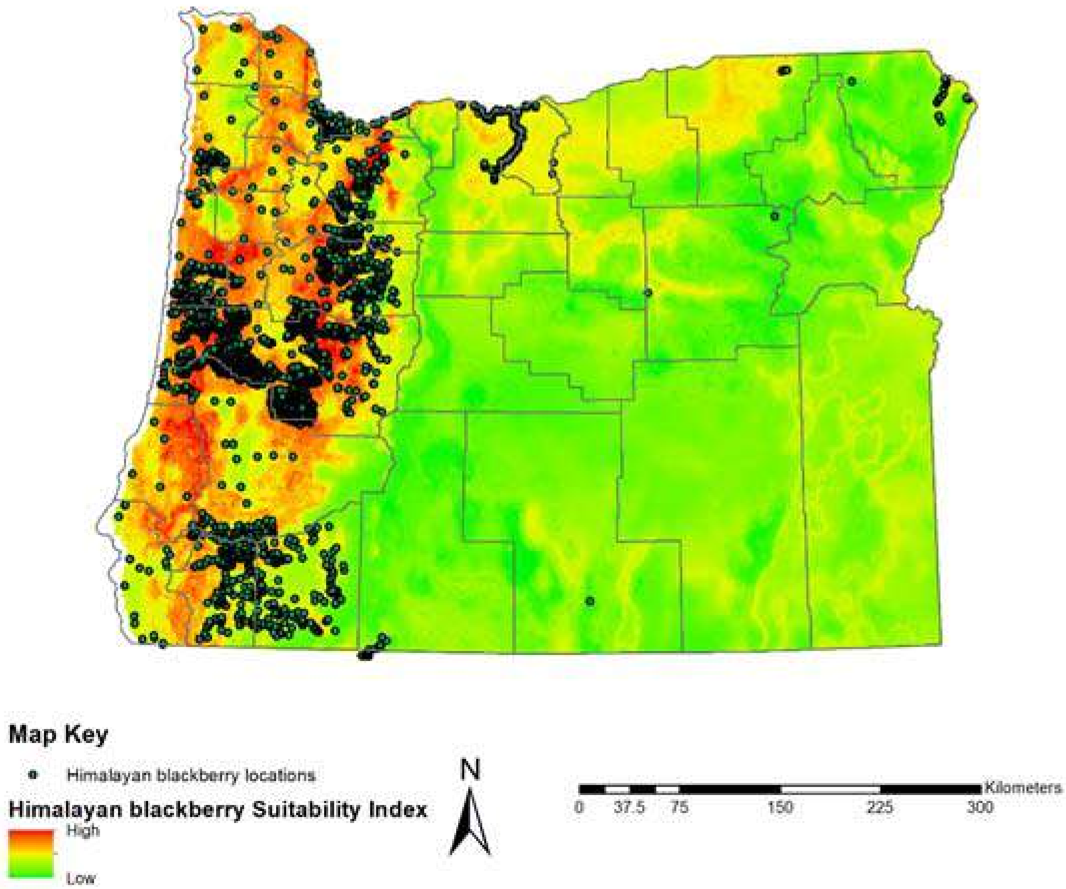
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.

Native Area/Arrival in the U.S.

Armenian blackberry was first noted in Oregon in 1922 in Marion County.

Current Status in Oregon

Predicted Suitability Zone and Currently Known Infestations



Photos

Diffuse knapweed, *Centaurea diffusa*

Description

Biennial; plant forms rosettes in first year, bolts and flowers the next year midsummer to fall. Grows to 3 feet tall. The species is single-stemmed plant with numerous lateral branches and can be quite robust in better soils. Flowers generally white to rose, rarely purplish. Flower heads slender with pointed, fringed bracts. Reproduction is by seed, dispersed by the tumbling of windblown mature plants and by adhering to the fur of animals. Moving water is also a major dispersal agent.

Impacts

Diffuse knapweed will form dense stands on any open ground, excluding more desirable forage species. Once established, the necessary extensive control measures are often more expensive than the income potential of the land. Grows under a wide range of conditions, such as riparian areas, sandy river shores, gravel banks, rock outcrops, rangelands and roadsides. There are possible health hazards from absorbing plant juice through bare hand pulling of plants. It is recommended that gloves are worn while handling plants. Mature plants are scratchy and are host to mites that bite and irritate skin.

Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
275,000	$36,000	16,191,000	$1,379,000

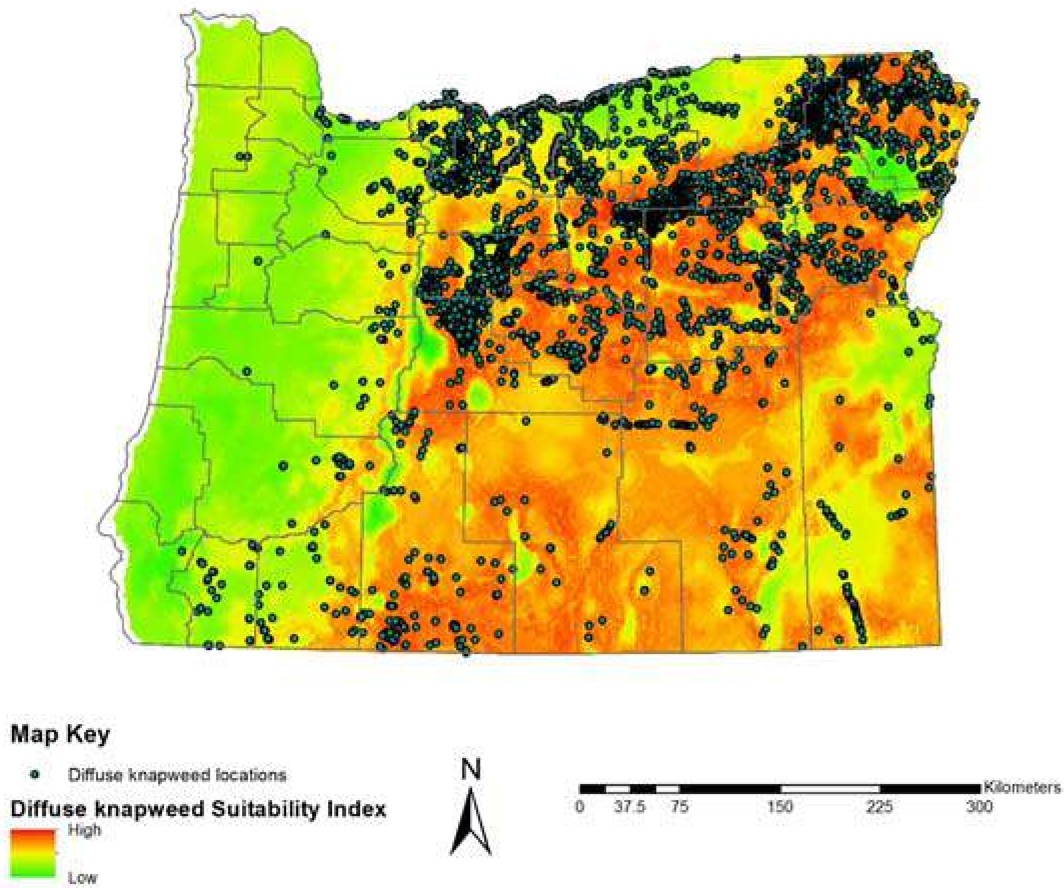
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.

Native Area/Arrival in the U.S.

Diffuse knapweed is a member of a large genus of over 400 species, most originating in the Mediterranean region. Diffuse knapweed was first introduced to the Pacific Northwest at the turn of the century as a contaminant in alfalfa seed imported from Turkestan, Turkmenistan or hybrid alfalfa seed from Germany. Diffuse knapweed is a common rangeland invader in every western state in the U.S.

Current Status in Oregon

Predicted Suitability Zone and Currently Known Infestations



Photos


Giant hogweed, *Heracleum mantegazzianum*

Description

Perennial; flowers May-July. Grows 10-15 feet tall. Stalk and flower head develop after two to four years, then the plant dies back. Stalks are two to four inches in diameter, hollow, have reddish-purple blotches and pustules with a single erect hair in the center. Flower head is a large umbrella-like inflorescence up to two and one half feet in diameter. Leaves are three to five feet wide, compound and deeply incised. This plant closely resembles native cow parsnip which rarely exceeds six feet with a flower head 8-12 inches wide. Cow parsnip is a common native plant in the northwest and grows in riparian areas and roadsides. Giant hogweed is a member of the carrot or parsley family and its most impressive characteristic is its massive size.

Impacts

This plant is a health hazard to humans. Because of its invasive nature it soon becomes a pest within the garden and readily escapes. It has naturalized in many of the places where it was introduced, and is one of the most invasive weeds in Europe. This plant is a public health hazard. Do not expose bare human skin to the plant or breathe the smoke from fires if it is being burned. The plant exudes a clear watery sap which sensitizes the skin to ultraviolet radiation. Humans often develop severe burns to the affected areas resulting in blistering and painful dermatitis. Blisters can later develop into purplish or blackened scars.

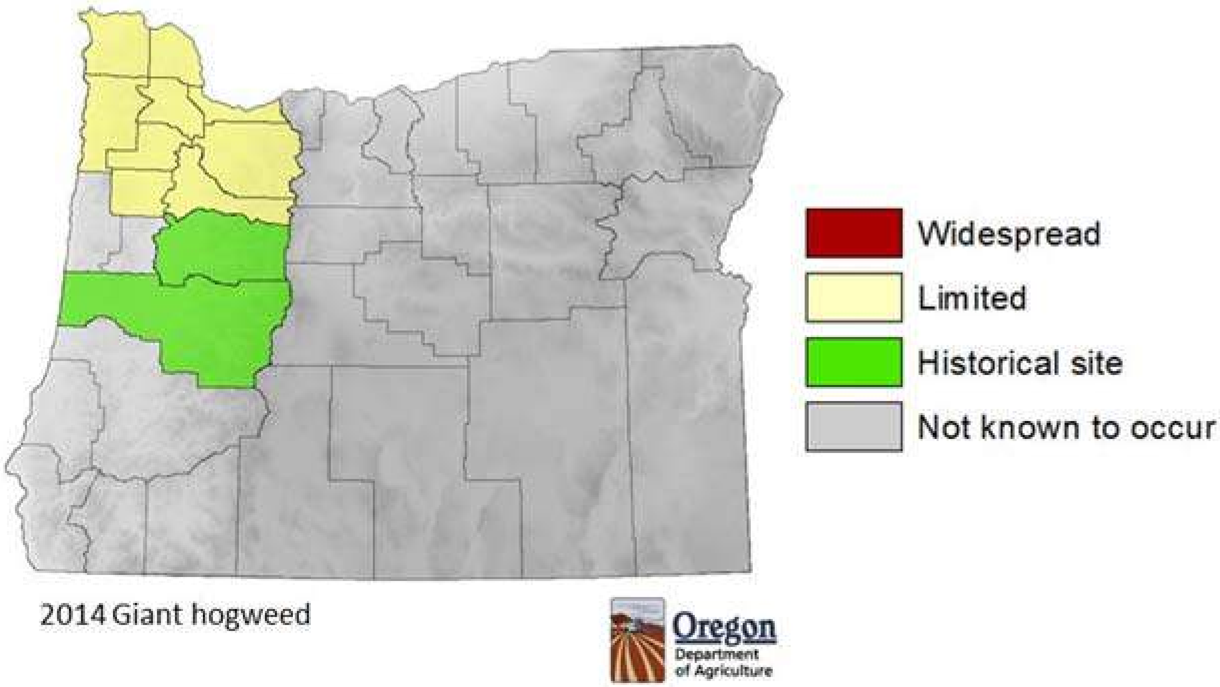
Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
<500	<$500	2,077,000	$1,071,000

Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.

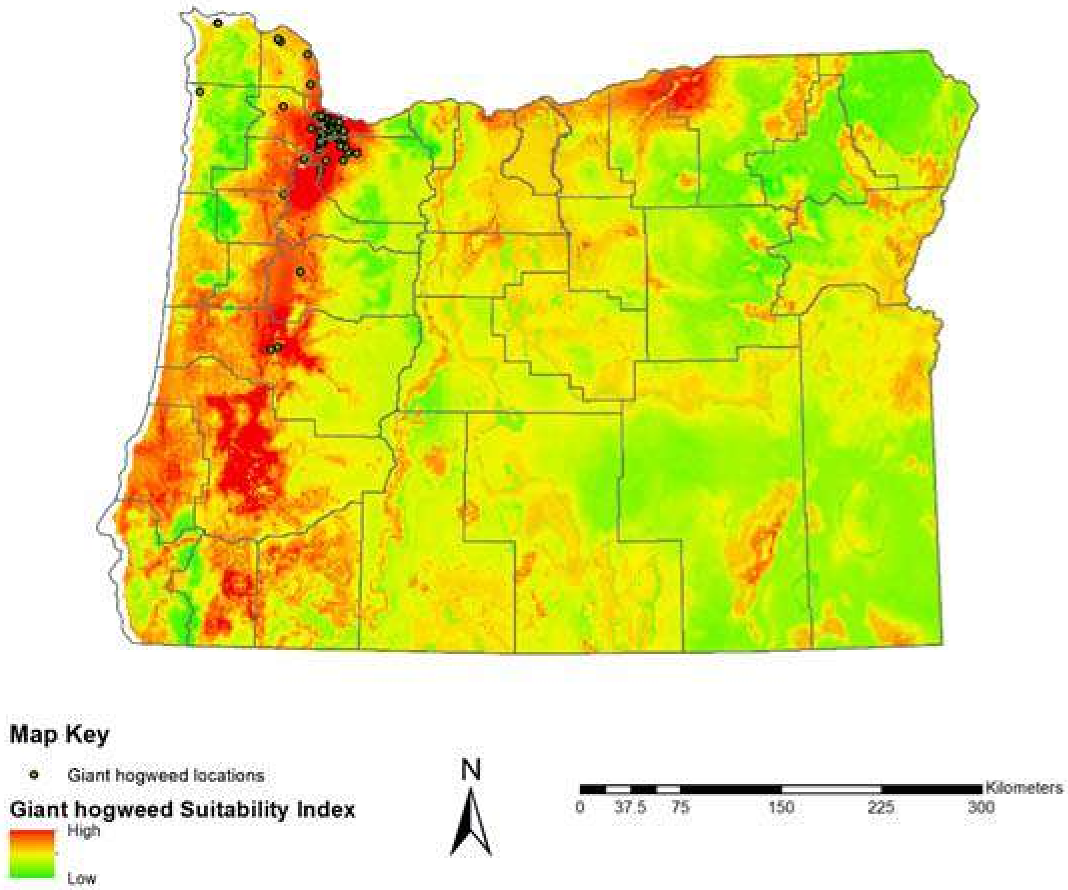
Native Area/Arrival in the U.S.

Giant hogweed grows as a native in the Caucasus Mountains, a region of Asia between the Black and Caspian seas. Planted as a curiosity in arboretums and private gardens in Europe and North America early in the twentieth century, it soon escaped and naturalized in surrounding areas, especially riparian and urban sites. It is reported to be a problem weed in Europe, England, Scotland, Scandinavia and Germany. In North America it grows in Ontario, British Columbia, Maine, Maryland, New York, Washington and now in Oregon.

Current Status in Oregon



Predicted Suitability Zone and Currently Known Infestations



References For More Information

Gorse, *Ulex europaeus*

Description

Perennial, spiny evergreen shrub which blooms March to May. Growing from one to nine feet tall, the stiff, spiny, much-branched shrub forms dense thickets. Branches are dark green, spine-tipped, with clusters of orange-yellow pea-like flowers near the ends. Fruit are more or less covered by long white hairs (Gilkey 1957).

Impacts

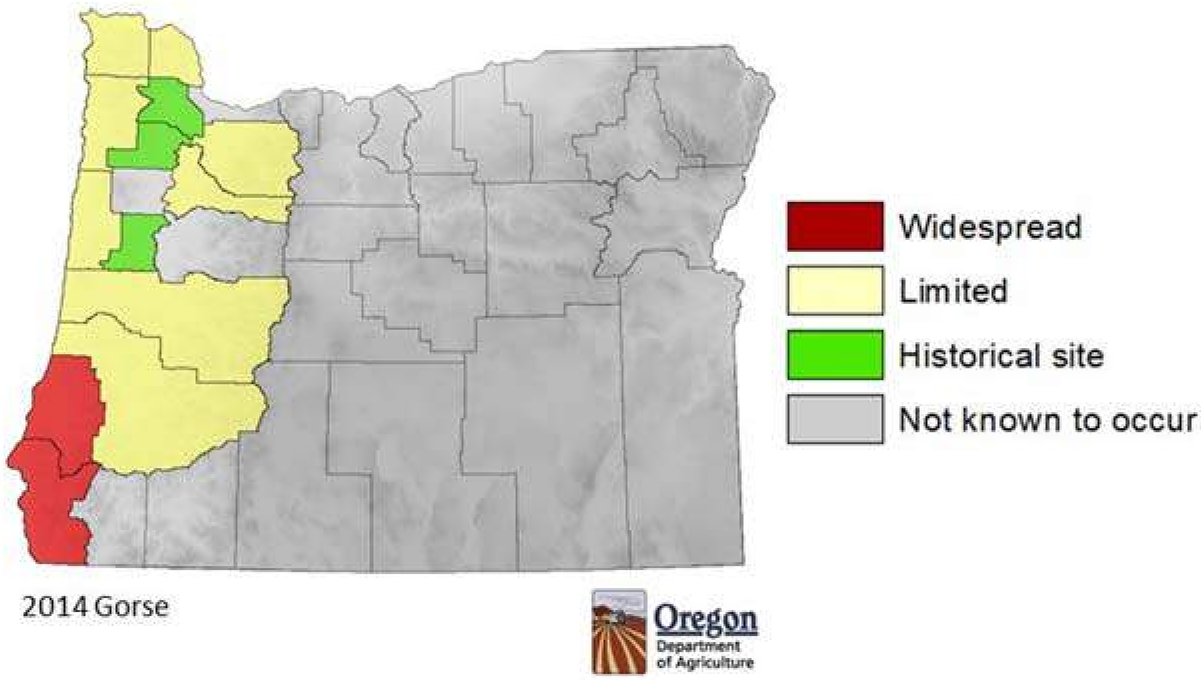
Gorse is a persistent, spinney, pioneer species adapted to a wide range of environmental conditions. Plant growth and stand density increase at a rapid rate, crowding out native and cultivated plants, impacting forest production, inhabiting parklands and pastures, and rendering infested land unusable (ODA 2013, ISSG 2010). Control costs are high and re-infestation is a constant threat. Gorse stands develop a long-lived persistent seed bank requiring long-term management of established sites. High levels of natural oils in the spines make this plant highly flammable and an extreme fire hazard.

Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
28,000	$441,000	16,580,000	$205,576,000
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.			

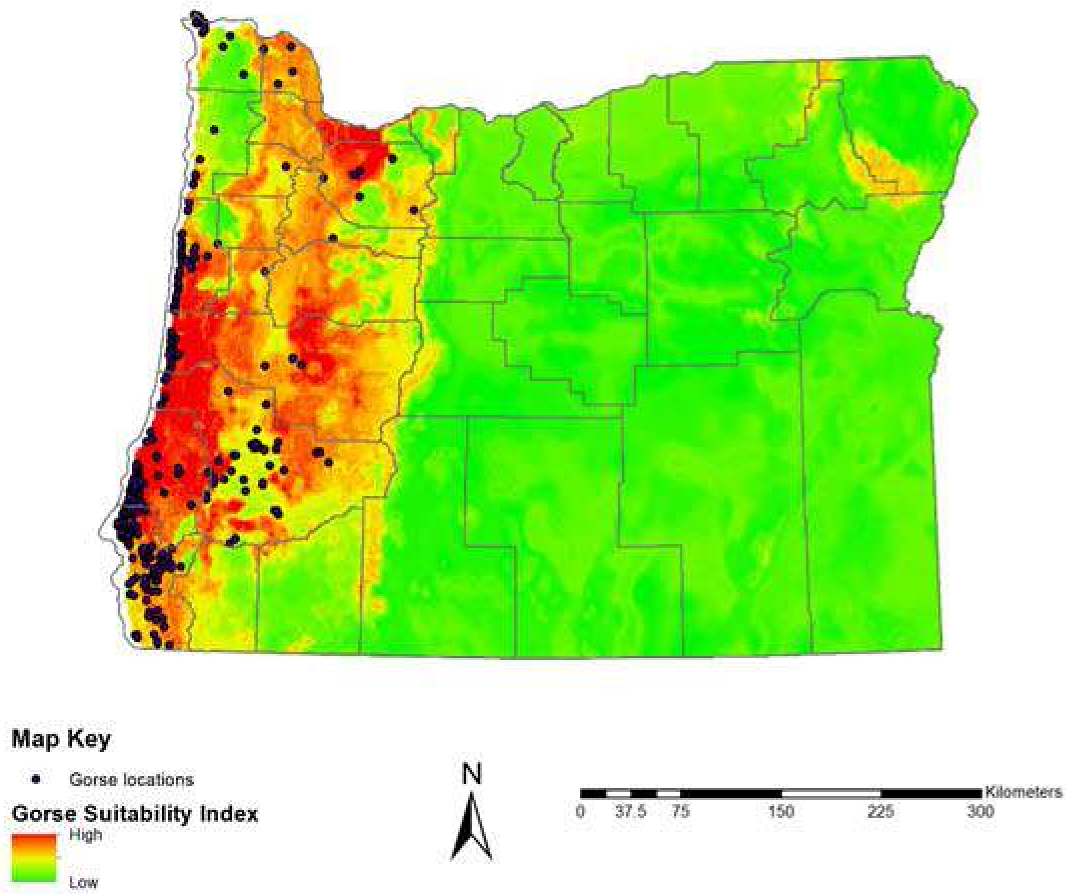
Native Area/Arrival in the U.S.

Gorse is a native of Europe, and was originally brought to the United States as an ornamental shrub. Like many invasive species, gorse escaped these cultivated areas and invaded in all three western states of California, Oregon, Washington and the Provence of British Columbia. The plant is also a problem species in Eastern seaboard states (USDA 2013).

Current Status in Oregon



Predicted Suitability Zone and Currently Known Infestations



Photos

Orange hawkweed, *Hieracium aurantiacum*

Meadow hawkweed, *Hieracium pratense*

Description

Orange hawkweed is a perennial weed with above-ground runners (stolons) that root at the tips. Roots are shallow and fibrous. The plant grows up to 12 inches tall and contains milky juice. The vibrant orange-red colored flowers are clustered at the top of a leafless stem. Stiff, black, glandular hairs cover flower stalks. Leaves are hairy, lance shaped, up to five inches long, and exclusively basal.

Meadow hawkweed has stems and leaves that exudes milky juice when broken. The stems are bristly and usually leafless, although occasionally a small leaf appears near the midpoint. Stems can reach three feet tall and bear up to 30 half inch flower heads near the top. Flowers are yellow and appears in May - July depending on elevation.

Impacts

Plants of the hawkweed complex produce mats of rosettes preventing desirable plants from establishing or surviving. Hawkweeds dominate sites by outcompeting other species for water and nutrients and by releasing alleopathic compounds from their own decaying leaves. Plants grow well in moist grassy areas but do not tolerate shade well. Hawkweeds are becoming troublesome in native meadows, prairies, pastures and lawns. Wilderness areas in the Pacific Northwest are at risk of invasion. Hawkweed tends to grow in places where there isn't constant grazing such as meadows, roadsides, pastures, lawns, and fields.

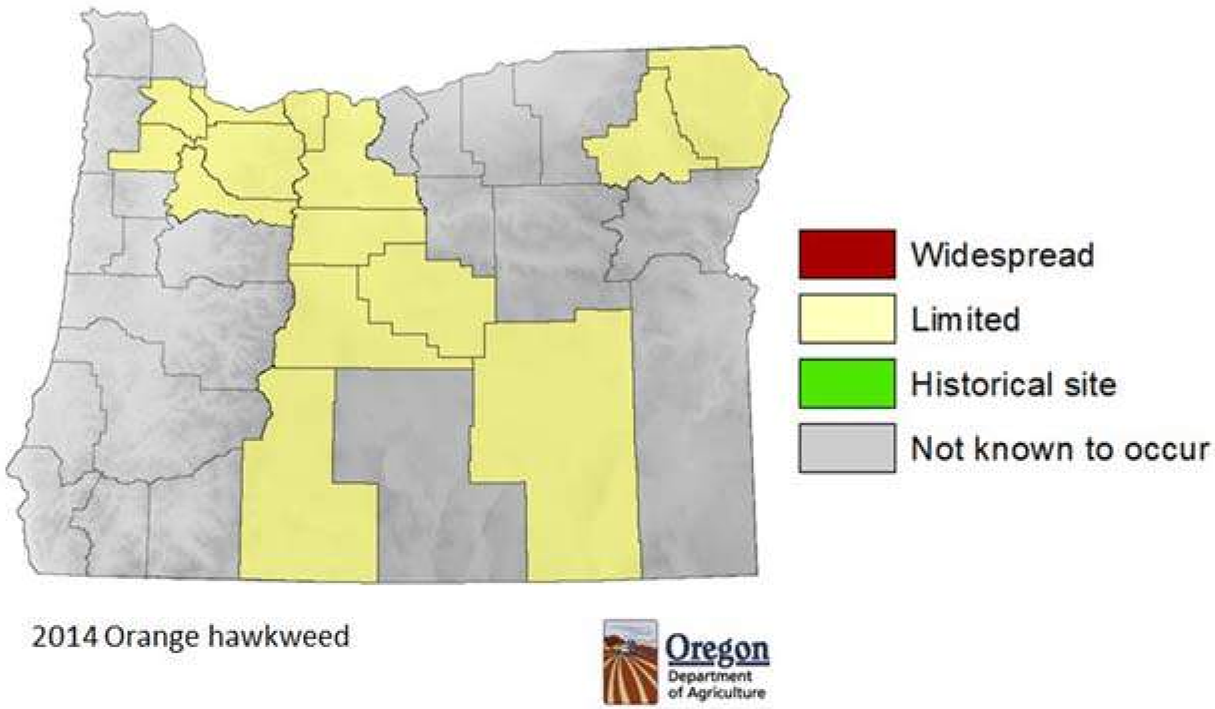
Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
1,000	$1,000	17,888,000	$18,448,000
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.			

Native Area/Arrival in the U.S.

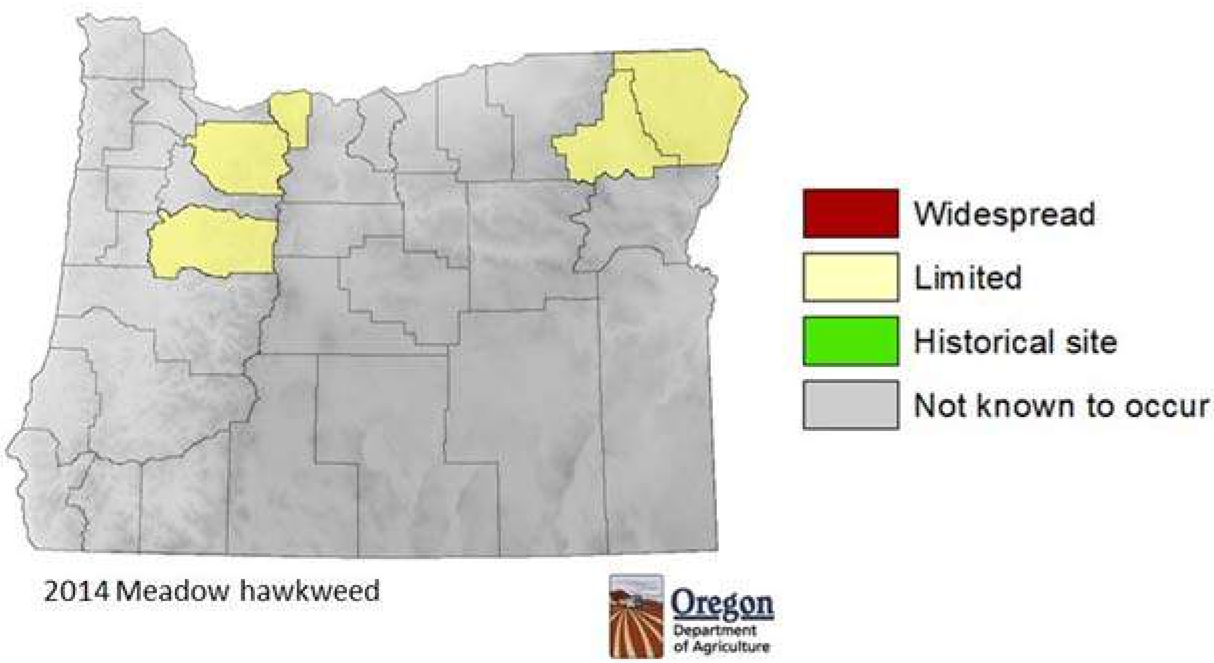
Orange hawkweed is found from western Washington to Wyoming and is known to occur in eastern states. Due to its striking flowers, plant enthusiasts have assisted in the distribution of this weed. Meadow hawkweed is known to occur in Wallowa, Hood River and Clackamas counties but has potential to occur in other counties in Oregon.

Current Status in Oregon

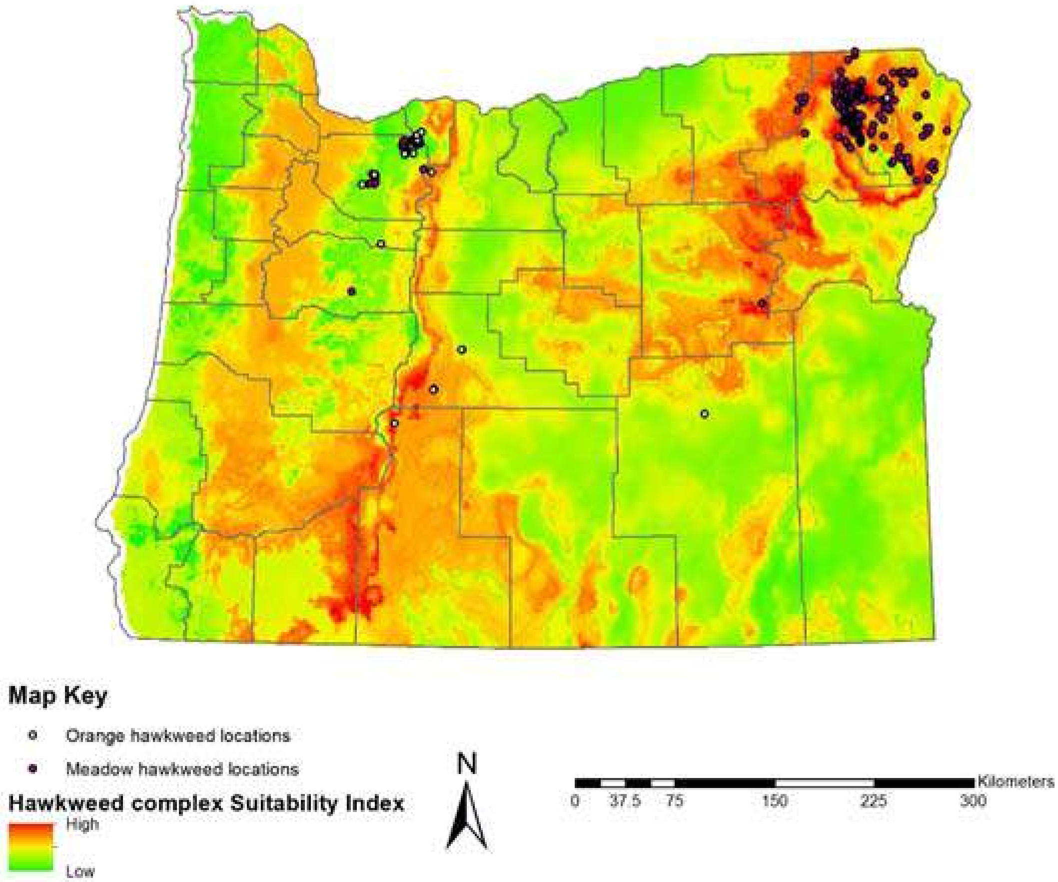
Orange hawkweed



Meadow hawkweed



Predicted Suitability Zone and Currently Known Infestations



Photos

Meadow hawkweed


Orange hawkweed

Japanese knotweed, *Polygonum cuspidalum*

Description

A herbaceous perennial, stem stout which blooms July to October. It grows four to nine foot tall, woody but dying at the end of the growing season which become hollow and have a pattern of purple speckles (Gilkey 1957, ISSG 2010). Stout reddish-brown stems, nodes slightly swollen. Leaves short stalked, truncate, broadly ovate and 2-6" long by 2-4" wide. Flowers greenish-white to cream in large plume-like clusters at the ends of the stems. It has long creeping rhizomes. Hybridization with giant knotweed is common.

Impacts

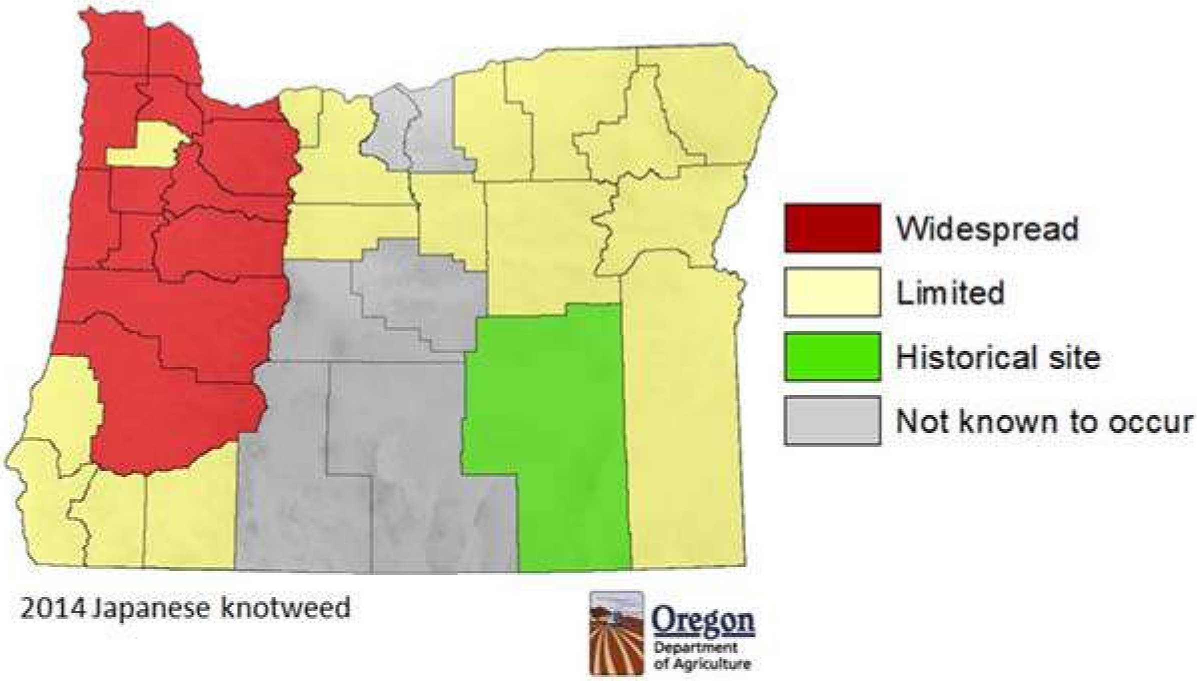
Japanese knotweed grows vigorously along roadsides, waste areas, streams and ditch banks and creates dense colonies that exclude native vegetation and greatly alter natural tree regeneration. Established populations are extremely persistent and do not respond to mowing/cutting. Large infestations can be eliminated with approved herbicides, but treatments are costly and time consuming. It poses a significant threat in riparian areas, where it disperses during flood events rapidly colonizing scoured shorelines, islands and adjacent forestland.

Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
42,000	$31,000	1,799,000	$1,338,000
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.			

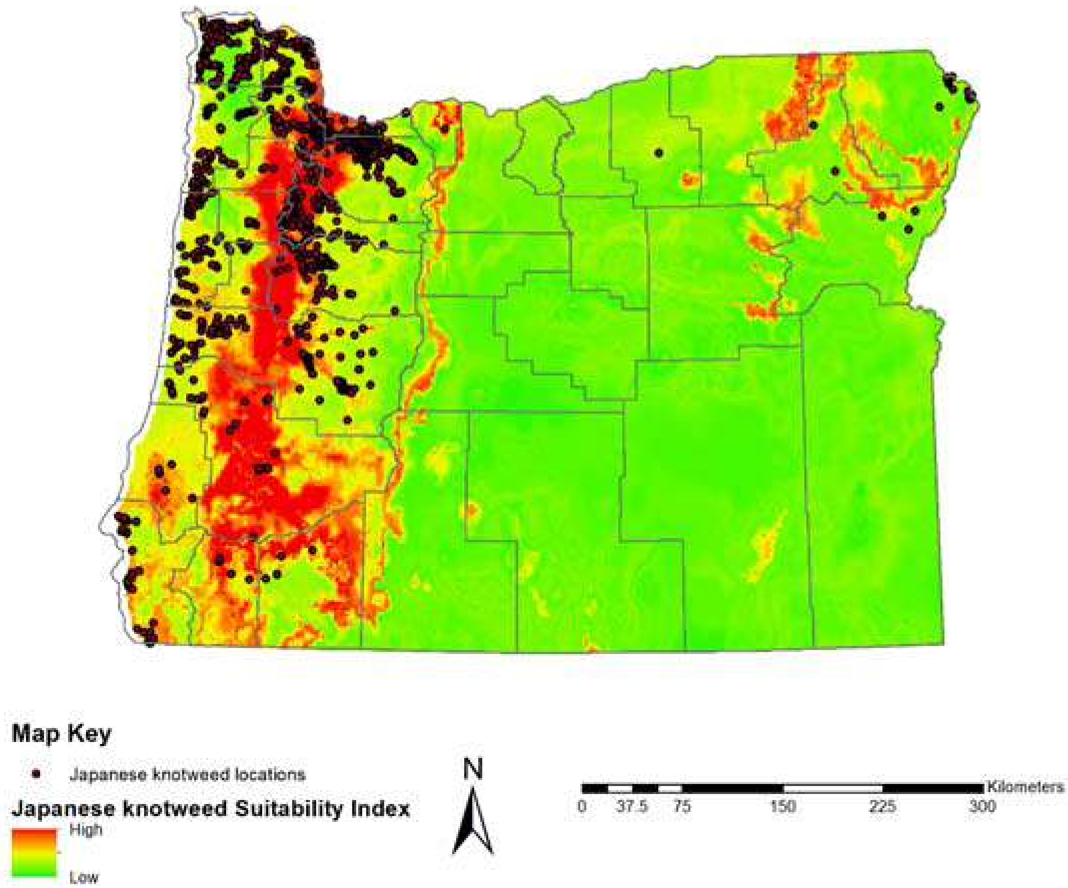
Native Area/Arrival in the U.S.

Japanese knotweed is a native of Eurasia and was introduced to the United States as an ornamental. It has become a prolific invader across most of the lower 48 states in the United States and many provinces in Canada (USDA 2013).

Current Status in Oregon



Predicted Suitability Zone and Currently Known Infestations



Photos

Kudzu, *Pueraria lobata*

Description

This high climbing vine often completely covers trees, shrubs and man-made structure forming "kudzu sculptures". The leaves are alternate, six to eight inches long, have fuzzy leaflets three to four inches long, oval, lobed or nearly heart shaped. Flowers are large hanging clusters of pea-like, purple to red color, with a grape-like smell and appearing in midsummer. Fruit are dark brown flattened pods in clusters, very hairy and ripens in the fall. Stems are velvety with hairs turning brown. Trunk or vines may reach up to four inches in diameter. Older stems and vines turn brown and smooth and eventually form a fine scaly bark. Vines may extend thirty to one hundred feet in length with stems one half to four inches in diameter. As many as thirty vines may grow from a single root crown. Roots are fleshy massive taproot seven inches or more in diameter, six feet or more in length and weighing as much as four hundred pounds.

Impacts

Kudzu kills or degrades native and desirable plants by smothering them under a solid blanket of leaves, by girdling woody stems and tree trunks, and by the sheer force of its weight breaking branches or uprooting entire trees and shrubs. Trees covered by kudzu become damaged by its weight during ice events or die from insufficient light. Once established kudzu grows at a rapid rate extending as much as 60 feet per season at a rate of about one foot per day. Kudzu grows well under a wide range of conditions and soil types. It favors habitats such as forest edges, abandoned fields, roadsides, and disturbed areas where sunlight is abundant. Kudzu grows best where winters are mild, summer temperature are above eighty degrees and annual rainfall is forty inches or more.

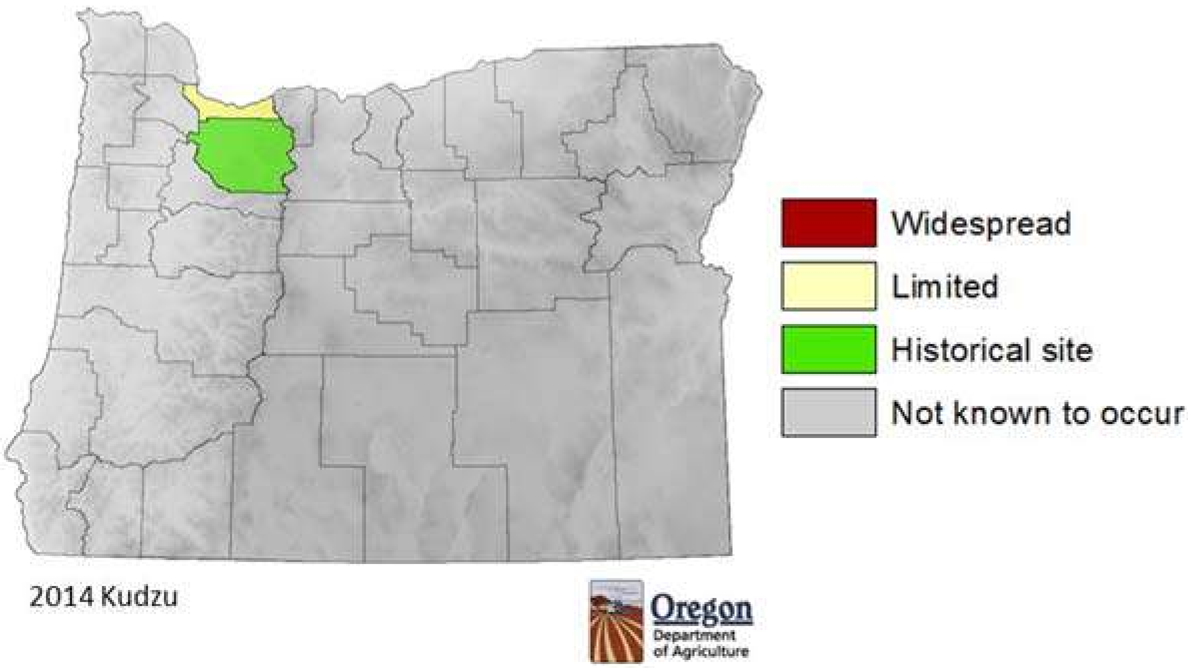
Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
<500	<$500	7,313,000	$173,590,000

Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.

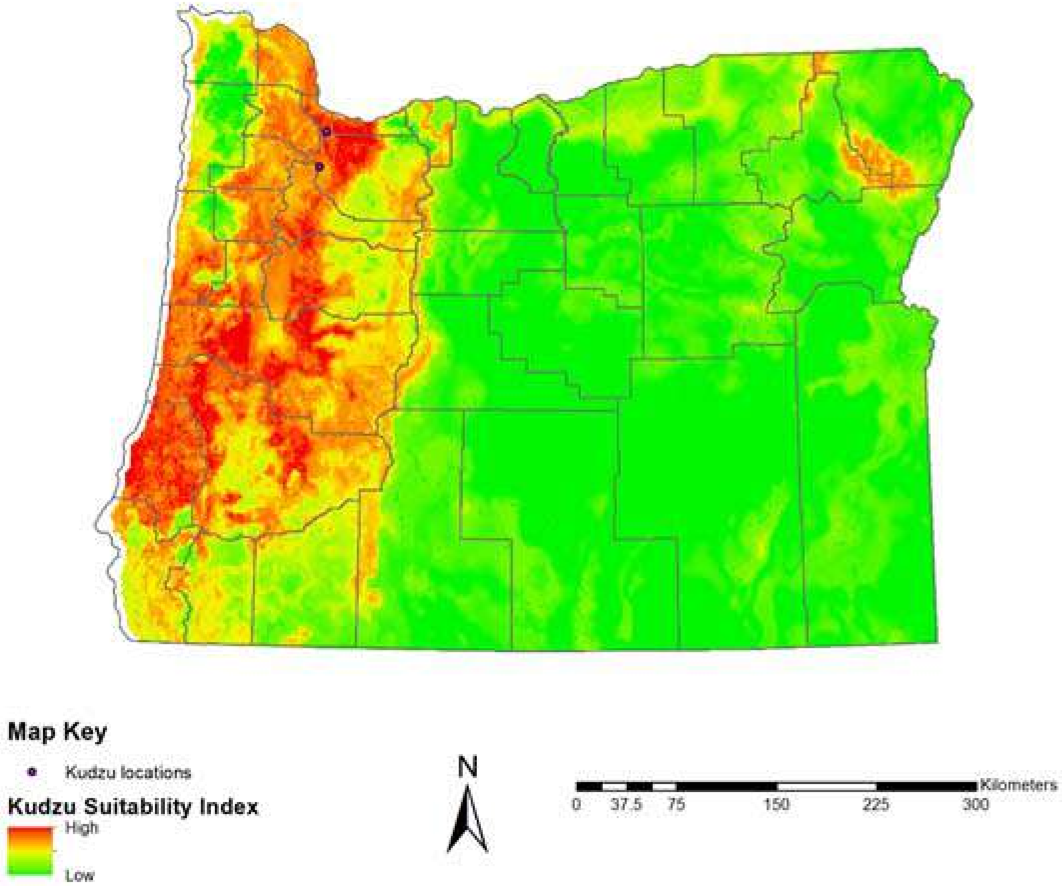
Native Area/Arrival in the U.S.

Kudzu was introduced to the United States in 1876 at the Centennial Exposition in Philadelphia, Pennsylvania. At a celebration of 100th birthday of the U.S. the Japanese government constructed a beautiful garden filled with plants from their country. The large leaves and sweet-smelling blooms of kudzu captured the imagination of American gardeners who used the plant for ornamental purposes. During the Great Depression of the 1930's, the Soil Conservation Service promoted kudzu for erosion control later declaring it a noxious weed.

Current Status in Oregon



Predicted Suitability Zone and Currently Known Infestations



Photos

Leafy spurge, *Euphorbia esula*

Description

Leafy spurge is an aggressive upright, branching perennial herb reaching two-three feet tall. Tough, woody stems exude a poisonous white latex sap when broken. Leaves are alternate, narrow, somewhat frosted and slightly wavy along the margins. Flowers are minute and borne in greenish-yellow structures surrounded by yellow heart-shaped bracts. The root system is extensive extending down 20 feet below the surface. Rhizomes are woody, brown, sporting numerous buds capable of producing above ground shoots. Leafy spurge tolerates moist to dry soil conditions but is most common in coarse-textured soils where competition from native plants is reduced. Seed production is copious. Dispersal occurs through an explosive rupturing of the seed capsule propelling seeds up to 10 feet.

Impacts

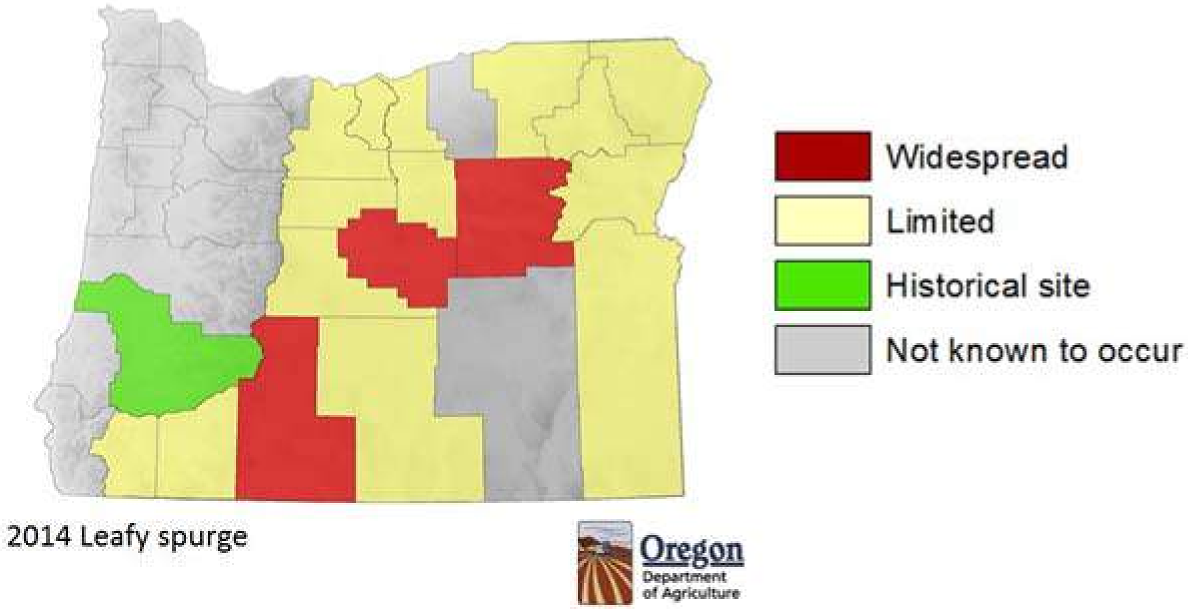
Leafy spurge is one of the West's most invasive and difficult to control weed species. It invades disturbed sites, prairies, savannas, pastures, abandoned fields and roadsides. It is considered toxic to cattle but sheep and goats readily feed on it following an acclimation period. Carrying capacity of infested rangelands can be reduced by 50 to 75%. Leafy spurge is very capable of dominating the plant community and habitat and significantly decreasing the diversity of native species. Leafy spurge also shows allelopathic tendencies. Once established, control is difficult, requiring annual treatments to contain populations. A milky latex exists throughout the plant causing skin irritations in humans, cattle, and horses and may cause permanent blindness if rubbed into the eye.

Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
8,000	$17,000	37,277,000	$65,174,000
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.			

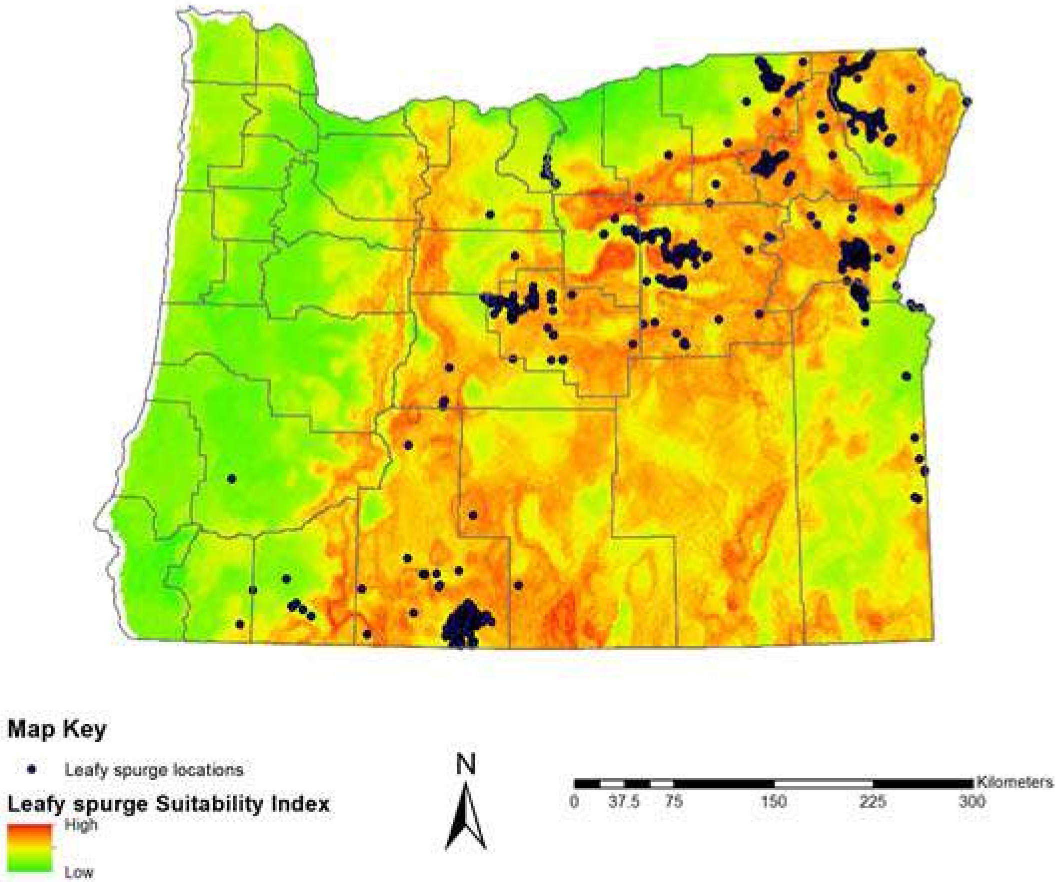
Native Area/Arrival in the U.S.

Native throughout Europe and Asia, brought to the U. S. from Eurasia about 1897 in contaminated grains. It now occurs across much of the northern states including the Pacific Northwest states. First reported in Oregon in 1930 in Klamath County.

Current Status in Oregon



Predicted Suitability Zone and Currently Known Infestations



Photos

Meadow knapweed, *Centaurea moncktonii*

Description

Meadow knapweed is a hybrid of black and brown knapweeds and may be difficult to distinguish from the two at a distance. It is one of the more moisture-loving knapweeds more commonly found in Western Oregon though it is increasingly common in NE Oregon. It is very leafy with showy purple blooms in opening midsummer to fall. It grows from woody root crown and up to 3 1/2 feet tall. The lower leaves are long-petioled, upper leaves have no petiol. Stems are many-branched and tipped by a solitary flower head up to one inch wide. Flower heads are pink to reddish purple, oval or almost globe-shaped. A key identifying feature is the fringed bracts on the flower head.

Impacts

Meadow knapweed out-competes grasses and other pasture species, causing productivity to decline. It is susceptible to herbicide treatments, but control efforts must persist for the long-term. It has the potential to invade native prairie and oak savannah. Meadow knapweed favors moist roadsides, sand or gravel bars, river banks, irrigated pastures, moist meadows, and forest openings. It also can invade industrial sites, tree farms, and grasslands.

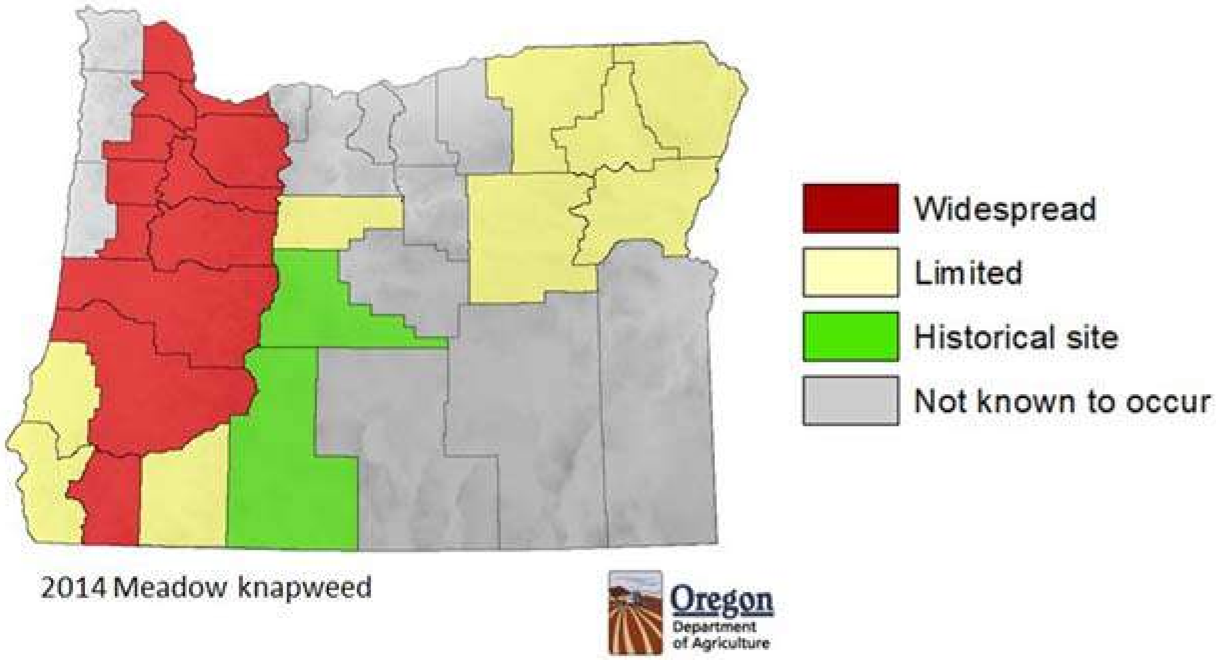
Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
125,000	$146,000	12,443,000	$15,070,000

Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.

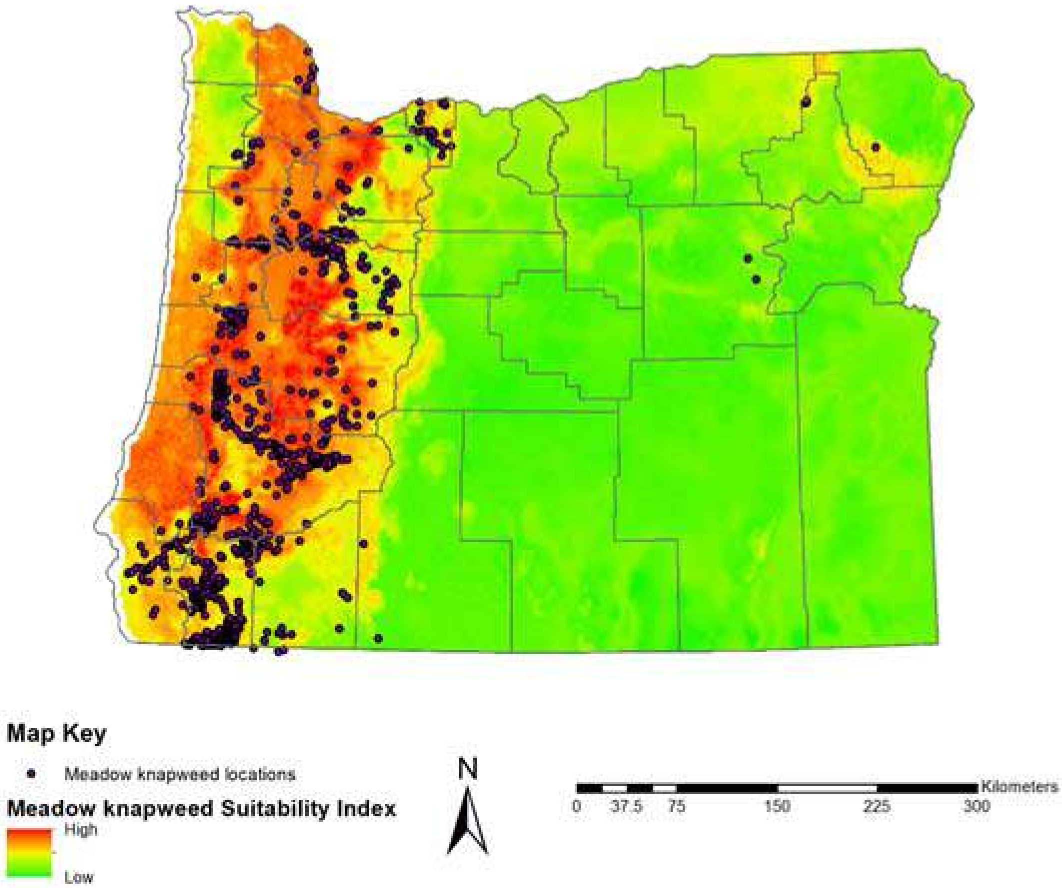
Native Area/Arrival in the U.S.

Its parent plants are native of Europe. It is well established throughout the Pacific Northwest. First noted in Oregon in 1910. It is not known if hybridization occurred in North America or in Europe.

Current Status in Oregon



Predicted Suitability Zone and Currently Known Infestations



Photos

Mediterranean sage, *Salvia aethiopsis*

Description

Mediterranean sage or Med sage for short is a pungent rangeland invader. With a biennial growth habit it produces a large grayish rosette with stout taproot the first growing season and a two to three foot tall flower stalk the second. Blooming occurs June to July. Snapdragon-like flowers are produced one half to one inch long, yellowish-white, forming woolly clusters in a profusely-branched arrangement. When mature, old stalks break off and tumble, spreading seeds throughout. The leaves of the plant have a pungent aroma when crushed.

Impacts

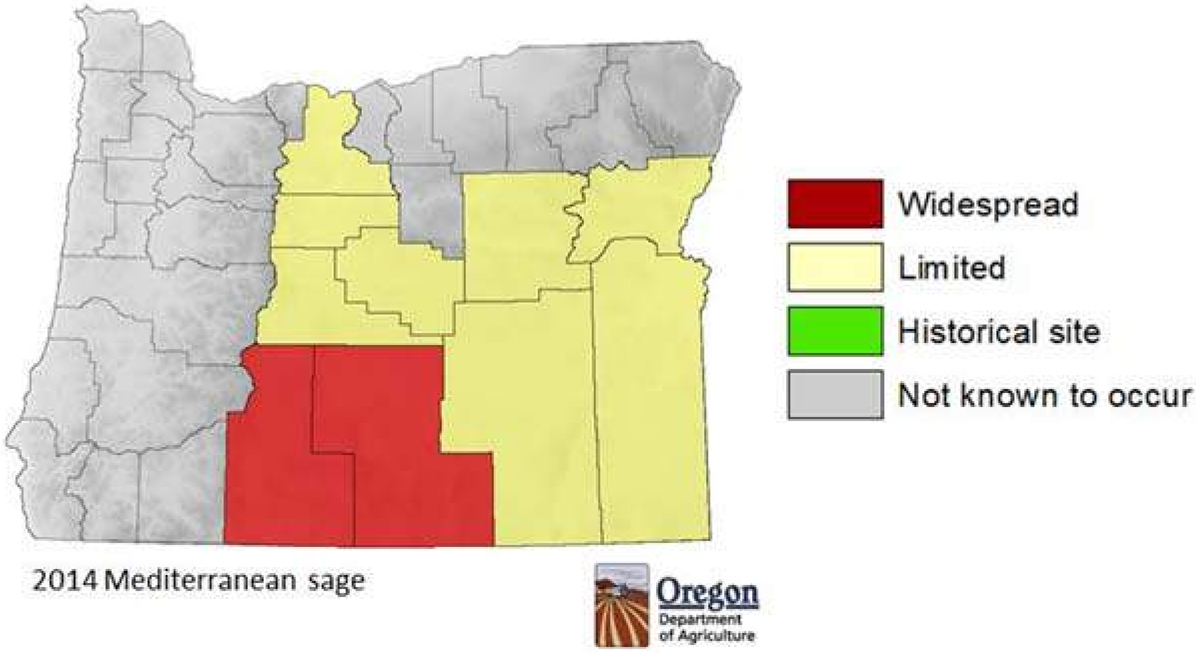
Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
90,000	<$500	15,410,000	$1,132,000
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.			

Though not as dominant in range as many other weed species, Mediterranean sage is still a troublesome pest in pastures and rangelands of eastern Oregon, predominantly in the south central part of the state. It is highly competitive replacing grasses especially when moisture is sparse reducing forage quality and yield. It can also grow well in alfalfa and wheat. Biocontrol insects have aided in limiting the rapid spread of the plant.

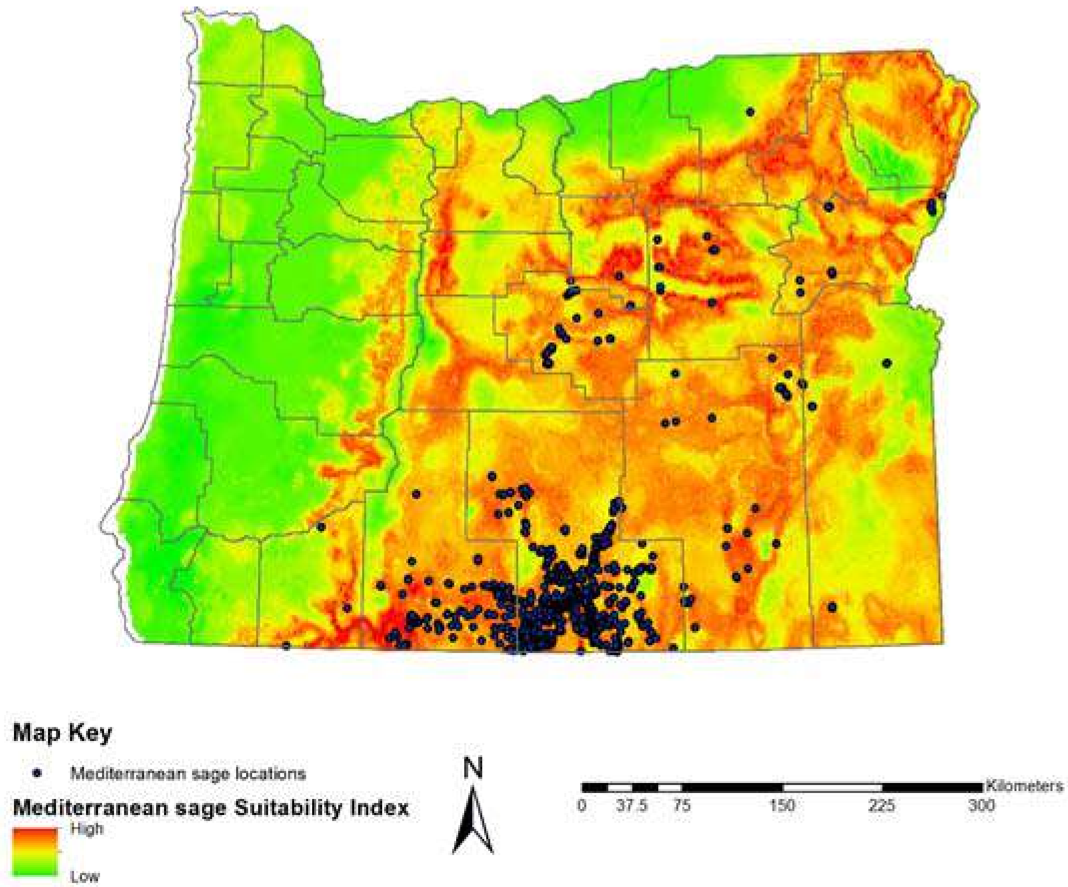
Native Area/Arrival in the U.S.

Mediterranean sage is a native of southern and southeastern Europe and was introduced in the United States in 1892 as an alfalfa seed contaminate (Roche and Wilson 1999).

Current Status in Oregon



Predicted Suitability Zone and Currently Known Infestations



Photos

Perennial pepperweed, *Lepidium latifolium*

Description

Perennial pepperweed is a showy, leafy forb hosting an abundance of small white flowers. Also known as tall whitetop, it blooms May to September. It can grow to 6 feet tall with its basal leaves larger than upper leaves. The lanceolate leaves are bright green to gray green, entire to toothed. Flowers are white, very small, and form dense clusters near the ends of branches. They have a distinctive odor. Seeds are very small, flattened, slightly hairy, and reddish brown. They are easily transported by waterfowl, livestock and in hay shipments.

Impacts

Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
89,000	$110,000	15,992,000	$5,329,000

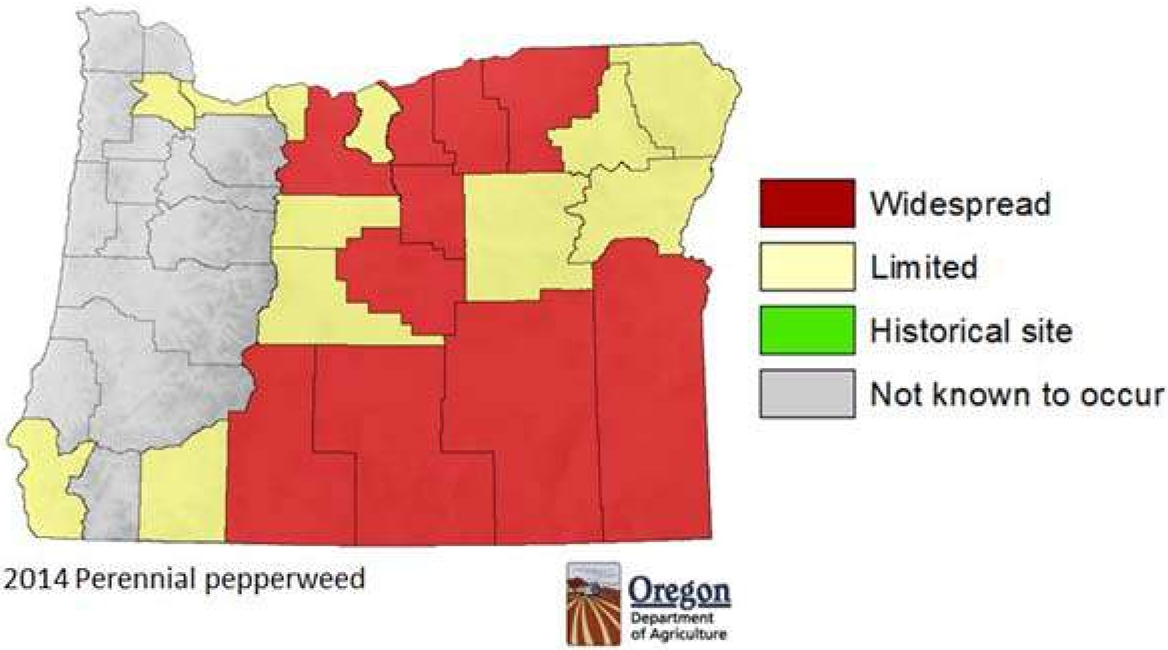
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.

Perennial pepperweed rapidly colonizes wetlands, moist pastures and estuaries. It degrades bird nesting habitat and displaces desirable species in natural areas and hay meadows. Contaminated hay is of lower quality and it competes heavily with native grasses, reducing grazing potential. Infestations can be so damaging that they have been known to significantly affect crop land values. The weed can also be found in disturbed areas and farmyards, agricultural land, range, roadside and irrigation ditches. It is salt tolerant and highly adapted to a range of soil conditions.

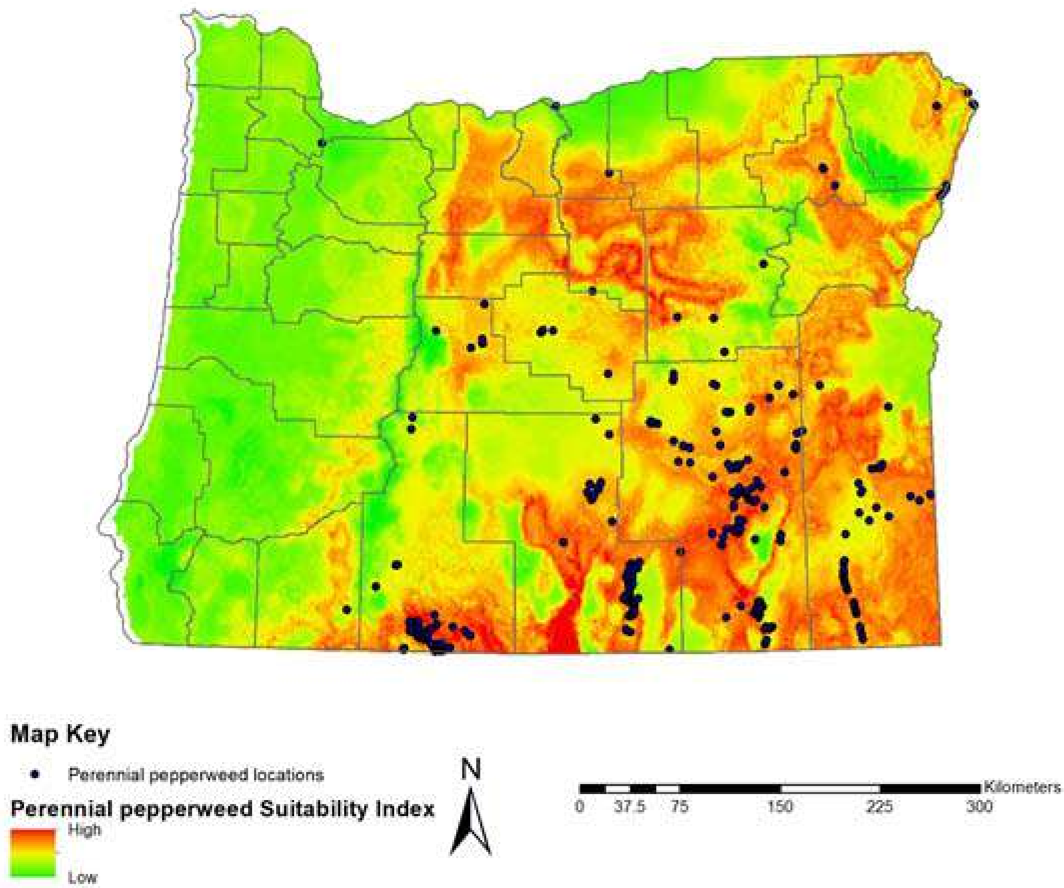
Native Area/Arrival in the U.S.

Perennial pepperweed is native to Southern Europe and Western Asia and now widely distributed throughout the U.S. Introduction into U.S. is thought to result from imported sugar beet seed in the 1930's.

Current Status in Oregon



Predicted Suitability Zone and Currently Known Infestations



Photos

Purple starthistle, *Centaurea calcitrapa*

Description

Purple starthistle is a heavily armored pioneering species that rapidly establishes disturbed sites and open niches. It inhabits fields, roadsides, grasslands, rangelands, waste areas, and open forests. It grows in full sun and does not persist in shade. It prefers fertile alluvial soils of bottomlands. The life cycle of purple starthistle is variable and it can develop as an annual, biennial, or short-lived perennial depending on the environmental conditions. It grows upright to three feet tall as an erect, branched, shrubby herb. Light dusty green in color, the leaves and stems are covered with fine hairs and resin glands giving the plant a dusty appearance. Leaves are divided into narrow elongated segments. Bracts on the flower heads are tipped with sharp rigid spines over one inch long. Flower color is lavender to deep purple and blooms July through October. Rosettes are crowned with a cluster of stiff straw-colored spines in the center; leaves are deeply-lobed with light-colored midribs.

Impacts

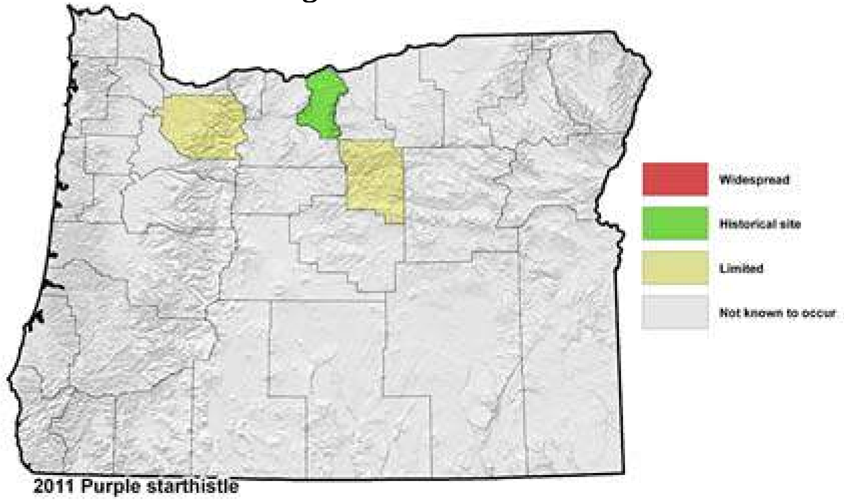
It is highly competitive and displaces desirable plants and forage over a wide range of conditions. The plant can thrive in arid regions of eastern Oregon as well as in high rainfall areas west of the Cascades. It prefers fertile soils and forms dense stands in pasture, range, open forest, and riparian areas. A long taproot provides a competitive advantage over annual and perennial grasses reducing available forage. The rigid spines make it unpalatable and reduce the quality of hay. It restricts access and deters grazing by livestock and wildlife. Infestations can restrict recreational opportunities and degrade the quality of parks and natural areas.

Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
<500	<$500	4,017,000	$4,729,000
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.			

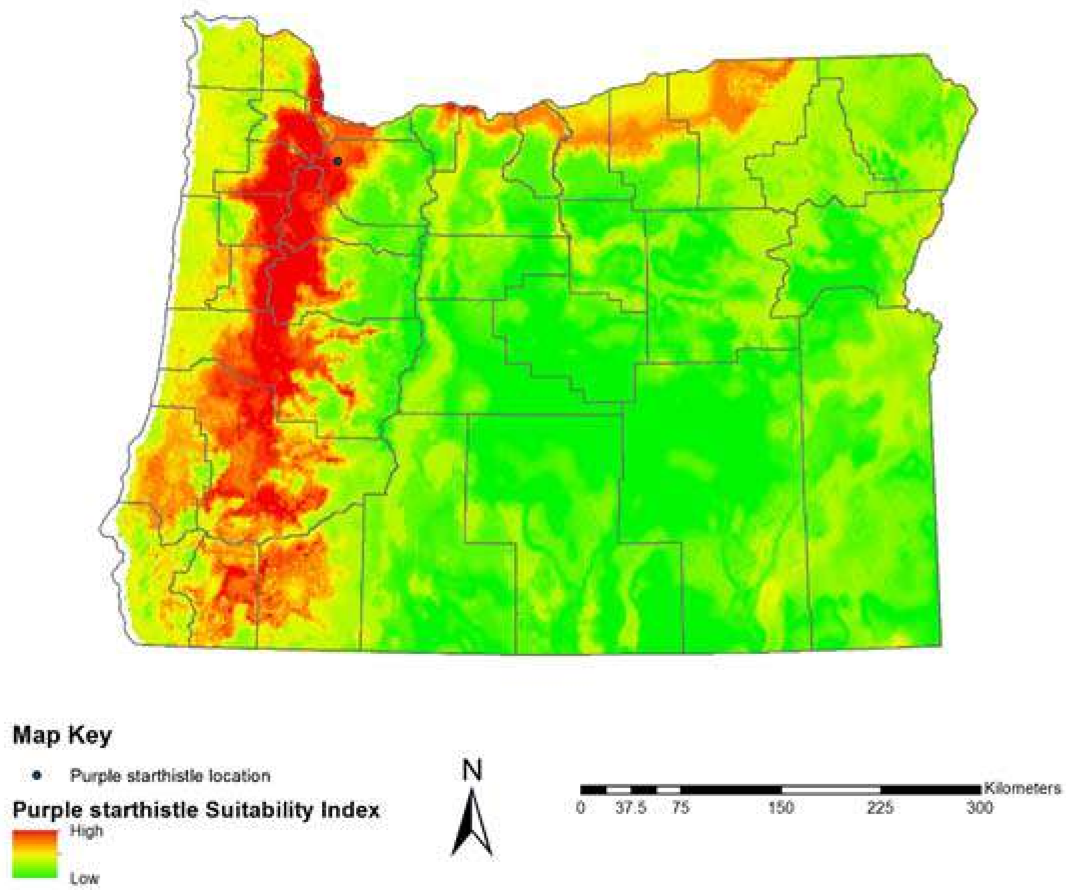
Native Area/Arrival in the U.S.

Mediterranean Europe and northern Africa. Purple starthistle is prevalent throughout most of California. Populations are documented in the Pacific Northwest (PNW), three recent sites in Oregon and three from Washington.

Current Status in Oregon



Predicted Suitability Zone and Currently Known Infestations



Photos

Rush skeletonweed, *Chondrilla juncea*

Description

Rush skeletonweed is noted for having few sparse leaves and wiry dark-green stems giving it a skeleton appearance. As a member of the sunflower family, its stems exude a white latex sap similar to dandelions. It is a deep-rooted perennial growing 1-4 feet tall that is able to access soil moisture deep within the soil profile late in the season. Small yellow flowers emerge July to September producing small pappus covered seeds that disperse long-distances in the wind. Cultivation increases stand densities by root fragmentation, dispersing them throughout fields. Contaminated grains shipped and planted in other fields also contribute to dispersal.

Impacts

Rush skeletonweed is an aggressive plant in both rangeland and cropland, particularly in light textured soil and has been the target of large control projects for decades. Skeletonweed infestations can become quite dense outcompeting native vegetation. Cereal grain and potato production areas are at risk from skeletonweed invasion. Impacts include reduced yield due to competition and harvest difficulties when combining due to the latex sap that gums up the machines. Extensive efforts have been made to eradicate or contain outbreaks, but new sites are being found each year in the eastern part of Oregon.

Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
110,000	$1,397,000	15,365,000	$228,219,000

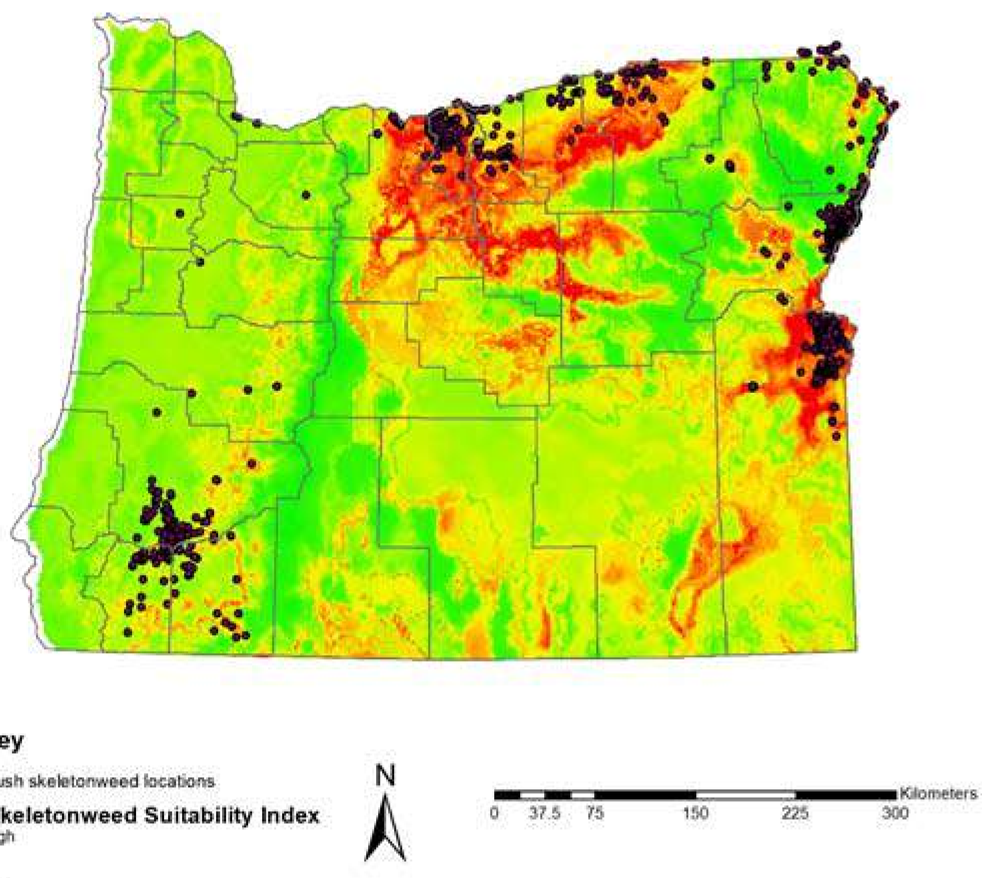
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.

Native Area/Arrival in the U.S.

Native to Eurasia, this noxious weed now infests several million acres in the Pacific Northwest and California especially in Idaho. The first documented site (1974) in Oregon was in Douglas County in SW Oregon.

Current Status in Oregon

Predicted Suitability Zone and Currently Known Infestations



Photos


Scotch broom or Scot's broom, *Cytisus scoparius*

Description

Easily the most recognized and disliked weed species in Western Oregon. Scotch broom is a perennial evergreen shrub with many slender, erect, dark green angled branches with small, simple leaves growing up to 8-10 feet tall. Bloom time spans from April to June. Abundant, bright yellow, pea-shaped flowers adorn the plants turning infested hillsides flaming yellow. When the seeds mature in dark black seedpods, they are ejected and thrown several feet away from the parent plant to start new seedlings. It is a pioneer species, complete with root nodules that fix nitrogen in nutrient poor soils. Allergy sufferers hate the plant for its prolific pollen production. Scotch broom can be easily confused with French broom, *Genista monspessulana (*which has smaller flowers and more permanent leaves) or Spanish broom *(Spartium junceum)*, (has round stems, very few leaves, and larger yellow flowers). All three species grow in Oregon.

Impacts

Scotch broom is a pioneer species known to displace native plant species and increase the costs of tree reforestation. It readily invades disturbed sites, natural areas, dunes and forestlands. Scotch broom control on rights-of-way, facilities, parkland and private property costs millions of dollars each year because of rapid growth and persistent nature due to long-lived seeds (50 years plus). Mature plants are prolific seed producers, establishing persistent seed banks requiring long-term commitments to control. The largest costs attributed to Scotch broom come from additional inputs needed to establish trees in commercial and public timberlands.

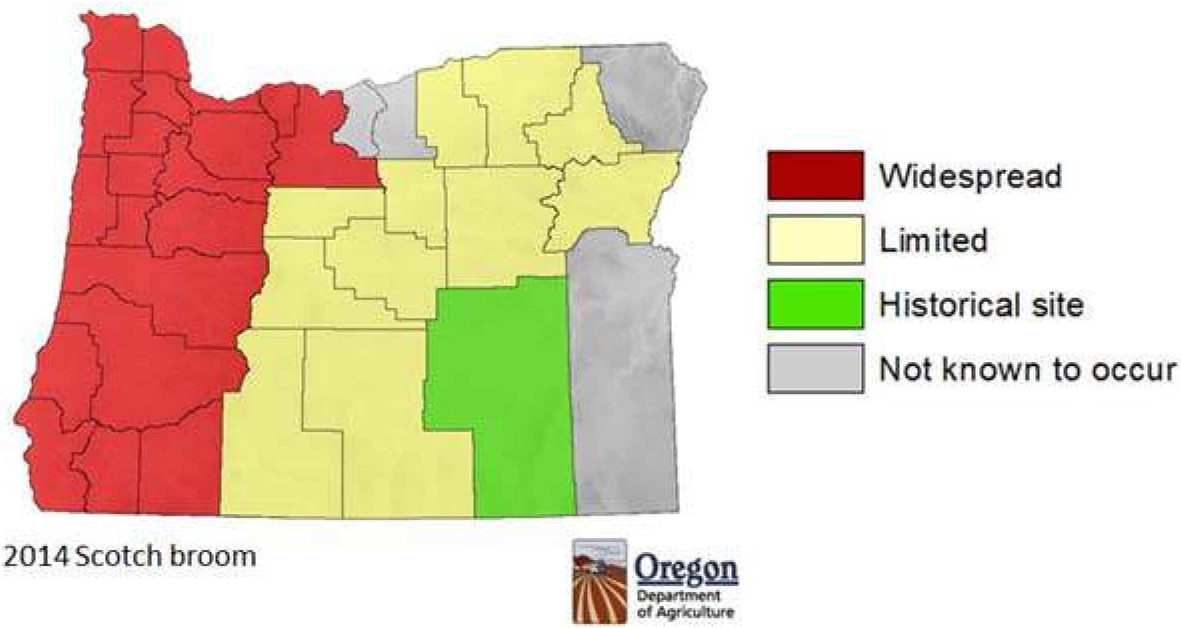
Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
1,528,000	$39,465,000	7,601,000	$179,838,000

Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.

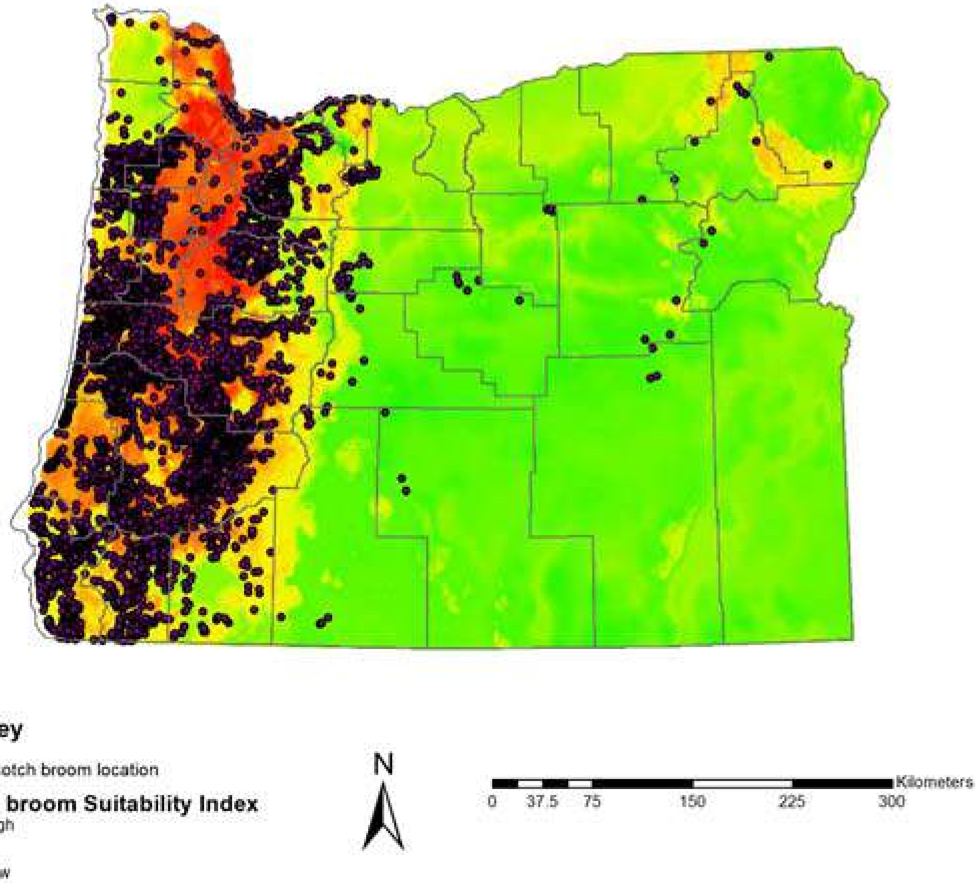
Native Area/Arrival in the U.S.

Scotch broom is a European native. It was introduced into North America in the 1700's as an ornamental plant. The first documented Oregon site was in Benton County in 1892.

Current Status in Oregon



Predicted Suitability Zone and Currently Known Infestations



Photos

Scotch thistle, *Onopordum acanthium*

Description

Scotch thistle is a robust biennial thistle. It often produces a rosette the first year than bolts in year two, sometimes reaching heights over 10 feet in better soils. Large purple flowers several inches across (blooming May-June) are produced during the second year. It may act as an annual growing 2-4 feet the first year and flowering before dying back. Scotch thistle has a distinctive blue-grey color with large leaves and spiny winged stems. Dense soft white hair on upper leaf surfaces give it its distinctive color. Thistle stands can become quite dense and practically impenetrable because of spiny nature and large size. Spreads by seed. Dispersal primarily by animals, humans and water. Thousands of seeds may be produced per plant. They are large not generally windblown.

Impacts

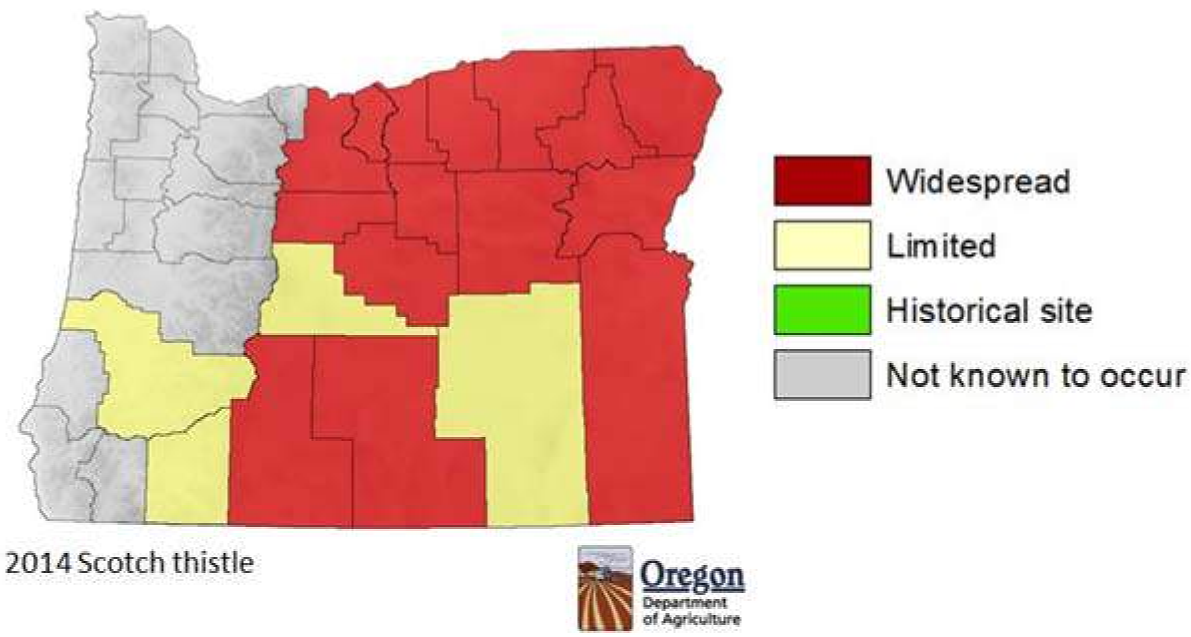
Scotch thistle is a wasteland weed that generally inhabits moist sites or drainages in drier climates. It thrives in right of ways, along irrigation canals and any location with coarse well drained soils not under active management. If not controlled, it invades farmland or forms dense canopies in any area overgrazed or not under intense cultivation. It is a major issue in rangeland management in northeastern Oregon and is expanding rapidly in Central Oregon.

Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
102,000	$6,000	19,241,000	$1,923,000
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.			

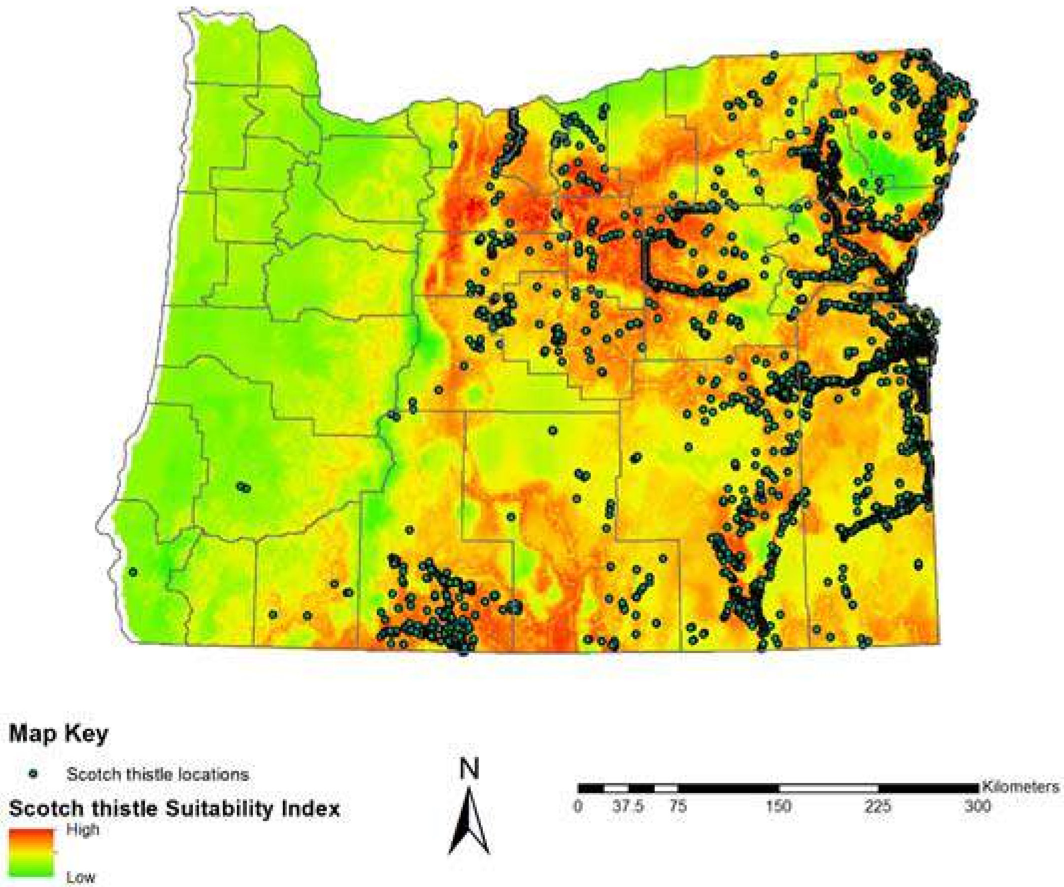
Native Area/Arrival in the U.S.

Scotch thistle is a native thistle of Asia and Europe that was introduced in the 1800's as an ornamental garden plant. It is now found throughout North America.

Current Status in Oregon



Predicted Suitability Zone and Currently Known Infestations



Photos

Spotted knapweed, *Centaurea stoebe* (formerly *maculosa*)

Description

Often referred to as a short-lived perennial, spotted knapweed plants can survive for many years. It is a multi-stemmed plant growing up to 3 feet tall. Leaves are greyish to greyish-green deeply indented and lacy. Blooming begins in midsummer continuing through the fall with purple flowers or occasional cream colored ones. Tips of flower head bracts are usually black, thus the name "spotted." Seed production is prolific with the seeds dispersed by wind, animals, and people. The root grows as a deep taproot drawing moisture from deeper soils late in the summer. This deep taproot makes manual removal very difficult.

Impacts

Spotted knapweed is one of the most dominant weed species in the western United States. Millions of acres of prime range and native habitat are infested throughout the northern Rocky Mountain states. Infested acres in Oregon are still limited but gradually increasing. This species will form dense stands on any open ground, excluding more desirable forage species and native plants. Root exudates are known to be allelopathic contributing to its competitive success. On heavily infested range, the control and restoration practices per acre are often more expensive than the income potential derived from grazing. Control success is also hampered by seed longevity. Weeds in the *Centaurea* genus have more negative impacts attributed to them in natural and agricultural ecosystems than any other plant group in the western U.S.

Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
168,000	$33,000	37,297,000	$138,064,000
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.			

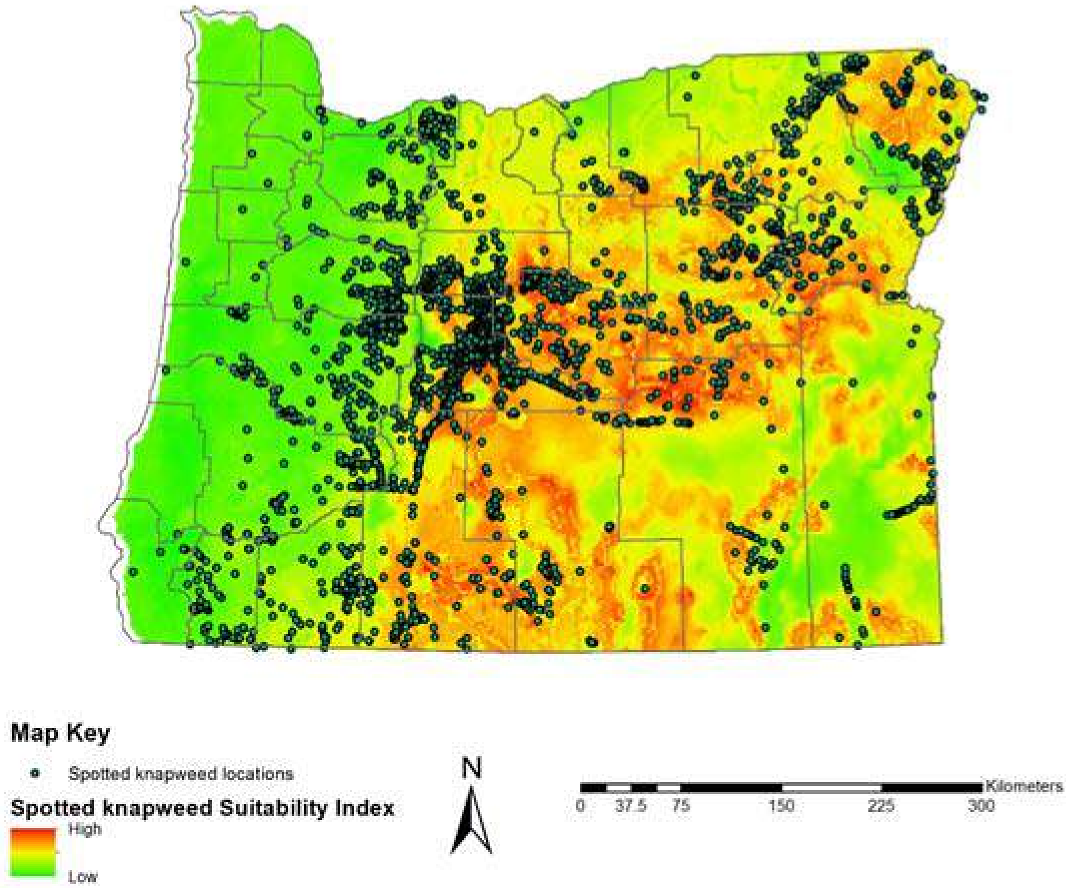
Native Area/Arrival in the U.S.

Spotted knapweed was accidentally introduced into North America from Europe and western Asia in the late 1800's in contaminated alfalfa and clover seed and in soil used for ship ballast. It is now found in virtually every on of the lower 48 states. It is a serious invader of range especially in Montana.

Current Status in Oregon

Oregon Department of Agriculture

Predicted Suitability Zone and Currently Known Infestations



Photos

Squarrose knapweed, *Centaurea virgata ssp. squarrosa*

Description

Squarrose knapweed is a long-lived perennial *Centaurea* species with deep roots and a large crown. Rosettes will grow slowly for a number of years before blooming. The plants morphology is rounded, somewhat like a tumbleweed. Flower heads are smaller than the other knapweeds, showing rose-colored flowers beginning in early to mid June and having up to 8 seeds per head. The terminal bracts around the flower heads are enlarged and recurved. Squarrose knapweed is not a showy plant and may escape detection if found in the presence of other knapweeds. It can be confused with short-growing diffuse knapweed. Seed heads readily detach from the plants when mature, acting as a very effective dispersal mechanism by catching in animal hair and on clothing. Whole plants can also detach and tumble with the wind dropping seed heads as they go. The seed heads do not open at maturity, ensuring that they are dispersed far from the parent plant and slowly shaken out over time. Sheep are heavily implicated in the spread of squarrose knapweed.

Impacts

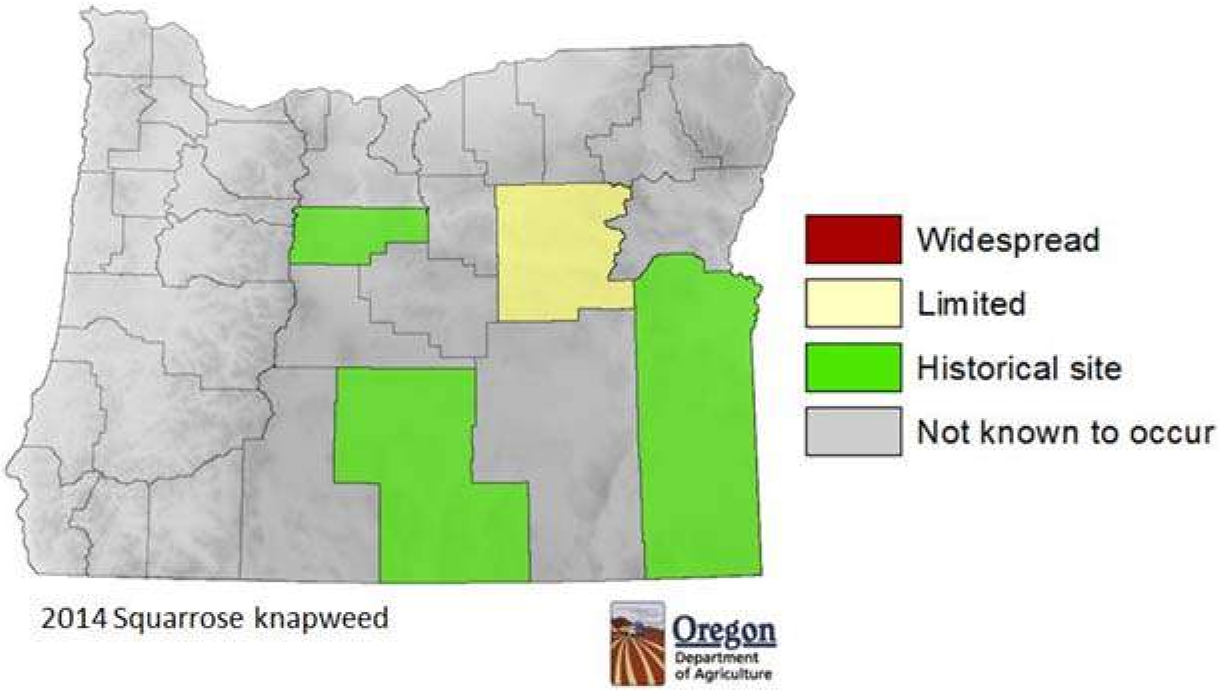
Squarrose knapweed is one of the least common of our invasive *Centaureas* in Oregon, but has the greatest potential for impacting Eastern Oregon's arid to moist rangelands because it can form very dense stands even ruining healthy native bunchgrass communities. The economic and environmental costs of large-scale infestations would be high. Rangeland in Oregon supports the vital livestock industry, as well as providing habitat for sage grouse, antelope and numerous rare plants. Squarrose knapweed quickly re-establishes after a fire, and is said to carry a fire as handily as cheatgrass in dense infestations.

Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
<500	<$500	14,003,000	$2,057,000
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.			

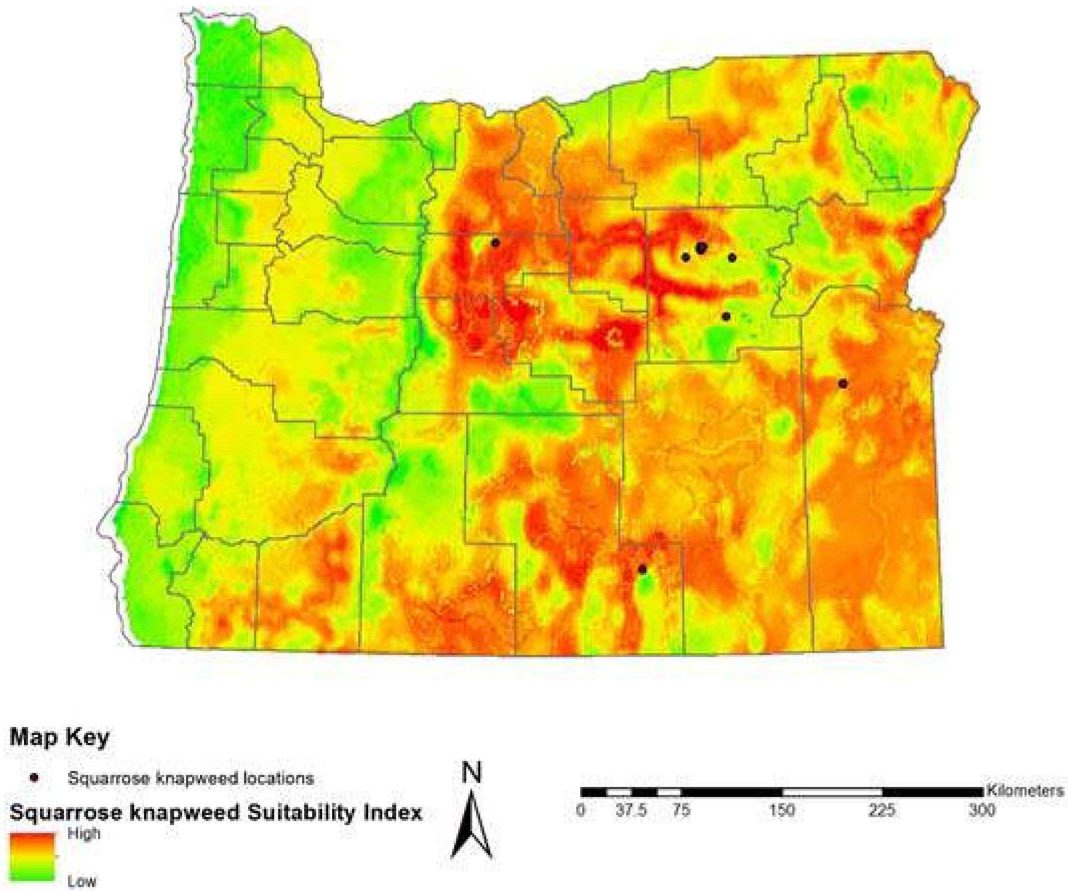
Native Area/Arrival in the U.S.

Squarrose knapweed is native to parts of Southern Asia; Bulgaria, Lebanon, Iraq, Iran, Afghanistan, and Turkey and parts of China. In the Western U.S. it can be found in Wyoming, California, Oregon, Nevada and Utah which hosts over 200,000 acres in three counties.

Current Status in Oregon



Predicted Suitability Zone and Currently Known Infestations



Photos

Dalmatian toadflax, *Linaria dalmatica*

Description

Perennial; blooms summer to fall. Grows two-three feet tall. Leaves waxy, green, heart-shaped and one-three inches long. Flowers are one inch long and similar to snapdragons. Spreads both by seeds and creeping lateral roots. This hardy, glabrous plant has a vigorous reproductive cycle both vegetatively and by seed. Germinating in the spring and fall, seedlings can rapidly establish 51 cm long taproot within eight weeks and produce two to five stems in the first season that can flower and set seed. In subsequent growing seasons they can reach up to 65 stems per plant. If pollinated, a mature plant can drop up to 500,000 seeds through the fall and winter, with seed a dormancy of 10 years

Impacts

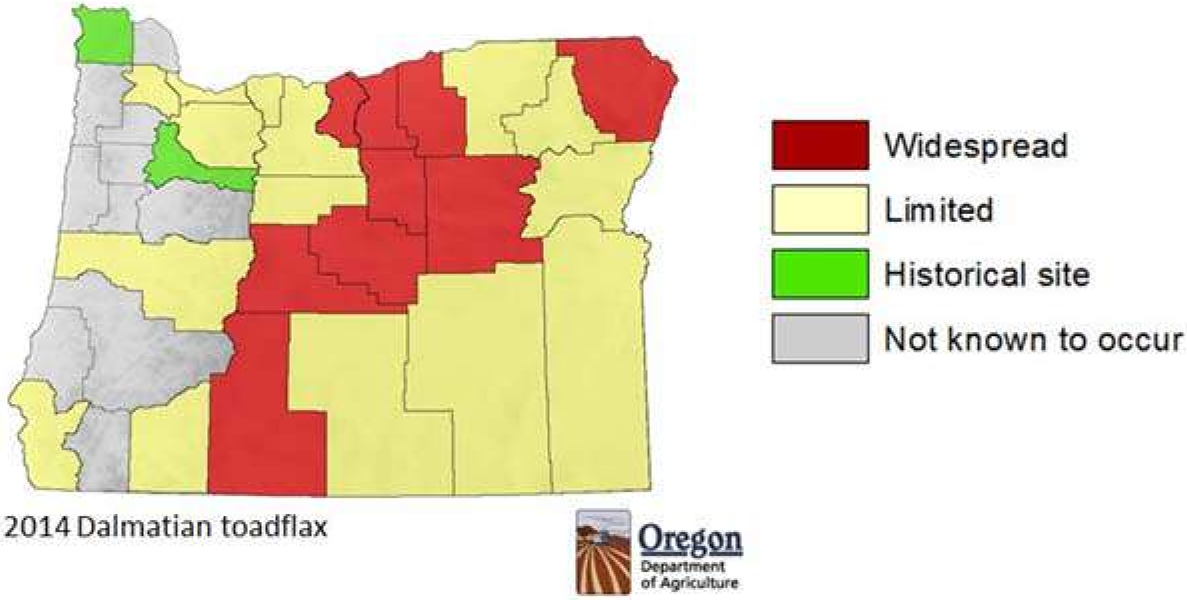
This deep rooted perennial out-competes desirable forage plants for moisture and nutrients. Thrives in arid rangelands, pastures, and railways. Dalmatian toadflax's ability to outcompete native vegetation impacts forage plants for livestock and reduces endemic plant species densities. It is also somewhat toxic to livestock as it contains a glucoside antirrhinoside, a quinolone alkaloid, and peganine which cattle actively avoid consuming, displacing grazing cattle from areas infested with substantial forage. The sheer density of healthy, established Dalmatian toadflax populations can deter cattle from grazing infested areas as well.

Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
345,000	$254,000	31,724,000	$20,335,000
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.			

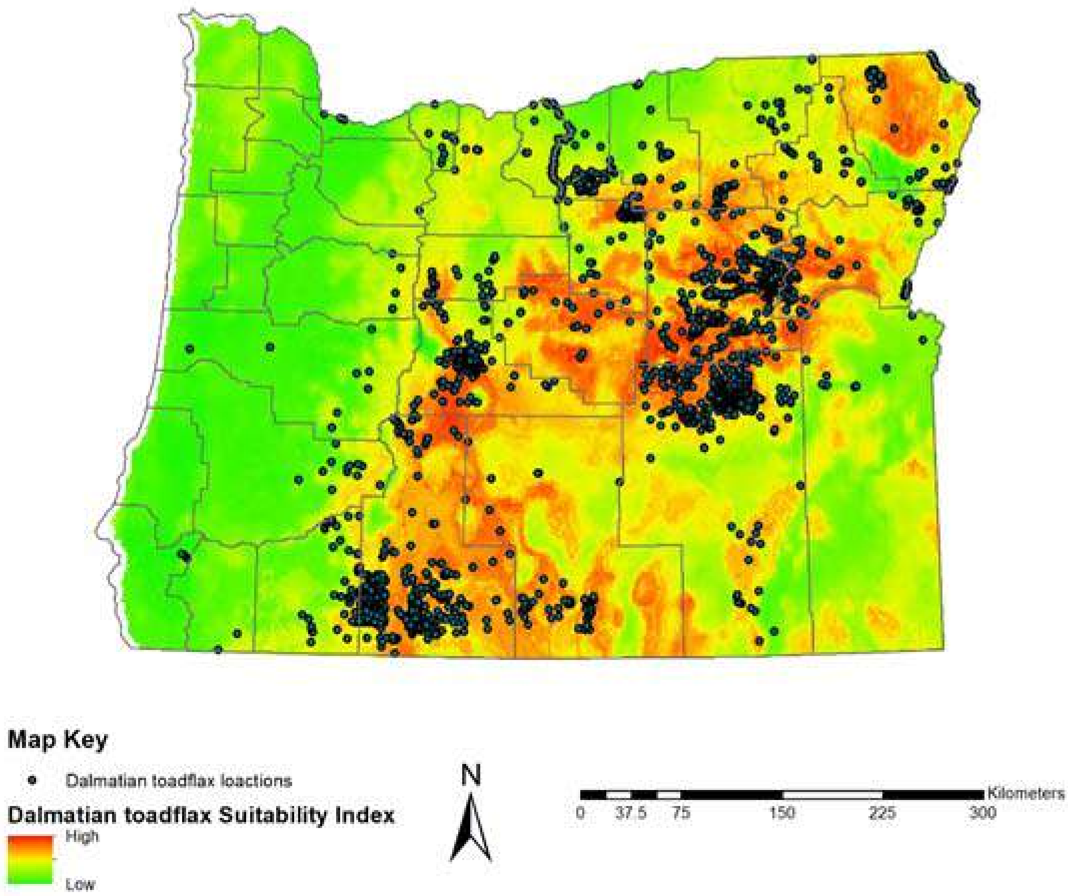
Native Area/Arrival in the U.S.

Dalmatian Toadflax was introduced in the mid-1800's and is considered an escaped ornamental. It is a native of the Dalmatian Coast of Croatia in the Mediterranean region.

Current Status in Oregon



Predicted Suitability Zone and Currently Known Infestations



Photos

Whitetop, *Cardaria draba*

Description

A perennial species; blooms typically in early May. Grows up to 2 feet tall. Root systems extensive and deep. Lower leaves blue-green and lance shaped; upper leaves have two lobes clasping the stem. Many white flowers growing densely on plant each with four petals, giving plant a white, flat-topped appearance. Three known species, lens-podded, globe-podded, and heart-podded whitetop, identified by different shaped seed pods. Plants usually die back to roots in summer as seeds mature.

Impacts

Whitetop is a common weed species on alkaline soils, but is not restricted to them. It forms dense patches that can completely dominate sites, restricting the growth of other species. *Cardaria draba* often impacts early season forage growth in pastures. The species is not toxic to livestock but neither is it grazed. Tens of thousands of acres are found in Oregon primarily on the dryer eastern side of the state.

Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
191,000	$559,000	15,558,000	$55,263,000

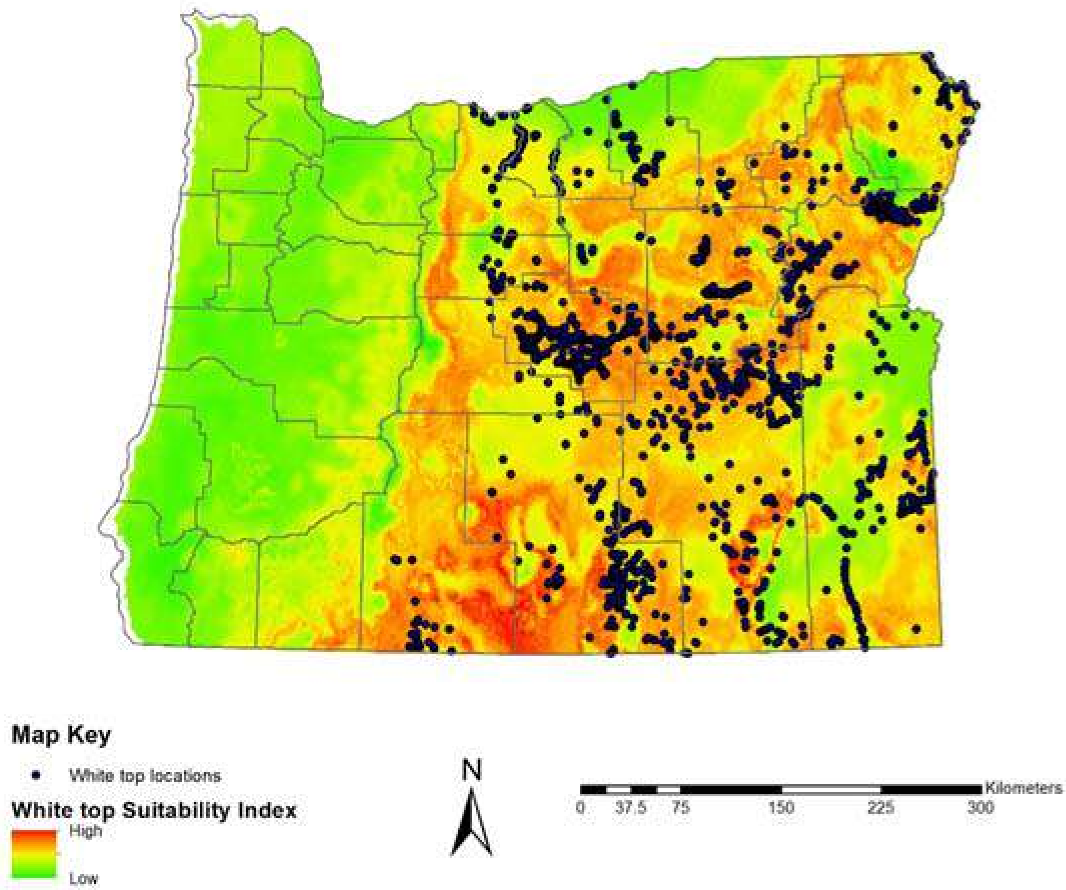
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.

Native Area/Arrival in the U.S.

Native to southwest Asia, eastern Europe. This invader is now distributed throughout the Pacific Northwest. Probably introduced through the import of contaminated grains in the early 1900's.

Current Status in Oregon

Predicted Suitability Zone and Currently Known Infestations



Photos

Yellow Starthistle, *Centaurea solstialis*

Description

This well-armored *Centaurea* looks more like a thistle and often confused as one. It is a fall-spring germinating annual sporting yellow flowers subtended by long spines. It grows 2 to 3 feet tall with adequate moisture but when under drought stress can bloom when only 2-3 inches tall. The stems are rigid, branching, winged and covered with cottony hairs, they do not contain spines like on thistles. Basal leaves deeply lobed while upper leaves entire and sharply pointed. Flower heads yellow, located singly on the ends of branches and armed with thorns up to 3/4 inch long. Some seeds have parachute hairs and some don't, resulting in a distribution that produces dense stands and rapid spreading.

Impacts

Yellow starthistle will grow wherever cheatgrass grows, in addition to growing in canyon grasslands, rangelands, pastures, edges of cropland, roadsides, and disturbed areas. It is an aggressive, adaptable weed that inhibits the growth of desirable plants in pasture, rangeland, and wasteland. This plant may become a problem in ground where the grass stand is weak. Yellow starthistle has been found in wheat crops where seed pressure is high. Yellow Starthistle is toxic to horses causing "chewing disease". It also can injure upland-game hunting dogs causing eye injury and infestations. Infested hunting grounds should be avoided.

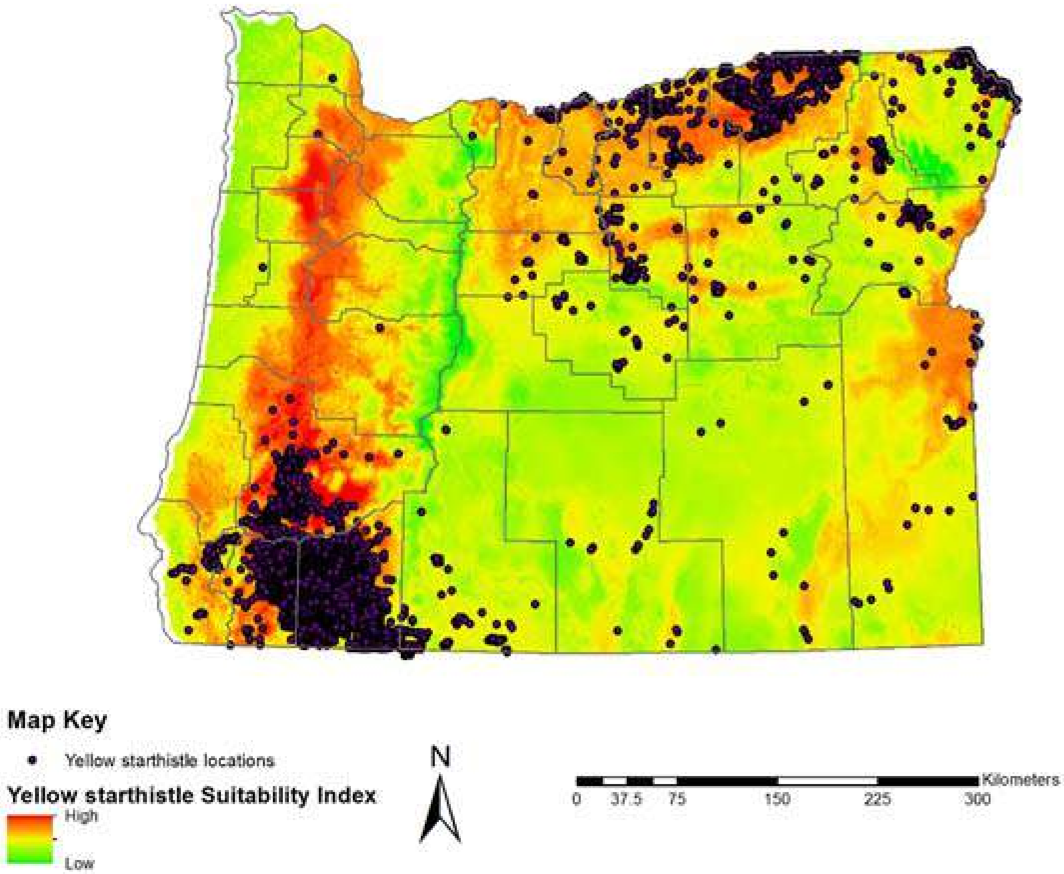
Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
376,000	$774,000	18,596,000	$27,911,000
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.			

Native Area/Arrival in the U.S.

Introduced from the Mediterranean regions, yellow starthistle will grow wherever poorly competitive environments exist, predominantly in dry slopes, grasslands, overgrazed rangelands, pastures, edges of cropland, roadsides, and disturbed areas. It has adapted to a wide range of habitats and environmental conditions, mostly in California, Oregon, Washington and Idaho. The first documented site in Oregon was 1933 in Deschutes County, probably introduced into North America in contaminated seeds or on imported livestock.

Current Status in Oregon

Predicted Suitability Zone and Currently Known Infestations



Photos


Case Study Species

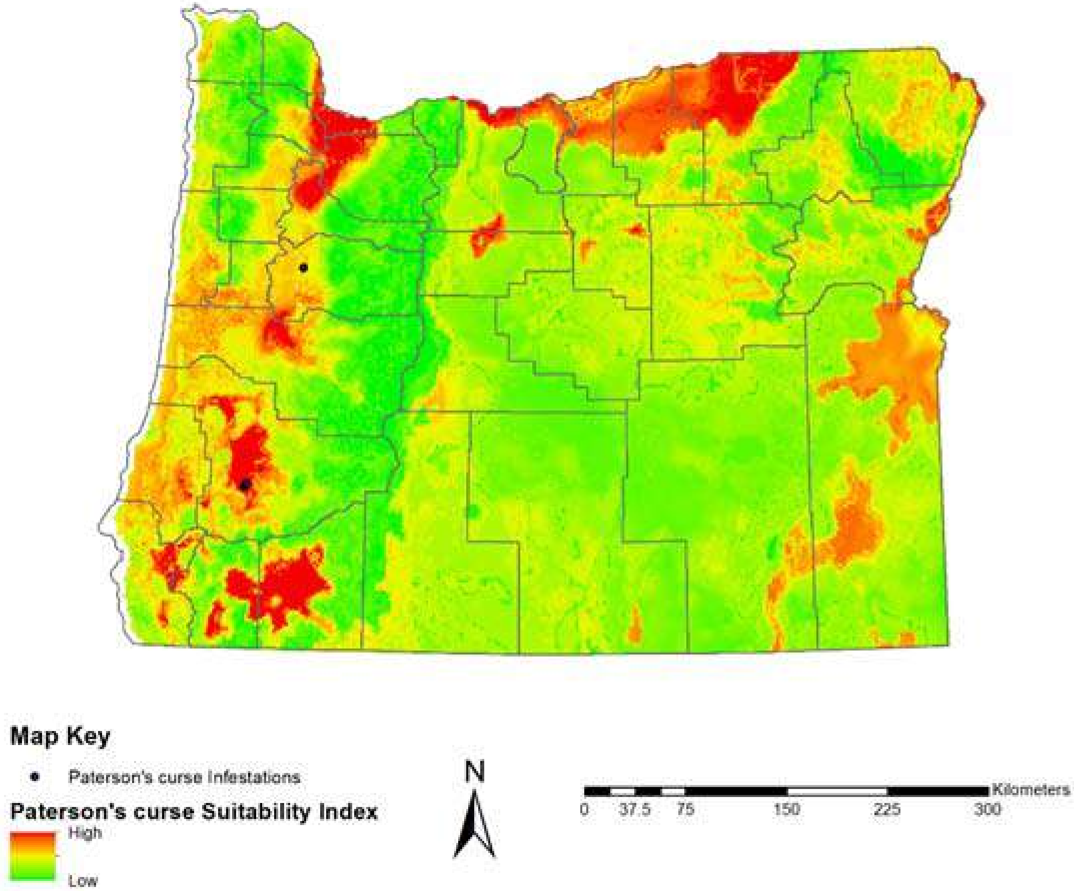
Paterson's Curse

Introduction

Despite a beautiful appearance, this annual invader is truly a curse. The biggest indicator of potential impacts in Oregon is realized in Australia where Paterson's curse infests millions of acres (Agriculture Today, 2011). Paterson's curse is extremely toxic to livestock and dramatically reduces forage quality and quantity (Muyt, 2001). Production of copious amounts of tiny seeds results in extensive and persistent stands that threaten valued native habitats (Burton, 2004). Once widely established, human health concerns include allergic reaction and skin irritation from contact with the rough hairy texture of the leaves and stems (Weed Risk Mgt. Guide, 2008).

Current Status and Distribution

A farmer in Linn County, familiar with the plant from travels to Australia, was the first to detected Paterson's curse in Oregon in 2013. A year later, ODA staff confirmed a second larger site in Douglas County. It is suspected that a wildflower mix is the source of at least one of these infestations. Since detection, both sites have been under intensive treatment. The infestation in Linn County has been reduced by 90% to 1/10th of an acre spread over two gross acres. In Douglas County, net acreage has dramatically decreased from 100 to 13 acres spread over a 300 gross acre area.



Known infestations of purple loosestrife (dots) and predicted vulnerable areas (shaded) based on known habitat features and requirements (Weedmapper 2013).

Control and Management Options

Australians rely on an integrated approach in attempt to merely manage Paterson's curse across an infested landscape. Integrated weed management methods have included: competitive plantings, grazing management, herbicide, spray grazing, slashing, hand weeding, and biological control (NSW Dept. Primary Industries, 2014). Paterson's curse is susceptible to most herbicides and mechanical treatments (Ensby, 2004). In sheep grazing areas, the "spray-graze" technique of spraying early with 2,4-D preserves valued pasture legumes while Paterson's curse plants elongate allowing intense grazing to be more effective (Pearce, 1972). From 1972 to 2001, Australia allocated $14 million towards the development of a Paterson's curse biological control program (Nordblom, 2001). Biological control is an option when eradication is not possible.

Early detection in Oregon initiated a rapid containment and eradication campaign. Herbicide and manual removal techniques are proving effective in Linn County. In Douglas County initial aerial and boom herbicide treatments reduced populations to levels that are now effectively addressed by a backpack spray crew.

Economics

Paterson's curse's ability to adapt to a wide range of environmental conditions is already evident in Oregon. This species tolerates the wet conditions of the Willamette Valley, as well as, the drier hillside pastures of Douglas County. Drought tolerance is significant with prolonged flowering and new flushes of seedlings produced all summer long. Due to phenomenal adaptability and phenotypic plasticity (Sharma and Esler 2008), the potential range of Paterson's curse would expand greatly if no control efforts were employed.

Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
<500	<$500	19,737,000	$176,765,000
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.			

Economic losses in Oregon have been limited to control expenses due to Paterson curse's limited range in the state. If allowed to spread, increased costs associated with grazing management and chemical controls would be realized. Impacts to native woodland and prairie habitats would be dramatic. Anything short of an aggressive eradication campaign would result in impacts to the livestock industry.

In the southern hemisphere, Paterson's curse dominates pastures reducing both forage quality and quantity (Landcare Notes, 2007). Field and confined feeding trials have demonstrated that sheep feeding on Paterson's curse put on less weight and produce less wool. In areas completely inundated by this curse, operations have switched from cattle to sheep grazing, completely altering the land use (NSW Dept. Primary Industries, 2014). Annual losses for livestock producers in Australia are estimated in excess of $100 million annually (Nugent, 2011). An Australian Risk Assessment determined that control costs add to farm operating budgets and eventually result in decreased land values (Weed Risk Mgt Guide, 2008).


Infestation in Australia, where millions of acres curse the countryside.
Photos from Australia's NSW Department of Primary Industries.

Conclusion

The rapid expansion of Paterson's curse in western Oregon has not been realized due to ODA's early detection and rapid response. Invasion of native oak woodland habitat across state, federal and private boundaries has been prevented. Had this tenacious invader been left unchecked, the 'curse' would have greatly expanded into prime agricultural ground in Linn and Douglas Counties. Spread to neighboring counties would have been inevitable. Preventing the spread of Paterson's curse in Oregon is a prime example of the value of maintaining a strategic and comprehensive statewide weed program.

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Purple loosestrife

Introduction

Purple loosestrife, *Lythrum salicaria* Lythraceae, is an exotic invasive plant from Eurasia that infests wetlands and riparian zones in North America. After its arrival in the early 1800's, and without natural enemies to keep it in check, it has since spread across much of the middle and northern latitudes of the U.S. (Thompson et al. 1987, Mullin 1999, Piper et al. 2004). The plant reproduces by seed and fragmentation of plants, allowing infestations to proliferate and spread.

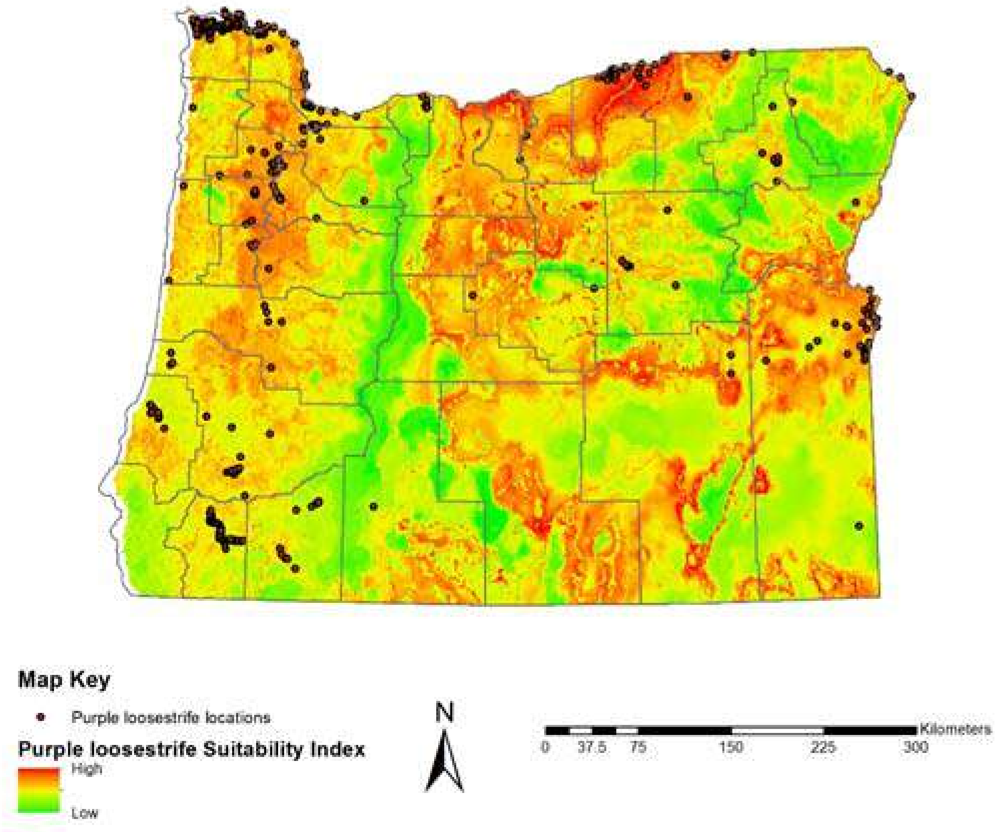
Identification

Purple loosestrife is a semi-woody herbaceous plant with long showy spikes made of showy purple flowers consisting of 5-6 petals. The seeds are very small, and large plants can produce over one million seeds. Stems are four to six sided and leaves are lance-shaped with smooth margins. Plants can be 3-10 feet tall, and have a single flowering spike or many, depending on age and habitat.


Purple loosestrife flower (L) and infestation at Horseshoe Lake, Marion County (R).

Current Status & Distribution

Purple loosestrife is widely established in Oregon, occurring along rivers, streams, ponds, marshes, wetlands, seeps and wet meadows. Sites where the native wetland vegetation have been disturbed and created wetlands lacking natural wetland flora are particularly vulnerable to loosestrife infestation.



Known infestations of purple loosestrife (dots) and predicted vulnerable areas (shaded) based on known habitat features and requirements (Weedmapper 2013).

Control and Management Options

Because purple loosestrife inhabits wetlands and riparian zones, control options are often limited because of the sensitive nature of the infested habitats. Intensive management of purple loosestrife can be a difficult problem, in that water quality can be severely impacted, threatening ecosystem function and services. For small infestations (<0.1A), manual control may be sufficient. Some chemical control has been implemented using a limited number of approved aquatic herbicides can be sporadically effective, but reinfestation from seeds is often the result, along with loss of susceptible plant species. For most sites more than 0.25A, biological control (the use of four beetles which are host specific natural enemies) has been the priority control measure in Oregon since 1992. Successful control of purple loosestrife was manifested as early as 1997 at multiple sites in eastern and western Oregon, especially in areas that have less than one foot of standing water during the flood season. Purple loosestrife in tidally influenced rivers and marshes (i.e. lower Columbia and Umpqua rivers and Coos Bay tidal marshlands), and in streams that experience high intensity and short duration flooding in the spring (Rogue and Umpqua rivers and selected tributaries) are not as suitable for biological control.

Economics

The primary economic impacts of purple loosestrife occur when infestations interfere with ecosystem products and services (i.e. water quality, hunting, fishing, species diversity of wetlands, etc.). Purple loosestrife has a low ecological amplitude when compared to its potential distribution in Oregon. Once entrenched, purple loosestrife can form thick stands that exclude desirable flora and its important associated fauna (Schooler et al. 2009). Loosestrife infestations can also negatively impact the cycling of nutrients in aquatic systems (Schooler et al. 2006). The implementation of biological control may well prevent purple loosestrife from ever achieving its full biological potential in Oregon, saving millions of dollars in ecological and socioeconomic impacts and improving water quality in the state.

Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
7,000	$12,000	15,276,000	$28,444,000

Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.

Conclusion

Purple loosestrife is a difficult weed to control by nature of the unique and vulnerable habitats in which it occurs in Oregon. Small infestations are best handled with intensive control measures like manual and chemical control. Once infestations are too large for intensive control measures, biological control is the best option, achieving 50-95% control ability at inland sites. Coastal sites in tidal zones are especially difficult, and experiments are continuing to develop nursery sites in the upper elevational zones to maintain colonies of biocontrol agents.

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Compiled by Eric M. Coombs, Oregon Department Agriculture
12/16/2013 V1.1

Spartina

Introduction

Spartina densiflora, *S. alterniflora*, *and S. patens* are three of 14 to 17 different species in the genus *Spartina*. With its great capacity for reducing tidal wave energy, mitigating erosion and trapping sediments, *S. alterniflora* has been widely introduced in many coastal and estuarine regions of the world as a species for ecological engineering (Wang et al. 2010). The negative impacts of Spartina's include the replacement of native marsh species, colonization and elimination of mudflats leading to severe reductions of food and shelter for juvenile fish, crabs, migratory shorebirds and habitat for shellfish.

Although relatively free of these species, Oregon has several *Spartina* infestations located on the lower Columbia River, Siuslaw Estuary and Coos Bay Estuary. Large infestations in adjacent states, place Oregon at risk for additional introductions.

Identification

"*Spartina* species are robust, perennial grasses with stout, upright, densely spaced stems and thick mats of roots and rhizomes. They are prolific seed producers. Vegetatively spread by rhizomes, they can rapidly expand the area covered by a clone (Sytsma and Morgan, 2010)". Spartina patens is a lower growing, fine-leaved species with a distinctive lime-green color. One of the limiting differences between the species is that *Spartina*'s have varying optimal and survival elevations within the intertidal zone depending on the species (Qan et al., 2007). Spartina alterniflora and densiflora dominate the regularly flooded marsh ("low marsh") while S. patens occurs in the irregularly flooded marsh ("high marsh").

Current Status and Distribution

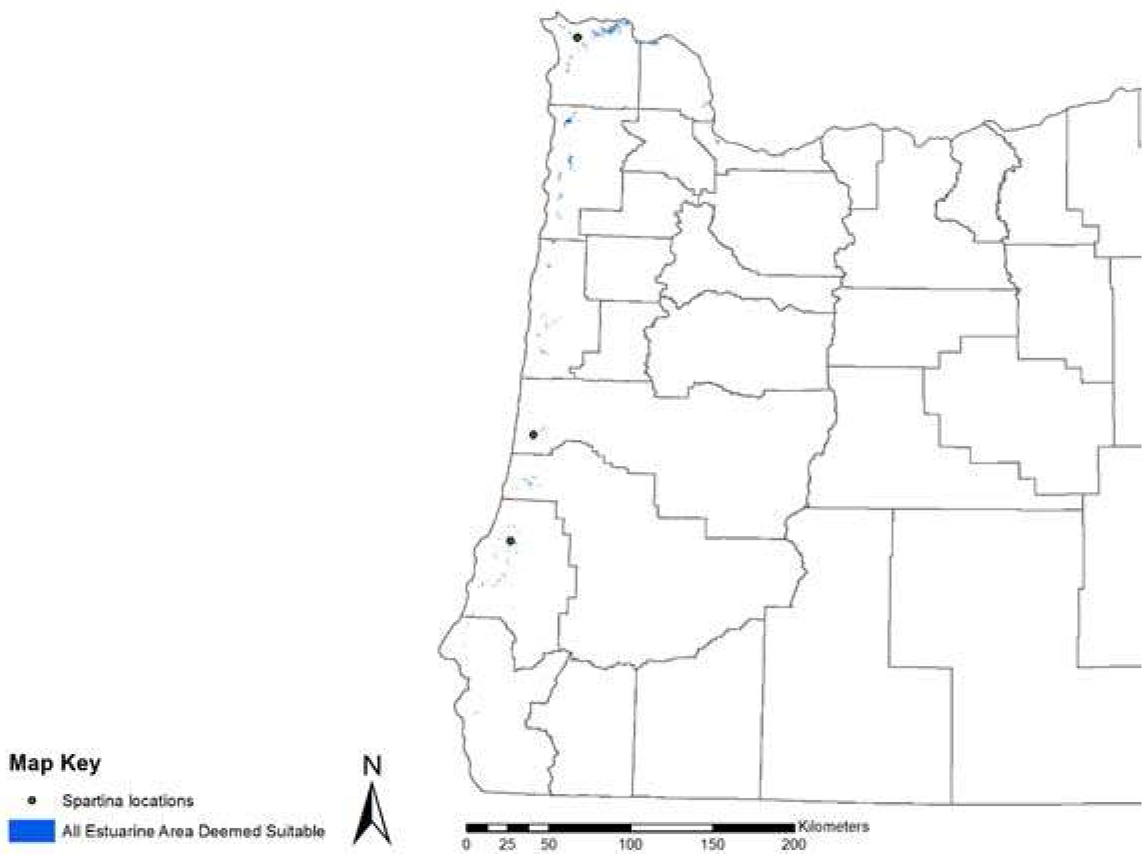
Oregon *Spartina* distribution:

Spartina patens: Cox Island, Siuslaw River Estuary: At its peak, Cox Island contained over 3 acres of Spartina patens. Since that time all patches have been covered with geotextile fabric.

Spartina alterniflora, Siuslaw River: Two patches of *S. alterniflora* were identified in 1990 by Portland State University staff. After the discovery, the patches were removed by the originator of the planting upon request. In 2005 a single plant was relocated by PSU staff at the Siuslaw location and an additional site was located in the Coos Bay Estuary, also the result of the original plantings. These sites have been eradicated.

Warrenton, Lower Columbia River: The only naturally introduced *Spartina alterniflora* infestation in Oregon was located on the Columbia River near the mouth of the Skipanon River at Warrenton. Portland State University's staff, discovered the infestation during a helicopter flyover in 2008. The seed source for the infestation was likely to have originated in Willapa Bay, Washington, less than 30 miles north of the site. The infestation is now eradicated.

Spartina densiflora: Coos Bay Estuary. The first Oregon discovery occurred in 2013. This difficult-to-control species has not been found adjacent to the Oregon border but is located distantly in Puget Sound, Washington and Humbolt Bay, California. Ten plants have been identified and removed during a boat survey organized by Weed Control Program and Portland State University staff.



Known infestations of purple loosestrife (dots) and predicted vulnerable areas (shaded) based on known habitat features and requirements (Weedmapper 2013).

Control and Management Options

The species have been controlled successfully using three methodologies. Herbicides have been used on the S. alterniflora patches. Products include glyphosate wiped on cut stems and foliar applications of imazapyr. The Spartina patens infestations have been controlled using geotextile fabric, held in place for two years. Spartina densiflora, known to be the hardest to control of the three, was removed by digging. Severed roots are a significant source of re-establishment so yearly examination of the infestation will be important.

Economics

Estuaries on the Pacific coast of North America evolved into large very flat shallow structures with limited vegetative growth. This shallow open environment encourages the growth of dense populations of mollusks, worms and crustaceans that provide a rich supply of food for commercially important species and wildlife. These mudflats also offer an excellent substrate for commercial shellfish production, primarily oysters. Juvenile Dungeness crabs by the millions also utilize the eelgrass beds for refuge and provide the stock for the multi-million dollar crab fishery. Spartina's change this dynamic. Rapid colonization of mudflats allow for the accumulation of sediments to occur at a much higher rate. Elevations of the former mudflats are raised causing channelization, creating much faster tidal flow rates. Invertebrate beds disappear creating significant looses in food for migrating shorebirds and waterfowl. Refuge for juvenile crabs and fish become restricted creating a loss of stock for commercial fisheries. Habitat for commercial shellfish production also becomes restricted causing reductions in harvest and a loss of economic activity in coastal communities. In direct costs, the impact to commercial fisheries in Oregon would be in the millions of dollars.

Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
<500	$1,000	40,000	$40,223,000

Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.

Conclusion

Oregon has been fortunate, escaping the complications of large-scale *Spartina* populations that have plagued all other Pacific Coast states and British Columbia. The Weed Control Program, the Center for Lakes and Reservoirs at Portland State University and the Nature Conservancy recognized early the threat posed to Oregon estuaries by these invasive plants. A *Spartina* action plan was formulated outlining the need for yearly surveys to identify outbreaks and a rapid response to eliminate them. The Weed Control Program has annually funded the Center for Lakes and Reservoirs to carry out much of the survey work that has yielded most of the discoveries. Recent surveys have been cooperative with staff of both programs involved, yielding the recent find of *Spartina densiflora* at Coos Bay and providing off-site control of *Spartina* patens in the Siuslaw Estuary. Add to this the work of the Nature Conservancy on Cox Island against *Spartina patens*, Oregon can now boast control or eradication of all known sites.

The expansion of boat-based surveys in additional estuaries will continue insuring a *Spartina* free Oregon for years to come.

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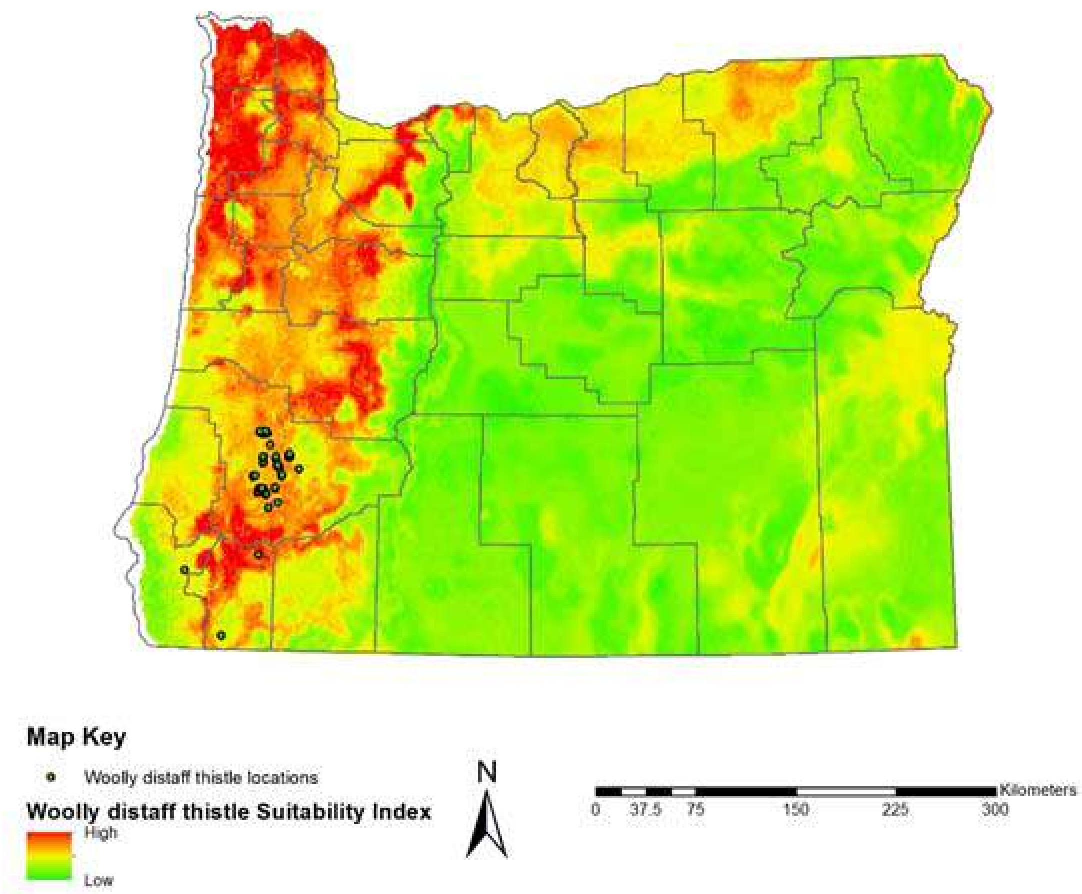
Woolly distaff thistle

Introduction

Woolly distaff thistle, *Carthamus lanatus*, is a federally listed noxious weed and is considered one of the worst pasture weeds in North America and Australia (Burrill, 1994). It is a highly adaptable member of the aster family, heavily armed with spines and produces an abundance of long-lived seeds. In dense infestations, it imposes significant impediments to forage production and quality meanwhile creating physical barriers to grazing access (Burrill, 1992). First reported in California in 1891, it has since become widespread in that region where it infests thousands of acres of seasonally dry hillside pasture (DiTomaso, 2013). In Oregon, the first infestation was identified in 1987, with infestations now occurring in three counties in southwest Oregon.

Current Status & Distribution

Distaff thistle infests acreage across 40 ownerships in 21 locations in Oregon. Eighteen of these locations are in Douglas County, two in the northern reaches of Josephine County, and one in Curry County. Woolly distaff thistle has been reduced by 97% from historic levels, from 123 net acres to less than 3.5. Since 2009, the population has fluctuated between 2.5 and 3.5 net acres. No new sites have been discovered since 2006; helicopter surveys are conducted periodically to rule out potential detection gaps.



Known infestations of Woolly Distaff Thistle (dots) and predicted vulnerable areas (shaded) based on known habitat features and requirements (Weedmapper 2013).

Control and Management Options

Elimination of seed production and seeds banked in the soil are key when battling an annual thistle. Early season applications with a selective herbicide or manual methods before flowering are effective in controlling distaff thistle (Peachey et. al). Mowing can be effective under dry soil conditions if done just prior to flowering. Mowing in wetter soils is only minimally effective as plants re-grow and flower. Distaff thistle is easier to control when immature, however individual plants are often hard to see until the surrounding forage starts to dry. Intense grazing management can be effective under certain conditions. Healthy grass stands make areas less susceptible to invasion. Woolly distaff thistle is so closely related to safflower that it is often confused with the commercially produced plant when located in a field (Abrams and Ferris, 1961). The genetic similarities between the two species are so great that biological control has not been pursued in the United States.

Economics

Wooly distaff thistle can drastically decrease forage availability for wildlife and grazing animals where heavy infestations occur (Burrill, L.C. 1994; DiTomaso 2006). Mature dead plants stay rigid and spiny after they mature and senesce, rendering vast acreage unusable and more prone to catastrophic wildfire (Grace 2002; Sindel, 1991). In Australia woolly distaff thistle reduces cereal grain yields, clogs harvesting equipment, and increases seed cleaning costs (Fromm, 1990). Distaff thistle spines are also known to result in contamination and downgrading of wool (Grace, 2002).

Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
<500	<$500	18,627,000	$163,800,000
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.			

Woolly distaff thistle's devastating impact to rangelands in Australia (left) and California (right)
Photos by Dennis Isaacson (left) and Joseph M. DiTomaso, UCCE (right)

Conclusion

Biologically distaff thistle represents the perfect case study of why a sustained, statewide weed eradication campaign is necessary. Distaff thistle, like yellow starthistle, is a classic long-lived winter annual. It germinates early and develops a long taproot that can draw water from deep in the soil profile, allowing flowering and seed-set after annual grasses have become dormant (Burrill, 1994). Seeds can lay dormant in the soil until conditions are ideal for seedling survival resulting in a slow distribution over time (Grace et. al., 2002). To complicate matters, distaff thistles is not exceptionally showy and new populations may establish and expand for years before they are located. Lastly, unmanaged distaff populations in California present a consent reintroduction threat to Oregon. In the late 1980's the ODA Weed Program made a calculated decision to protect Oregon from invasion by yet another aggressive thistle. The success of this longstanding eradication effort is undeniable, less than four net acres infested in the entire state.

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Tansy Ragwort

Introduction

Tansy ragwort, *Senecio jacobaea* (*Jacobaea vulgaris*) Asteracaeae, is a poisonous exotic biennial invasive plant from Europe that primarily infests pastures, clearcuts, roadsides and waste places in the Pacific Northwest west of the Cascade Range (Coombs et al. 1999 & 2004). Tansy was first reported in North America around 1900. It reproduces by seed. By the 1950's, it had become a serious pest in the Western Oregon, Washington, and Northern California, causing millions of dollars in agricultural losses (Coombs et al. 1996).

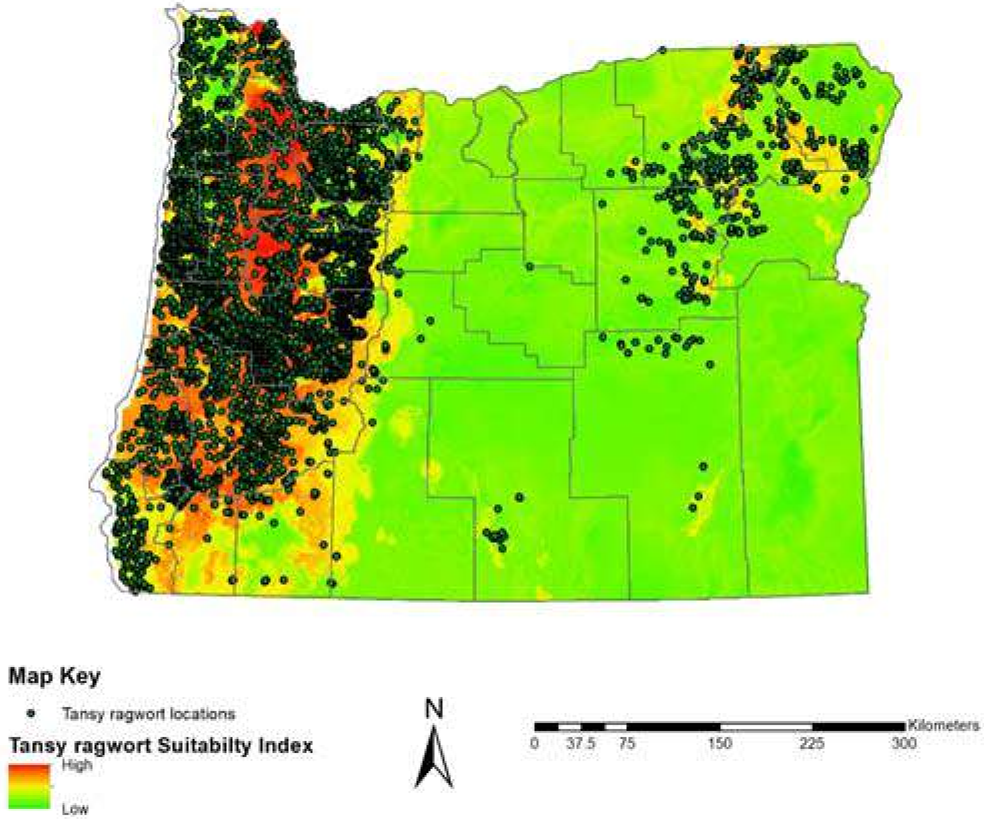
Identification

Tansy ragwort is an herbaceous plant with showy yellow daisy-like flowers that often consist of 13 yellow petals. Leaves when crushed emit a disagreeable odor. Seeds small, brownish and tufted with a hairy pappus that aids in local wind dissemination. Stems may be single or severally branched, with purplish base in the summer and grow 1.5 to 4 feet tall. Leaves are dark green, deeply divided and 2-5 inches long. A single plant can produce up to 150,000 seeds that can remain viable for up to 10 years.

Tansy ragwort plant (L) and infestation in Marion County (R).

Current Status and Distribution

Tansy ragwort in Oregon is primarily west of the Cascades at elevations of 4,000 feet to just above sea level. It occurs mostly in areas where bare soil has been exposed through localized perturbations such as overgrazing, floods, fire, construction, roads, and rodent outbreaks. Infestations can be as high as 10 plants per square yard. Scattered infestations in the mountains in Eastern Oregon are often associated with spike camps where hunters have brought in infested hay from Western Oregon. Many sites in Eastern Oregon have been eradicated through intensive control measures over the past several decades.



Known infestations of tansy ragwort (dots) and predicted vulnerable areas (shaded) based on known habitat features and requirements (Weedmapper 2014).

Control and Management Options

In areas where short-term and intensive control area warranted, selective herbicides can control outbreaks of tansy ragwort, particularly at small infestations in Eastern Oregon and localized outbreaks in pastures on the west side. Infestations are most vulnerable to treatment during the rosette stage. Large infestations in Western Oregon are primarily targeted with biological control through the introduction and management of three insects, which are natural enemies of tansy ragwort. Prevention of infestations in Eastern Oregon is now primarily through the regulation of only importing certified weed-free hay. Prevention in Western Oregon is through education of land owners and managers to promote healthy and competitive plant communities and avoid overgrazing and other disturbances that heavily impact intact plant communities.

Economics

Before biological control was implemented, tansy ragwort caused over $5 million in annual economic losses, primarily in livestock poisoning and contaminated hay (Radtke 1993). The successful implementation of biological control has lead to a steady benefit of $5 million per year and cattle losses are now rare (Coombs et al. 1996). Incipient outbreaks occasionally occur in areas where tansy was once under control, however if the sites are not continuously overgrazed, the biocontrol agents naturally build up and control the site within a couple of years.

Current Infestation		Susceptible Infestation	
Acres	Economic Impact	Acres	Economic Impact
125,000	$115,000	11,384,000	$12,661,000
Notes: The susceptible acres are from the KRESS model environmental variables using the "mean" statistical assumptions. Annual economic impact is measured by personal income in 2012 dollars and includes the "multiplier" effect.			

Conclusion

Tansy ragwort is not a difficult plant to control, except when the acreages are large or occur in areas where conventional control is difficult to implement. Gross acreages in Western Oregon remain steady, however net acreages remain low with occasional transient outbreaks in disturbed areas. Biological control in the western part of the state remains the primary control option. East of the Cascades tansy ragwort is targeted for eradication and intensive control. Biological control of tansy ragwort is heralded as Oregon's most successful control program.

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2/4/2014 V1.2

APPENDIX C

Economic Analysis Model Assumptions, Algorithms, and Dependencies

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Table C.1a
Economic Assessment Model Drivers for Current Study - Variables Independent of Species

Model Type and Variable Name	Model Inputs: REI: Sales	Income	Jobs	Source
1. Livestock				
AUM production per acre				
a. Production is land type dependent	0.14 to 4.0			TRG (2000)
b. Grazing months per year	3			Pratt and Rasmussen (2001)
c. AUM's per cow	15			Radtke (December 2013)
Livestock losses				
d. Herd replacement value per cow	$1,000.00			
e. I/O model response coefficient		0.58		IMPLAN 2011
2. Agriculture				
Cattle				
a. Sales per AUM (calf value / 15 AUM)	$38.13			Radtke (December 2013)
b. I/O model response coefficient		0.58		IMPLAN 2011
c. Grazing fee per AUM	$13.50			Bioeconomics, Inc. (2011)
Wheat				
d. Bushels per acre	45			OSU's Extension Service Budgets
e. Sales per bushel	$7.00			USDA National Agricultural Statistics Service
f. I/O model response coefficient		0.64		IMPLAN 2011
Bentgrass				
g. Pounds per acre	1,250			TRG (2000)
h. Sales per pound	$0.60			USDA National Agricultural Statistics Service
i. I/O model response coefficient		0.64		IMPLAN 2011
Aquaculture				
j. Oyster production per acre	$220.00			Radtke (December 2013)
k. I/O model response coefficient		1.48		TRG (September 2013)
3. Timber				
a. Growth of mbf per year per acre	0.25			Oregon Forest Resources Institute (2012)
b. Sales per mbf	$500.00			Oregon Forest Resources Institute (2012)
c. I/O model response coefficient		0.88		Oregon Forest Resources Institute (2012)
4. Wildlife				
Hunting				
a. Cow-deer equivalency	4.5			Ruyle and Ogden (1993)
b. $73.66/day, 15.2 days/deer, 30% harves	$335.89			ODFW (2003)
c. I/O model response coefficient		0.75		ODFW (2003)
Fishing				
d. Adult salmonids production/stream mile	2.5			NOAA Fisheries (2014)
e. Exploitation rate	50%			
f. Value per fish				
i. Commercial ex-vessel	$100			TRG (September 2013)
ii. Recreational @ $100/day, 4 days/fish	$400			TRG (July 2013)
g. I/O model response coefficient				
i. Commercial		1.48		TRG (September 2013)
ii. Recreational		0.41		Southwick Associates, Inc. (2007)
Boating (bays and lakes)				
h. Bay expend. per party boat day	$172.84			Chang and Jackson (2003)
i. Boat party days per acre	15			Oregon State Marine Board (2009)
j. I/O model response coefficient		0.77		National Marine Manufacturers Assoc. (2014)
5. Jobs				
a. Full-time and part-time net earnings for employees and proprietors			$45,021	U.S. Bureau of Economic Analysis

Table C.1a (cont.)

Notes: 1. Some prices and expenditures required adjusting to 2012 dollars using the GDP implicit price deflator developed by the U.S. Bureau of Economic Analysis.
2. Variables are shown in shading where inputs are functional, and no shading where they are calculated.
3. Some parameters for the previous study, such as prices, I/O response coefficients, etc., have been adjusted to current year economic conditions. The economic activity extent and production function methodology have been preserved.

Source: Study.

Table C.1b
Economic Assessment Model Drivers for Current Study - Variables Associated With Species

Model Type and Variable Name	Model Inputs			Economic Impacts		
	Net	REI		Current	REI	
	Acres	Sales	Income	Acres	Sales	Income
Group 1 - Tansy Ragwort						
1. Livestock (rangeland)	156,480	$6,781	$3,907	0	$0	$0
a. Plant cover/impact per area	96%	$43.33	$24.97			
b. Degradation - livestock mortal	10%					
c. AUM production per acre		1.30				
2. Agriculture						
Component A (rangeland)	156,480	$2,327	$1,341	9,194	$137	$79
a. Plant cover/impact per area	96%	$14.87	$8.57			
b. Degradation	30%					
c. AUM production per acre		1.30				
Component B (farmland, bentgrass)	6,520	$587	$377	0	$0	$0
a. Plant cover/impact per area	4%	$90.00	$57.78			
b. Degradation	12%					
3. Timber (forestland)				0	$0	$0
4. Wildlife (rangeland and wildland)	156,480	$65	$48	115,626	$48	$36
a. Plant cover/impact per area		$0.41	$0.31			
b. AUM production per acre		0.14				
c. Degradation - hunting	10%	$65	$48			
d. Degradation - fishing						
e. Degradation - boating						
5. Total economic impact ($000)	163,000	$9,759	$5,673	124,819	$185	$115
Group 2 - Yellow Starthistle and Japanese Knotweed						
1. Livestock (rangeland)	94,707	$410	$236	228,485	$990	$571
a. Plant cover/impact per area	10%	$4.33	$2.50			
b. Tansy ragwort index	0.1					
2. Agriculture						
Component A (rangeland)	947,068	$3,463	$1,995	68,570	$251	$144
a. Plant cover/impact per area	100%	$3.66	$2.11			
b. Degradation	70%					
c. AUM production per acre		0.14				
3. Timber (forestland)				0	$0	$0
4. Wildlife (rangeland and wildland)	947,068	$948	$704	121,102	$121	$90
a. Plant cover/impact per area		$1.00	$0.74			
b. AUM production per acre		0.14				
c. Degradation - hunting	10%	$915	$684			
d. Degradation - fishing	100%	$33	$21			
e. Degradation - boating						
5. Total economic impact ($000)	947,068	$4,822	$2,936	418,157	$1,362	$805

Table C.1b (cont.)

Model Type and Variable Name	Model Inputs			Economic Impacts		
	Net	REI		Current	REI	
	Acres	Sales	Income	Acres	Sales	Income
Group 3 - Distaff Thistle and Paterson's Curse						
1. Livestock (rangeland)				12	$0	$0
a. Plant cover/impact per area		$4.33	$2.50			
2. Agriculture						
Component A (rangeland)	1	$0	$0	0	$0	$0
a. Plant cover/impact per area	10%	$6.58	$3.79			
b. Yellow starthistle index	1.8					
Component B	0	$0	$0	1	$0	$0
a. Plant cover/impact per area		$90.00	$57.78			
3. Timber (forestland)				0	$0	$0
4. Wildlife (rangeland and wildland)	1	$0	$0	0	$0	$0
a. Plant cover/impact per area		$1.74	$1.30			
b. Yellow starthistle index	1.8					
c. Degradation - hunting		$0	$0			
d. Degradation - fishing						
e. Degradation - boating						
5. Total economic impact ($000)	10	$0	$0	13	$0	$0
Group 4 - Scotch Broom						
1. Livestock (rangeland)				0	$0	$0
2. Agriculture						
Component A (rangeland)	750,000	$4,290	$2,472	0	$0	$0
a. Plant cover/impact per area	50%	$5.72	$3.30			
b. Degradation	30%					
c. AUM production per acre		0.50				
3. Timber (forestland)	750,000	$23,438	$20,625	1,434,036	$44,814	$39,436
a. Plant cover/impact per area	50%	$31.25	$27.50			
b. Production degradation	25%					
4. Wildlife (rangeland and wildland)	750,000	$311	$232	94,105	$39	$29
a. Plant cover/impact per area		$0.41	$0.31			
b. AUM production per acre		0.14				
c. Degradation - hunting	10%	$311	$232			
d. Degradation - fishing						
e. Degradation - boating						
5. Total economic impact ($000)	1,500,000	$28,038	$23,329	1,528,141	$44,853	$39,465

Table C.1b (cont.)

Model Type and Variable Name	Model Inputs			Economic Impacts		
	Net	REI		Current	REI	
	Acres	Sales	Income	Acres	Sales	Income
Group 5 - Knapweeds and Kudzu						
1. Livestock (rangeland)				394,794	$0	$0
2. Agriculture						
Component A (rangeland)	907,796	$4,742	$2,732	18,254	$95	$55
a. Plant cover/impact per area	50%	$5.22	$3.01			
b. Degradation	100%					
c. AUM production per acre		0.14				
3. Timber (forestland)	907,796	$28,369	$24,964	0	$0	$0
a. Plant cover/impact per area	50%	$31.25	$27.50			
4. Wildlife (rangeland and wildland)	907,796	$1,253	$936	155,466	$215	$160
a. Plant cover/impact per area		$1.38	$1.03			
b. AUM production per acre		0.14				
c. Degradation - hunting	10%	$1,253	$936			
d. Degradation - fishing						
e. Degradation - boating						
5. Total economic impact ($000)	1,815,591	$34,363	$28,633	568,514	$310	$215
Group 6 - Gorse and Armenian Blackberry (Himalayan)						
1. Livestock (rangeland)				0	$0	$0
2. Agriculture						
Component A (rangeland)	15,677	$90	$52	42,264	$242	$139
a. Plant cover/impact per area	50%	$5.72	$3.30			
b. Degradation						
Component B (farmland)				28,993	$2,609	$1,675
a. Plant cover/impact per area		$90.00	$57.78			
3. Timber (forestland)	15,677	$490	$431	1,373,399	$42,919	$37,768
a. Plant cover/impact per area	50%	$31.25	$27.50			
4. Wildlife (rangeland and wildland)	15,677	$111	$70	221,694	$1,577	$991
a. Plant cover/impact per area		$7.11	$4.47			
c. Degradation - hunting		$6	$5			
d. Degradation - fishing	100%	$105	$65			
e. Degradation - boating						
5. Total economic impact ($000)	31,354	$691	$553	1,666,350	$47,346	$40,573

Table C.1b (cont.)

Model Type and Variable Name	Model Inputs: Net Acres	Model Inputs: REI Sales	Model Inputs: REI Income	Economic Impacts: Current Acres	Economic Impacts: REI Sales	Economic Impacts: REI Income
Group 7 - Leafy Spurge						
1. Livestock (rangeland)	732	$3	$2	4,461	$19	$11
a. Plant cover/impact per area	10%	$4.33	$2.50			
b. Tansy ragwort index	0.1					
2. Agriculture						
Component A (rangeland)	7,324	$140	$80	229	$4	$3
a. Plant cover/impact per area	100%	$19.07	$10.99			
b. Degradation	100%					
c. AUM production per acre		0.50				
3. Timber (forestland)				0	$0	$0
4. Wildlife (rangeland and wildland)	7,324	$10	$8	3,524	$5	$4
a. Plant cover/impact per area		$1.39	$1.04			
b. AUM production per acre		0.14				
c. Degradation - hunting	10%	$10	$8			
d. Degradation - fishing	100%	$0	$0			
e. Degradation - boating						
5. Total economic impact ($000)	7,324	$153	$90	8,214	$29	$17
Group 8 - Rush Skeletonweed and Giant Hogweed						
1. Livestock (rangeland)				96,543	$0	$0
2. Agriculture						
Component A (rangeland)	30,000	$286	$165	0	$0	$0
a. Plant cover/impact per area	50%	$9.53	$5.49			
b. Degradation	50%					
c. AUM production per acre		0.50				
Component B (farmland, wheat)	30,000	$4,725	$3,033	13,821	$2,177	$1,397
a. Plant cover/impact per area	50%	$157.50	$101.11			
b. Degradation	50%					
3. Timber (forestland)				0	$0	$0
4. Wildlife (rangeland and wildland)	30,000	$21	$15	5	$0	$0
a. Plant cover/impact per area		$0.69	$0.52			
b. AUM production per acre		0.14				
c. Degradation - hunting	10%	$21	$15			
d. Degradation - fishing	100%	$0	$0			
e. Degradation - boating						
5. Total economic impact ($000)	60,000	$5,032	$3,214	110,369	$2,177	$1,397

Table C.1b (cont.)

Model Type and Variable Name	Model Inputs: Net Acres	Model Inputs: REI Sales	Model Inputs: REI Income	Economic Impacts: Current Acres	Economic Impacts: REI Sales	Economic Impacts: REI Income
Group 9 - Purple Loosestrife						
1. Livestock (rangeland)				0	$0	$0
2. Agriculture						
Component A (rangeland)				0	$0	$0
a. Plant cover/impact per area	100%					
3. Timber (forestland)				0	$0	$0
4. Wildlife (rangeland and wildland)	2,230	$7	$4	6,684	$20	$12
a. Plant cover/impact per area		$3.00	$1.86			
c. Degradation - hunting						
d. Degradation - fishing	100%	$7	$4			
e. Degradation - boating						
5. Total economic impact ($000)	2,230	$7	$4	6,684	$20	$12
Group 10 - White Top, Perennial Pepperweed, and Dalmatian Toadflax						
1. Livestock (rangeland)				333,686	$0	$0
a. Plant cover/impact per area						
2. Agriculture						
Component A (rangeland)	1,125,110	$21,450	$12,360	13,607	$259	$149
a. Plant cover/impact per area	95%	$19.07	$10.99			
b. Degradation	100%					
c. AUM production per acre		0.50				
Component B (farmland, hay)	59,216	$5,329	$3,421	8,605	$774	$497
a. Plant cover/impact per area	5%	$90.00	$57.78			
3. Timber (forestland)				0	$0	$0
4. Wildlife (rangeland and wildland)	1,125,110	$1,553	$1,160	268,568	$371	$277
a. Plant cover/impact per area		$1.38	$1.03			
b. AUM production per acre		0.14				
c. Degradation - hunting	10%	$1,553	$1,160			
d. Degradation - fishing	100%	$0	$0			
e. Degradation - boating						
5. Total economic impact ($000)	1,184,326	$28,333	$16,942	624,467	$1,405	$924

Table C.1b (cont.)

Model Type and Variable Name	Model Inputs			Economic Impacts		
	Net	REI		Current	REI	
	Acres	Sales	Income	Acres	Sales	Income
Group 11 - Scotch Thistle						
1. Livestock (rangeland)				96,874	$0	$0
a. Plant cover/impact per area						
2. Agriculture						
Component A (rangeland)	526,800	$2,752	$1,586	0	$0	$0
a. Plant cover/impact per area	100%	$5.22	$3.01			
b. Degradation	100%					
c. AUM production per acre		0.14				
3. Timber (forestland)				0	$0	$0
4. Wildlife (rangeland and wildland)	526,800	$727	$543	5,518	$8	$6
a. Plant cover/impact per area		$1.38	$1.03			
b. AUM production per acre		0.14				
c. Degradation - hunting	10%	$727	$543			
d. Degradation - fishing						
e. Degradation - boating						
5. Total economic impact ($000)	526,800	$3,479	$2,129	102,391	$8	$6
Group 12 - Mediterranean Sage						
1. Livestock (rangeland)				90,120	$0	$0
2. Agriculture						
Component A (rangeland)	250,000	$1,306	$752	0	$0	$0
a. Plant cover/impact per area	100%	$5.22	$3.01			
b. Degradation	100%					
c. AUM production per acre		0.14				
3. Timber (forestland)				0	$0	$0
4. Wildlife (rangeland and wildland)	250,000	$345	$258	0	$0	$0
a. Plant cover/impact per area		$1.38	$1.03			
b. AUM production per acre		0.14				
c. Degradation - hunting	10%	$345	$258			
d. Degradation - fishing						
e. Degradation - boating						
5. Total economic impact ($000)	250,000	$1,651	$1,010	90,120	$0	$0

Table C.1b (cont.)

Model Type and Variable Name	Model Inputs: Net Acres	Model Inputs: REI Sales	Model Inputs: REI Income	Economic Impacts: Current Acres	Economic Impacts: REI Sales	Economic Impacts: REI Income
Group 13 - Purple Starthistle						
1. Livestock (rangeland)				1	$0	$0
2. Agriculture						
Component A (rangeland)	0.1	$0	$0	0	$0	$0
a. Plant cover/impact per area		$6.58	$3.79			
3. Timber (forestland)				0	$0	$0
4. Wildlife (rangeland and wildland)	0.1	$0	$0	0	$0	$0
a. Plant cover/impact per area		$0.97	$0.72			
b. AUM production per acre		0.14				
c. Degradation - hunting		$0	$0			
d. Degradation - fishing						
e. Degradation - boating						
5. Total economic impact ($000)	1	$0	$0	1	$0	$0
Group 14 - Hawkweeds						
1. Livestock (rangeland)				0	$0	$0
2. Agriculture						
Component A (rangeland)	95	$2	$1	0	$0	$0
a. Plant cover/impact per area	95%	$19.07	$10.99			
b. Degradation	100%					
c. AUM production per acre		0.50				
Component B (farmland, wheat)				0	$0	$0
a. Plant cover/impact per area						
b. Degradation						
3. Timber (forestland)				0	$0	$0
4. Wildlife (rangeland and wildland)	95	$0	$0	1,074	$1	$1
a. Plant cover/impact per area		$1.38	$1.03			
b. AUM production per acre		0.14				
c. Degradation - hunting	10%	$0	$0			
d. Degradation - fishing						
e. Degradation - boating						
5. Total economic impact ($000)	100	$2	$1	1,074	$1	$1

Table C.1b (cont.)

Model Type and Variable Name	Model Inputs: Net Acres	Model Inputs: REI Sales	Model Inputs: REI Income	Economic Impacts: Current Acres	Economic Impacts: REI Sales	Economic Impacts: REI Income
Group 15 - Spartina						
1. Livestock (rangeland)				0	$0	$0
2. Agriculture						
Component B (oysters)	1	$0	$0	0	$0	$0
a. Plant cover/impact per area	100%	$220.00	$325.60			
b. Degradation	100%					
3. Timber (forestland)				0	$0	$0
4. Wildlife (rangeland and wildland)	1	$1	$1	1	$1	$1
a. Plant cover/impact per area		$1,296.32	$998.17			
c. Degradation - hunting						
d. Degradation - fishing						
e. Degradation - boating	50%	$1	$1			
5. Total economic impact ($000)	1	$2	$1	1	$1	$1

Notes:
1. Some prices and expenditures required adjusting to 2012 dollars using the GDP implicit price deflator developed by the U.S. Bureau of Economic Analysis.
2. Variables are shown in shading where inputs are functional, and no shading where they are calculated.
3. For some weed groups, the table may show current acres without corresponding economic activity model inputs. For example, Group 8 has acres for the livestock economic activity model with blank inputs. It is assumed in these situations that the economic impacts are insignificant.

Source: Study.

Table C.2
Economic Assessment Model Algorithms

Economic Model	1 - Tansy Ragwort	2 - Yellow Starthistle	3 - Distaff Thistle
Livestock			
REI			
Sales	A1d / A1b * B1a * B1b * B1c * area	t. ragwort sales per area * B1a * B1b * area	
Income	sales * A1e	sales * A1e	
Agricultural			
Component A			
REI			
Sales	A2a * B2a * B2b * B2c * area	A2a * B2a * B2b * B2c * area	y. starthistle sales per area * B2a * B2b * area
Income	sales * A2b	sales * A2b	y. starthistle income per area * B2a * B2b * area
Component B			
REI			
Sales	A2g * A2h * B2a * B2b * area		t. ragwort (sales per area * B2a) * area
Income	sales * A2i		t. ragwort (income per area * B2a) * area
Timber			
REI			
Sales			
Income			
Wildlife, Fish, Recreation			
REI			
Sales			
hunting	A4a * A4b * B2a * B2b * B4b * B4c * area / A1c	A4a * A4b * B2a * B2b * B4b * B4c * area / A1c	y. starthistle sales per area * B2a * B4b * area
comm. fish		A4d * stream miles / 2 * A4e * A4fi * B2a * B4d	
rec. fish		A4d * stream miles / 2 * A4e * A4fii * B2a * B4d	
boating			
Income			
hunting	sales * A4c	sales * A4c	sales * A4c
comm. fish		sales * A4gi	
rec. fish		sales * A4gii	
boating			

Table C.2 (cont.)

Economic Model	4 - Scotch Broom	5 - Knapweeds	6 - Gorse
Livestock			
REI			
Sales			
Income			
Agricultural			
Component A			
REI			
Sales	A2a * B2a * B2b * B2c * area	A2a * B2a * B2b * B2c * area	S. broom sales per area * B2a * area
Income	sales * A2b	sales * A2b	sales * A2b
Component B			
REI			
Sales			
Income			
Timber			
REI			
Sales	A3a * A3b * B3a * B3b * area	S. broom sales per area * B3a * area	S. broom sales per area * B3a * area
Income	sales * A3c	S. broom income per area * B3a * area	S. broom income per area * B3a * area
Wildlife, Fish, Recreat			
REI			
Sales			
hunting	A4a * A4b * B2a * B2b * B4b * B4c * area / A1c	A4a * A4b * B2a * B2b * B4b * B4c * area / A1c	S. broom sales per area * B2a * area
comm. fish			A4d * stream miles / 2 * A4e * A4fi * B2a * B4d
rec. fish			A4d * stream miles / 2 * A4e * A4fii * B2a * B4d
boating			
Income			
hunting	sales * A4c	sales * A4c	sales * A4c
comm. fish			sales * A4gi
rec. fish			sales * A4gii
boating			

Table C.2 (cont.)

Economic Model	7 - Leafy Spurge	8 - Rush Skeletonweed	9 - Purple Loosestrife
Livestock			
REI			
Sales	t. ragwort sales per area * B1a * B1b * area		
Income	sales * A1e		
Agricultural			
Component A			
REI			
Sales	A2a * B2a * B2b * B2c * area	A2a * B2a * B2b * B2c * area	
Income	sales * A2b	sales * A2b	
Component B			
REI			
Sales		A2d * A2e * B2a * B2b * area	
Income		sales * A2f	
Timber			
REI			
Sales			
Income			
Wildlife, Fish, Recreat			
REI			
Sales			
hunting	A4a * A4b * B2a * B2b * B4b * B4c * area / A1c	A4a * A4b * B2a * B2b * B4b * B4c * area / A1c	
comm. fish	A4d * stream miles / 2 * A4e * A4fi * B2a * B4d	A4d * stream miles / 2 * A4e * A4fi * B2a * B4d	A4d * stream miles / 2 * A4e * A4fi * B2a * B4d
rec. fish	A4d * stream miles / 2 * A4e * A4fii * B2a * B4d	A4d * stream miles / 2 * A4e * A4fii * B2a * B4d	A4d * stream miles / 2 * A4e * A4fii * B2a * B4d
boating			
Income			
hunting	sales * A4c	sales * A4c	
comm. fish	sales * A4gi	sales * A4gi	sales * A4gi
rec. fish	sales * A4gii	sales * A4gii	sales * A4gii
boating			

Table C.2 (cont.)

Economic Model	10 - White Top and Perennial Pepperweed	11 - Scotch Thistle	12 - Mediterranean Sage
Livestock			
REI			
Sales			
Income			
Agricultural			
Component A			
REI			
Sales	A2a * B2a * B2b * B2c * area	A2a * B2a * B2b * B2c * area	A2a * B2a * B2b * B2c * area
Income	sales * A2b	sales * A2b	sales * A2b
Component B			
REI			
Sales	t. ragwort sales per area * B2a * area		
Income	t. ragwort income per area * B2a * area		
Timber			
REI			
Sales			
Income			
Wildlife, Fish, Recreat			
REI			
Sales			
hunting	A4a * A4b * B2a * B2b * B4b * B4c * area / A1c	A4a * A4b * B2a * B2b * B4b * B4c * area / A1c	A4a * A4b * B2a * B2b * B4b * B4c * area / A1c
comm. fish	A4d * stream miles / 2 * A4e * A4fi * B2a * B4d		
rec. fish	A4d * stream miles / 2 * A4e * A4fii * B2a * B4d		
boating			
Income			
hunting	sales * A4c	sales * A4c	sales * A4c
comm. fish	sales * A4gi		
rec. fish	sales * A4gii		
boating			

Table C.2 (cont.)

Economic Model	13 - Purple Starthistle	14 - Hawkweeds	15 - Spartina
Livestock			
REI			
Sales	d. thistle (sales per area * B2a) * area		
Income	d. thistle (income per area * B2a) * area		
Agricultural			
Component A			
REI			
Sales		A2a * B2a * B2b * B2c * area	
Income		sales * A2b	
Component B			
REI			
Sales			A2j * B2a * B2b * area
Income			sales * A2k
Timber			
REI			
Sales			
Income			
Wildlife, Fish, Recreat			
REI			
Sales			
hunting	y. starthistle sales per area * d. thistle B2a * area	A4a * A4b * B2a * B2b * B4b * B4c * area / A1c	
comm. fish			
rec. fish			
boating			A4h * A4i * B2a * B4e * area
Income			
hunting	sales * A4c	sales * A4c	
comm. fish			
rec. fish			
boating			sales * A4j

Notes: 1. "A" refers to Table C.1a, and "B" refers to Table C.1b.
Source: Study.

Table C.3

Economic Activity Model Inputs for Infestation Area, Degradation, and Plant Coverage, and Resultant Regional Economic Impacts Per Acre

	Previous Study Weeds										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Economic Activity	Tansy Ragwort	Yellow Starthistle	Distaff Thistle	Scotch Broom	Knapweeds	Gorse	Leafy Spurge	Rush Skel-etonweed	Purple Loosestrife	White Top/ Per. Pepp.	Scotch Thistle
Net infestation area	163,000	947,068	10	1,500,000	1,815,591	31,354	7,324	60,000	2,230	1,184,326	526,800
Livestock (rangeland)											
Plant coverage share	96%	10%					10%				
Degradation (mortality)*/3ix*	10%	10%					10%				
REI	$ 3,907,325	$ 236,484					$ 1,829				
REI per acre */3iv*	$ 24.97	$ 2.50					$ 2.50				
Ag-A (rangeland)											
Plant coverage share */3ii*	96%	100%	10%	50%	50%	50%	100%	50%	100%	95%	100%
Degradation */3x*	30%	70%	70%	30%	100%	30%	100%	50%		100%	100%
REI	$ 1,340,877	$ 1,995,362	$ 4	$ 2,471,826	$ 2,732,314	$ 51,668	$ 80,461	$ 164,788		$ 12,360,337	$ 1,585,581
REI per acre */3v*	$ 8.57	$ 2.11	$ 3.79	$ 3.30	$ 3.01	$ 3.30	$ 10.99	$ 5.49		$ 10.99	$ 3.01
Ag-B (farmland)											
Plant coverage share */3i*	4%		4%					50%		5%	
Degradation */3xi*	12%		12%					50%		12%	
REI	$ 376,713		$ 23					$ 3,033,348		$ 3,421,403	
REI per acre */3vi*	$ 57.78		$ 57.78					$ 101.11		$ 57.78	
Timber (forestland)											
Plant coverage share				50%	50%	50%					
Degradation */3xii*				25%	25%	25%					
REI				$ 20,625,000	$ 24,964,376	$ 431,118					
REI per acre */3vii*				$ 27.50	$ 27.50	$ 27.50					
Wildlife (rangeland and wildland)											
Plant coverage share */3iii*	96%	100%	10%	50%	50%	50%	100%	50%	100%	95%	100%
Degradation											
Hunting */3xiii*	10%	10%	10%	10%	10%	10%	10%	10%		10%	10%
Fishing		100%				100%	100%	100%	100%	100%	
Boating											
REI	$ 48,412	$ 704,399	$ 1	$ 232,038	$ 936,193	$ 70,046	$ 7,619	$ 15,469	$ 4,152	$ 1,160,452	$ 543,279
REI per acre */3viii*	$ 0.31	$ 0.74	$ 1.30	$ 0.31	$ 1.03	$ 4.47	$ 1.04	$ 0.52	$ 1.86	$ 1.03	$ 1.03
Hunting	$ 0.31	$ 0.72	$ 1.30	$ 0.31	$ 1.03	$ 0.31	$ 1.03	$ 0.52		$ 1.03	$ 1.03
Fishing		$ 0.02				$ 4.16	$ 0.01	$ -	$ 1.86	$ 0.00	
Boating											
All Activity Types											
REI	$ 5,673,327	$ 2,936,245	$ 28	$ 23,328,865	$ 28,632,883	$ 552,832	$ 89,909	$ 3,213,606	$ 4,152	$ 16,942,192	$ 2,128,860

Table C.3 (cont.)

Economic Activity	Mediterranean Sage (12)	Purple Starthistle (13)	Hawk-weeds (14)	Spartina (15)	Armenian Blackberry	Dalmatian Toadflax	Giant Hogweed	Japanese Knotweed	Kudzu	Paterson's Curse
	Previous Study Weeds (cont.)				Weeds New to Current Study /4i					
Net infestation area	250,000	1	100	1						
Livestock (rangeland)										
Plant coverage share										
Degradation (mortality)/3ix								10%		10%
REI										
REI per acre /3iv								$ 2.50		$ 2.50
Ag-A (rangeland)										
Plant coverage share /3ii	100%	10%	95%							
Degradation /3x	100%	70%	100%		30%	100%	50%	70%	100%	70%
REI	$ 752,459	$ 0	$ 1,044							
REI per acre /3v	$ 3.01	$ 3.79	$ 10.99		$ 3.30	$ 10.99	$ 5.49	$ 2.11	$ 3.01	$ 3.79
Ag-B (farmland)										
Plant coverage share /3i				100%						
Degradation /3xi				100%	12%	12%	50%			12%
REI				$ 326						
REI per acre /3vi				$ 325.60	$ 57.78	$ 57.78	$ 101.11			$ 57.78
Timber (forestland)										
Plant coverage share										
Degradation /3xii					25%				25%	
REI										
REI per acre /3vii					$ 27.50				$ 27.50	
Wildlife (rangeland and wildla										
Plant coverage share /3iii	100%	10%	95%	100%						
Degradation										
Hunting /3xiii	10%	10%	10%		10%	10%		10%	10%	10%
Fishing					100%	100%	100%	100%		
Boating				50%						
REI	$ 257,820	$ 0	$ 98	$ 998						
REI per acre /3viii	$ 1.03	$ 0.72	$ 1.03	$ 998.17	$ 4.47	$ 1.03	$ 0.52	$ 0.74	$ 1.03	$ 1.30
Hunting	$ 1.03	$ 0.72	$ 1.03		$ 0.31	$ 1.03	$ 0.52	$ 0.72	$ 1.03	$ 1.30
Fishing					$ 4.16	$ 0.00	$ -	$ 0.02		
Boating				$ 998.17						
All Activity Types										
REI	$ 1,010,279	$ 0	$ 1,142	$ 1,324						

Table C.3 (cont.)

Notes: 1. REI is measured (includes the "multiplier effect") by personal income in 2012 dollars.

2. The plant coverage share of the net infestation area is the area for which an economic activity model applies.

3. Some weed species use the plant coverage of another weed species or a different economic activity model type for the same weed species.

   i. Distaff thistle agriculture Component B uses plant coverage from tansy ragwort Component B.

   ii. Purple starthistle agriculture Component A uses plant coverage from distaff thistle agriculture Component A.

   iii. All species wildlife uses plant coverage from agriculture Component A, except distaff thistle and spartina. Spartina wildlife boating component uses plant coverage from agriculture Component B.

   Some weed species use the REI per acre of another weed species or a different economic activity model type for the same weed species.

   iv. Yellow starthistle and leafy spurge livestock use tansy ragwort REI per acre.

   v. Distaff thistle and purple starthistle agriculture Component A use yellow starthistle REI per acre with a factor, and gorse uses Scotch broom REI per acre.

   vi. Distaff thistle agriculture Component B uses tansy ragwort REI per acre.

   vii. Knapweeds and gorse timber use Scotch broom REI per acre.

   viii. Distaff thistle and purple starthistle wildlife hunting component use yellow starthistle REI per acre with an index applied, and gorse uses Scotch broom REI per acre.

   Some weed species use the degradation of another weed species or a different economic activity model type for the same weed species.

   ix. Yellow starthistle and leafy spurge livestock uses tansy ragwort degradation.

   x. Distaff thistle and purple starthistle agriculture Component A degradation use yellow starthistle, and gorse uses Scotch broom.

   xi. Distaff thistle and white top/perennial pepperweed agriculture Component B degradation use tansy ragwort.

   xii. Knapweeds and gorse timber degradation use Scotch broom.

   xiii. Distaff thistle and purple starthistle wildlife hunting use yellow starthistle, and gorse uses Scotch broom. All species wildlife hunting also use agriculture Component A degradation in addition to the shown degradation.

4. Species new to the current study use REI per acre from similar species from the previous study that have economic activity models.

   i. Armenian blackberry uses gorse economic activity models, except for agriculture Component B that uses white top/perennial pepperweed. Dalmatian toadflax uses perennial pepperweed. Giant hogweed uses rush skeletonweed. Japanese knotweed uses yellow starthistle. Kudzu uses Russian knapweed. Paterson's curse uses distaff thistle, except for livestock economic activity model uses leafy spurge.

5. Colored shading: no shading - economic activity model developed, current study areas (current and susceptible) are non-zero; green - economic activity model developed, current study areas are zero; purple - economic activity model assumes no impacts for current study non-zero areas; orange - economic activity model is developed, current study areas are zero, susceptible acres are not zero.

APPENDIX D

Analyzed Noxious Weed Habitat Suitability Determinations

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Table D.1
Noxious Weed Infestation Current Area by Land Type

					Acres (thousands)																
		Area	Remote	Adjust-	Agriculture		Rangeland		Urban		Riparian		Pasture		Forestry		Estuarine		Wildland		Total
	Invasive Species	Type	Sensed	ment	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount
1	Armenian blackberry (Himalayar	est.	1,637,857	100%	29	1%	0	0%	125	9%	83	4%	41	0%	1,360	6%	0	0%	0	0%	1,638
2	Cordgrass	actual	1	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0
3	Dalmatian toadflax	est.	1,378,483	25%	0	0%	98	0%	10	1%	10	0%	0	0%	0	0%	0	0%	227	1%	345
4	Giant hogweed	actual	5	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0
5	Gorse	est.	81,409	35%	0	0%	0	0%	4	0%	0	0%	1	0%	14	0%	0	0%	9	0%	28
6	Japanese knotweed	est.	169,177	25%	0	0%	0	0%	30	2%	12	1%	0	0%	0	0%	0	0%	0	0%	42
7	Kudzu	actual	1	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0
8	Leafy spurge	est.	410,678	2%	0	0%	4	0%	0	0%	0	0%	0	0%	0	0%	0	0%	3	0%	8
9	Hawkweeds (meadow and orang	est.	107,384	1%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	0%	1
10	Mediterranean sage	est.	186,418	50%	0	0%	90	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	90
11	Paterson's curse	actual	10	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0
12	Perennial pepperweed	est.	111,365	80%	0	0%	59	0%	0	0%	22	1%	8	0%	0	0%	0	0%	0	0%	89
13	Purple loosestrife	est.	66,836	10%	0	0%	0	0%	0	0%	2	0%	0	0%	0	0%	0	0%	4	0%	7
14	Purple starthistle	actual	1	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0
15	Rush skeletonweed	est.	147,153	75%	14	0%	97	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	110
16	Scotch broom	est.	3,056,282	50%	0	0%	0	0%	94	7%	0	0%	0	0%	1,434	7%	0	0%	0	0%	1,528
17	Scotch thistle	est.	1,023,911	10%	0	0%	97	0%	6	0%	0	0%	0	0%	0	0%	0	0%	0	0%	102
18	Tansy ragwort	est.	2,496,389	5%	0	0%	0	0%	0	0%	0	0%	9	1%	0	0%	0	0%	116	0%	125
19	White top (Hoary cress)	est.	763,018	25%	9	0%	176	1%	0	0%	0	0%	6	0%	0	0%	0	0%	0	0%	191
20	Woolly distaff thistle	actual	3	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0
21	Yellow starthistle	est.	751,726	50%	0	0%	228	1%	79	5%	0	0%	69	4%	0	0%	0	0%	0	0%	376
22	Knapweeds - Diffuse	est.	1,100,201	25%	0	0%	252	1%	17	1%	0	0%	6	0%	0	0%	0	0%	0	0%	275
23	Knapweeds - Meadow	est.	501,860	25%	0	0%	0	0%	9	1%	0	0%	8	1%	0	0%	0	0%	108	0%	125
24	Knapweeds -Spotted	est.	671,987	25%	0	0%	143	1%	21	1%	0	0%	4	0%	0	0%	0	0%	0	0%	168
25	Knapweeds -Squarrose	actual	1	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0

Notes:

1. Current estimated infestation area is determined through a combination of Geographic Information System (GIS) analysis, and expert knowledge of the species distribution. When infestation area is equal to or less than 10 acres, the infestation extent is known intimately by ODA staff and the estimated area can be accepted as "actual." For the other noxious weeds, known geographic location of each was converted to a generic area of 973 acres that would be further utilized in the modeling process. This arbitrary area often overestimated the extent of the weed infestations, thus the error was mitigated utilizing expert knowledge as an adjustment factor determined by ODA staff. The total amount column is a sum across land types after the correction factor was applied.
2. Susceptible agricultural areas were generated using the Kinetic Resource and Environmental Spatial System (KRESS). Generated models were overlaid on agricultural zones derived from remotely sensed data. Impacted areas were accepted if the invasive species reached its mean ecological amplitude. The mean was chosen as to improve precision across all models analyzed, while negating the natural inclination of fitting models to data thus reducing human error. These models are an approximation of the susceptible habitable zone based on their current distributions. The models were found to be statistically significant utilizing the Receiver Operating Characteristic (ROC) analysis. The susceptible percent areas represent the share that could be impacted if the weed were to reach its mean ecological amplitude.

Table D.1 (cont.)

3. The selection criteria applied for the different land types relied on a weed location dataset from different land management agencies. (There were different agency collection protocols and assessments occurred at different dates.)

Land Types	Selection Criteria
1. Agriculture	utilized for crop production.
2. Rangeland	habitats that have historically been grazed for livestock production.
3. Urban	designated to be in urban areas, including parks and roadways in Oregon.
4. Riparian	designated to be waterways, or adjacent waterways in Oregon.
5. Pasture	designated to be irrigated for grazing purposes.
6. Forestry	designated to be harvestable standing timber.
7. Estuarine	influenced heavily by saline water along the coast.
8. Wildland	under the management of federal and state agencies.

Sources: Coombs et al. (2013), OBIC (2010), and Johnson et al. (2005).

Table D.2
Noxious Weed Infestation Susceptible Mean Area by Land Type

Acres (thousands)

		Agriculture		Rangeland		Urban		Riparian		Pasture		Forestry		Estuarine		Wildland		Total
	Invasive Species	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount
1	Armenian blackberry (Himalayan)	1,968	60%	0	0%	1,022	71%	821	38%	1,102	67%	9,891	47%	0	0%	0	0%	14,804
2	Cordgrass	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	40	100%	0	0%	40
3	Dalmatian toadflax	0	0%	12,008	61%	182	13%	896	42%	0	0%	0	0%	0	0%	18,638	55%	31,724
4	Giant hogweed	0	0%	0	0%	1,117	77%	960	45%	0	0%	0	0%	0	0%	0	0%	2,077
5	Gorse	0	0%	0	0%	969	67%	0	0%	1,094	66%	10,981	52%	0	0%	8,752	26%	21,796
6	Japanese knotweed	0	0%	0	0%	1,024	71%	775	36%	0	0%	0	0%	0	0%	0	0%	1,799
7	Kudzu	0	0%	0	0%	1,039	72%	0	0%	0	0%	11,949	56%	0	0%	0	0%	12,989
8	Leafy spurge	0	0%	15,515	79%	0	0%	1,133	53%	381	23%	0	0%	0	0%	20,248	60%	37,277
9	Hawkweeds (meadow and orange	0	0%	0	0%	784	54%	1,047	49%	0	0%	0	0%	0	0%	16,058	47%	17,888
10	Mediterranean sage	0	0%	15,034	76%	0	0%	0	0%	376	23%	0	0%	0	0%	0	0%	15,410
11	Paterson's curse	2,503	76%	5,586	28%	1,050	73%	0	0%	1,236	75%	0	0%	0	0%	9,363	28%	19,737
12	Perennial pepperweed	0	0%	14,584	74%	0	0%	1,019	47%	389	24%	0	0%	0	0%	0	0%	15,992
13	Purple loosestrife	0	0%	0	0%	0	0%	1,240	58%	0	0%	0	0%	0	0%	14,036	41%	15,276
14	Purple starthistle	0	0%	2,770	14%	0	0%	0	0%	1,247	76%	0	0%	0	0%	0	0%	4,017
15	Rush skeletonweed	2,257	69%	13,108	67%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	15,365
16	Scotch broom	0	0%	0	0%	1,073	74%	0	0%	0	0%	12,433	59%	0	0%	0	0%	13,507
17	Scotch thistle	0	0%	18,359	93%	371	26%	0	0%	512	31%	0	0%	0	0%	0	0%	19,241
18	Tansy ragwort	0	0%	0	0%	0	0%	0	0%	1,106	67%	0	0%	0	0%	10,278	30%	11,384
19	White top (Hoary cress)	885	27%	14,296	73%	0	0%	0	0%	377	23%	0	0%	0	0%	0	0%	15,558
20	Woolly distaff thistle	2,522	77%	4,621	24%	1,090	75%	0	0%	1,265	77%	0	0%	0	0%	9,128	27%	18,627
21	Yellow starthistle	0	0%	7,034	36%	1,163	80%	0	0%	1,281	78%	0	0%	0	0%	9,118	27%	18,596
22	Knapweeds - Diffuse	0	0%	15,586	79%	223	15%	0	0%	382	23%	0	0%	0	0%	0	0%	16,191
23	Knapweeds - Meadow	0	0%	0	0%	1,068	74%	0	0%	1,131	68%	0	0%	0	0%	10,244	30%	12,443
24	Knapweeds -Spotted	0	0%	14,310	73%	218	15%	0	0%	335	20%	8,182	39%	0	0%	18,138	54%	41,183
25	Knapweeds -Squarrose	0	0%	13,029	66%	442	31%	0	0%	532	32%	0	0%	0	0%	0	0%	14,003

Notes. 1. Notes and sources for Table D.1 apply.

Table D.3
Noxious Weed Infestation Susceptible Upper Bound Area by Land Type

	Invasive Species	Acres (thousands)																
		Agriculture		Rangeland		Urban		Riparian		Pasture		Forestry		Estuarine		Wildland		Total
		Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount
1	Armenian blackberry (Himalayan)	2,958	90%	0	0%	1,297	90%	1,333	62%	1,388	84%	12,895	61%	0	0%	0	0%	19,870
2	Cordgrass	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	40	0%	0	0%	40
3	Dalmatian toadflax	0	0%	16,570	84%	328	23%	1,256	58%	0	0%	0	0%	0	0%	24,619	73%	42,774
4	Giant hogweed	0	0%	0	0%	1,252	87%	1,477	69%	0	0%	0	0%	0	0%	0	0%	2,729
5	Gorse	0	0%	0	0%	1,235	85%	0	0%	1,323	80%	13,102	62%	0	0%	15,707	46%	31,367
6	Japanese knotweed	0	0%	0	0%	1,224	85%	1,118	52%	0	0%	0	0%	0	0%	0	0%	2,341
7	Kudzu	0	0%	0	0%	1,166	81%	0	0%	0	0%	16,003	76%	0	0%	0	0%	17,169
8	Leafy spurge	0	0%	16,957	86%	0	0%	1,372	64%	396	24%	0	0%	0	0%	26,170	77%	44,895
9	Hawkweeds (meadow and orange	0	0%	0	0%	1,011	70%	1,282	59%	0	0%	0	0%	0	0%	21,234	63%	23,527
10	Mediterranean sage	0	0%	18,010	92%	0	0%	0	0%	418	25%	0	0%	0	0%	0	0%	18,427
11	Paterson's curse	2,883	88%	12,337	63%	1,223	85%	0	0%	1,492	90%	0	0%	0	0%	18,798	55%	36,733
12	Perennial pepperweed	0	0%	18,280	93%	0	0%	1,295	60%	438	27%	0	0%	0	0%	0	0%	20,014
13	Purple loosestrife	0	0%	0	0%	0	0%	1,539	71%	0	0%	0	0%	0	0%	21,162	62%	22,701
14	Purple starthistle	0	0%	6,509	33%	0	0%	0	0%	1,304	79%	0	0%	0	0%	0	0%	7,813
15	Rush skeletonweed	3,112	95%	17,374	88%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	20,485
16	Scotch broom	0	0%	0	0%	1,245	86%	0	0%	0	0%	14,208	67%	0	0%	0	0%	15,453
17	Scotch thistle	0	0%	19,055	97%	421	29%	0	0%	538	33%	0	0%	0	0%	0	0%	20,014
18	Tansy ragwort	0	0%	0	0%	0	0%	0	0%	1,197	72%	0	0%	0	0%	13,689	40%	14,886
19	White top (Hoary cress)	1,205	37%	16,951	86%	0	0%	0	0%	446	27%	0	0%	0	0%	0	0%	18,602
20	Woolly distaff thistle	2,859	87%	8,653	44%	1,263	87%	0	0%	1,346	81%	0	0%	0	0%	14,699	43%	28,819
21	Yellow starthistle	0	0%	13,030	66%	1,207	83%	0	0%	1,431	87%	0	0%	0	0%	9,118	0%	24,786
22	Knapweeds - Diffuse	0	0%	18,015	92%	280	19%	0	0%	413	25%	0	0%	0	0%	0	0%	18,708
23	Knapweeds - Meadow	0	0%	0	0%	1,241	86%	0	0%	1,280	77%	0	0%	0	0%	14,319	42%	16,840
24	Knapweeds -Spotted	0	0%	17,356	88%	349	24%	0	0%	506	31%	10,011	47%	0	0%	23,099	68%	51,321
25	Knapweeds -Squarrose	0	0%	17,678	90%	995	69%	0	0%	1,506	91%	0	0%	0	0%	0	0%	20,179

Notes. 1. Upper bound estimates based on minus one standard deviation of the ecological amplitude.
2. Other notes and sources for Table D.1 apply.

Table D.4
Noxious Weed Infestation Susceptible Lower Bound Area by Land Type

	Acres (thousands)																
	Agriculture		Rangeland		Urban		Riparian		Pasture		Forestry		Estuarine		Wildland		Total
Invasive Species	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount	Correction	Amount
1 Armenian blackberry (Himalayan)	940	29%	0	0%	717	50%	617	29%	791	48%	8,515	40%	0	0%	0	0%	11,579
2 Cordgrass	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	40	0%	0	0%	40
3 Dalmatian toadflax	0	0%	7,462	38%	100	7%	668	31%	0	0%	0	0%	0	0%	13,066	39%	21,296
4 Giant hogweed	0	0%	0	0%	942	65%	588	27%	0	0%	0	0%	0	0%	0	0%	1,529
5 Gorse	0	0%	0	0%	892	62%	0	0%	1,024	62%	9,653	46%	0	0%	7,437	22%	19,006
6 Japanese knotweed	0	0%	0	0%	849	59%	535	25%	0	0%	0	0%	0	0%	0	0%	1,384
7 Kudzu	0	0%	0	0%	936	65%	0	0%	0	0%	10,271	49%	0	0%	0	0%	11,207
8 Leafy spurge	0	0%	8,382	43%	0	0%	817	38%	221	13%	0	0%	0	0%	15,241	45%	24,661
9 Hawkweeds (meadow and orange	0	0%	0	0%	691	48%	827	38%	0	0%	0	0%	0	0%	11,916	35%	13,435
10 Mediterranean sage	0	0%	10,425	53%	0	0%	0	0%	287	17%	0	0%	0	0%	0	0%	10,712
11 Paterson's curse	2,203	67%	3,219	16%	882	61%	0	0%	1,036	63%	0	0%	0	0%	5,099	15%	12,440
12 Perennial pepperweed	0	0%	12,197	62%	0	0%	753	35%	299	18%	0	0%	0	0%	0	0%	13,249
13 Purple loosestrife	0	0%	0	0%	0	0%	673	31%	0	0%	0	0%	0	0%	8,305	25%	8,978
14 Purple starthistle	0	0%	1,003	5%	0	0%	0	0%	1,210	73%	0	0%	0	0%	0	0%	2,213
15 Rush skeletonweed	1,915	58%	8,713	44%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	10,628
16 Scotch broom	0	0%	0	0%	947	66%	0	0%	0	0%	10,150	48%	0	0%	0	0%	11,098
17 Scotch thistle	0	0%	10,262	52%	170	12%	0	0%	188	11%	0	0%	0	0%	0	0%	10,620
18 Tansy ragwort	0	0%	0	0%	0	0%	0	0%	1,085	66%	0	0%	0	0%	8,089	24%	9,174
19 White top (Hoary cress)	529	16%	9,924	50%	0	0%	0	0%	315	19%	0	0%	0	0%	0	0%	10,767
20 Woolly distaff thistle	2,031	62%	2,206	11%	888	61%	0	0%	1,123	68%	0	0%	0	0%	5,664	17%	11,912
21 Yellow starthistle	0	0%	3,974	20%	874	60%	0	0%	1,167	71%	0	0%	0	0%	9,118	0%	15,133
22 Knapweeds - Diffuse	0	0%	11,116	57%	166	12%	0	0%	336	20%	0	0%	0	0%	0	0%	11,618
23 Knapweeds - Meadow	0	0%	0	0%	967	67%	0	0%	1,094	66%	0	0%	0	0%	7,783	23%	9,843
24 Knapweeds -Spotted	0	0%	9,438	48%	138	10%	0	0%	210	13%	6,060	29%	0	0%	12,808	38%	28,654
25 Knapweeds -Squarrose	0	0%	11,956	61%	244	17%	0	0%	368	22%	0	0%	0	0%	0	0%	12,568

Notes. 1. Lower bound estimates based on plus one standard deviation of the ecological amplitude.
2. Other notes and sources for Table D.1 apply.

Table D.5
Anadromous Fish Habitat Noxious Weed Affected Stream Length

	Current	Susceptible Mean	Susceptible Upper Bound	Susceptible Lower Bound
Fall Chinook				
Armenian blackberry (Himalayan)	672	4,011	4,731	3,221
Giant hogweed	0	3,981	4,229	3,487
Japanese knotweed	107	4,086	4,691	3,132
Leafy spurge	0	29	192	8
Perennial pepperweed	1	166	241	79
Purple loosestrife	21	3,419	4,425	2,025
Spring Chinook				
Armenian blackberry (Himalayan)	459	3,777	4,767	2,727
Giant hogweed	0	3,640	4,437	2,876
Japanese knotweed	93	3,356	4,775	2,609
Leafy spurge	4	1,291	1,928	868
Perennial pepperweed	1	1,343	1,956	833
Purple loosestrife	15	3,851	4,801	2,562
Chum				
Armenian blackberry (Himalayan)	40	482	495	434
Giant hogweed	0	390	441	223
Japanese knotweed	22	470	495	290
Leafy spurge	0	0	14	0
Perennial pepperweed	0	0	0	0
Purple loosestrife	3	465	489	336
Coho				
Armenian blackberry (Himalayan)	1,289	9,724	10,950	8,018
Giant hogweed	0	9,210	9,914	7,971
Japanese knotweed	209	9,917	10,927	7,284
Leafy spurge	0	160	669	58
Perennial pepperweed	0	169	432	36
Purple loosestrife	31	7,928	10,384	4,480
Summer steelhead				
Armenian blackberry (Himalayan)	547	4,082	6,441	2,238
Giant hogweed	0	4,599	5,927	3,169
Japanese knotweed	66	3,906	6,958	2,908
Leafy spurge	6	4,829	6,024	3,812
Perennial pepperweed	2	4,308	5,810	2,873
Purple loosestrife	17	5,250	7,060	3,141
Winter steelhead				
Armenian blackberry (Himalayan)	1,442	11,428	12,735	9,354
Giant hogweed	0	10,554	11,602	9,071
Japanese knotweed	221	11,647	12,795	8,875
Leafy spurge	0	403	1,047	139
Perennial pepperweed	0	328	764	108
Purple loosestrife	29	8,875	11,782	5,064

Notes: 1. Stream length is in habitat river miles.
2. Upper and lower bound estimates based on minus and plus one standard deviation of the ecological amplitude.