United States
Department of
Agriculture

Forest
Service

Forest Health
Technology Enterprise
Team

180 Canfield Street
Morgantown, WV 26505
(304) 285-1563
(304) 285-1564 Fax

Special Technology Development Program

New Project Proposal

PROJECT NUMBER R6-2002-01

PROJECT TITLE: Risk Assessment Model for Invasive Plant Species

PROJECT STATUS: New

EXPECTED PROJECT DURATION: 1 year

EXPECTED COMPLETION DATE OF THE PROJECT: Dec. 31, 2002

Caring for the Land and Serving People

Printed on Recycled Paper

SUBJECT:

1. Total Suppression/Prevention Technology	%		2. Survey and Monitoring Technology	%	
a. Total Biological Control i. Microbial % ii. Parasitoides % iii. Synthetic hormones/pheromones % iv. Other %		%	a. Advancements in Detection Technology		%
			b. Landscape Level Assessment Technology i. Data Visualization		%
b. Total Modeling i. Pesticide (Insecticide) Application % **ii. <u>Disturbance %</u>** iii. Growth and Yield % **iv. <u>Organism %</u>** **v. <u>Population %</u>** vi. **<u>Terrain %</u>**	**30**	%	c. Remote Sensing i. Aerial % ii. Hyperspectral % iii. Satellite %		%
			d. Other **Decision support for invasive plant survey and monitoring design and priority-setting**	**20**	%
c. Genetic, Cultural and Silvicultural Innovations For Controlling Pest Species i. Fire % ii. Methyl Bromide Alternatives % iii. Thinning/Regeneration Techniques and other Silvicultural Guidelines % iv. Resistance, Screening, and Breeding %		%	3. Assessment Technology	%	
			a. GIS % b. Spatial Analysis % c. Landscape Analysis % **d. Decision Support %** **Risk and Hazard %** Expert Systems %	**50**	
d. Pesticide Application (Spray) Technology i. Equipment innovations % ii. Methods and Guidelines %		%	4. Social Values	%	
			5. Technology Transfer Innovations	%	
e. Other		%	6. Other	%	

STATUS OF SUBJECT SPECIES: Nonnative Invasive Plants

PROJECT OBJECTIVES: Develop and provide for use in PNW Region an Invasive Plant Risk Model that will provide integrated evaluation of physical, biotic and disturbance factors to assess relative risk of invasive plant establishment across wildland landscapes. The model will be used by the PNW Region Invasive Plant Management EIS in alternative development and evaluation. Additionally, the model will be available to Cooperative Weed Management Areas, and federal, state, and private landowners can use the model to assess invasive plant risks and prioritize management activities across western wildlands.

BRIEF DESCRIPTION OF PROJECT: One Year: develop Invasive Plant Risk Model and test in a GIS analysis of a priority subRegion in the Pacific Northwest.

FHP LEAD CONTACT :

Name	Affiliation (Office or Dept.)	Phone, E-mail, Fax
Gary K. Smith	PNW Region FID-RO	503-808-2914 gsmith03@fs.fed.us 503-808-2469

FHP LEAD INVOLVEMENT :

	Role	Time Commitment
Smith	Sponsor	10 days

PRINCIPAL INVESTIGATOR(S) :

Name	Affiliation (Office or Dept.)	Phone, E-mail, Fax
Steven R. Radosevich	Professor, Forest Science, Oregon State University	541-737-6081 Steve.Radosevich@orst.edu
David A. Pyke	Plant Ecologist, USGS; Forest Science, OSU	541-737-7307 pyked@fsl.orst.edu

PRINCIPAL INVESTIGATOR(S) INVOLVEMENT :

Name	Role	Time Commitment
Radosevich	Principal Investigator	15% FTE
Pyke	Co-Principal Investigator	5% FTE
Post-doc		100% FTE
Graduate Research Assistant		49%FTE

COOPERATORS:

Name	Affiliation (Office or Dept.)	Phone, E-mail, Fax
Nancy Diaz	PNW Region Weed EIS ID Team Leader	503-808- ndiaz@fs.fed.us
Catherine Parks	PNW Station, LaGrande Blue Mts. Invasives Research	541-962-6531 cparks@fs.fed.us

COOPERATOR INVOLVEMENT:

Name	Role	Time Commitment
Diaz	EIS ID Team leader	15 days
GIS staff, EIS team	Project GIS support	75% FTE
Parks	Blue Mt. Research/model liaison	5 days

JUSTIFICATION: FHP support will produce a science-based decision support model of ecosystem susceptibility and risk of invasive plant establishment and spread across landscapes. The computer based information GIS system will assist land managers in identifying and prioritizing areas for survey, monitoring, and application of prevention and/or control strategies. No precedent invasive plant risk model with GIS spatial link for landscape scale analysis has been developed.

URGENCY: **The PNW Region, USFS is beginning a new EIS for Integrated Non-native Invasive Plant Management in November, 2001. An analysis and decision support tool is urgently needed in FY 2002 to support the development of alternatives for the EIS. Alternatives must use integrated weed management strategies that are based on best available science and are legally defensible. Investigators will be closely coordinated with the EIS IDTeam and GIS support throughout model development. Investigators will also coordinate with PNW Research program on invasive plants in the Blue Mountain province of Oregon to incorporate new scientific findings.**

NATIONAL FHP TECHNOLOGY DEVELOPMENT PRIORITY:

Priority 3: "Develop techniques to quantify the impact of pest species as disturbance agents…including their interaction with other disturbances agents…"

This proposal will develop a risk rating model to evaluate the effects of plant community structure and ecosystem processes on the risk of weed introduction and establishment across landscapes, including plant community and invasive plant interactions with natural and human disturbance factors.

Priority 4: "Develop detection, analysis and management of pest species, especially technologies or methods that contribute to our ability to prevent introductions and eradicate new infestations."

The Invasive Plant Risk Model develops a predictive model to identify and prioritze the risks of invasive plant introduction and establishment across wildland landscapes. This information will be used to develop Integrated Invasive Plant Management strategies and EIS alternatives.

TECHNICAL COMMITTEE DEVELOPMENT PRIORITY (check at least one and describe how proposed work addresses the priorities):

Priority 7: "Use state-of-the-art analytical tools…or develop new tools which are then applied to existing resource data to answer questions that are of Regional and/or National in scope."

This project will develop a risk rating model for invasive plant introduction and establishment across PNW Region landscapes. The model will be applied to priority landscapes within the analysis area for the PNW Region Integrated Weed Management EIS to develop and analyze alternative management strategies for potential effects on invasive plant establishment and spread.

The model will be useful to other landscape-level invasive plants analyses throughout the geographic area. Such analyses would be used by federal, state and private land managers for prioritizing survey, prevention, treatment and monitoring programs, particularly where interownership cooperation and coordination, such as in Coopeative Weed Management Areas.

The scientific basis and structure of this Invasive Plant Risk Model will be applicable to Integrated Weed Management planning and environmental analysis throughout the western United States, where weed invasion risks are comparable, and potentially even to other areas of the US, or other countries.

Priority 9: "Development/refinement of…inventory and monitoring technology for invasive plants."

Invasive plant surveys and monitoring are two elements of an Integrated Invasive Plant Management strategy. The Invasive Plant Risk Model will help managers prioritize survey efforts and monitoring programs for both prevention and treatment.

SCOPE OF APPLICATION: The model will be applied to a priority subregion such as the Blue Mountains of Oregon as a test case. Documentation and further information needs for applying the model throughout the PNW Region in the EIS analysis will be provided by the investigators. The scientific basis and structure of this Invasive Plant Risk Model will be applicable to Integrated Weed Management planning and environmental analysis throughout the western United States, where weed invasion risks are comparable, and potentially even to other areas of the US, or other countries.

RESEARCH BASIS

Overview and Objectives:

Range expansion of non-native invasive plant species (aka "weeds") into new areas can profoundly influence local, regional, and global biota over time. The movement of organisms beyond their natural range has devastating ecological and economic consequences. Recent estimates suggest that noxious plants are encroaching at a rate of 14% area annually (BLM 1994). In total, invasive plants now occupy about 100 million acres nationally, and each year three million additional acres become inhabited (FICMNEW 1997). These plants pose a serious threat to the integrity of the region's ecosystems, and land managers need tools to focus their limited weed management resources to identify lands with high risk of weed invasion, concentrate monitoring efforts, and successfully treat new invasions before they become infestations. We propose to develop a risk model linked to GIS to assist managers in surveying, monitoring, prevention and control on their lands. To develop this tool, we will:

- Develop a relational database of noxious plant species containing fields of information with ecological and managerial data about each species.
- Develop a set of geo-referenced databases for soils, climate, elevation, land uses, transportation systems, water, and current vegetation including noxious plant infestations for the study area.
- Sample the landscape for noxious species using an environmental grid stratification approach to determine environmental indicators associated with the identified noxious species.
- Provide GIS-based modules of the program that will allow the user to identify new weed populations before or as they occur, and to plan monitoring and treatment for such populations.

Approach

A weed, by definition, is aggressive and can invade, dominate and persist in most ecosystems (Cousens and Mortimer 1995, Radosevic et al. 1997). Weed species have particular traits that enable rapid colonization which can be examined using life history characteristics (Radosevich et al. 1997). There are a variety of characteristics that are associated with aggressive traits and with the displacement of native plants, such as escaping native predators, small seed size, short juvenile period, persistent seed bank, and young reproductive age (Rejmanek and Richardson 1996). However, these characteristics do not encompass invasions worldwide and do not account for weed-ecosystem interactions. For instance, there are significantly more invasive plants occupying grassland and semi-arid areas in contrast to forests and marshes. Hence, vulnerability to invasion varies by community. Disturbed ecosystems (either by human or natural causes) may have a higher susceptibility to invasions than systems that spend long periods in late successional phases. One explanation for semi-arid and grassland vulnerability is that these areas have spatially open niches; sites that are devoid of vascular plants, for some or most of the year (Baker 1986). In some cases, ecosystems are invaded by weeds that have life forms dissimilar to the native vegetation, e.g. conversion to annual grasslands from tussock grasslands in California

and the invasion of *Opuntia stricta* into Australia where no members of Cactaceae existed previously. The intrinsic biology of the weed and the extrinsic nature of the ecosystem are equally important in modeling expansion ranges for invasive weed species (Figure 1).

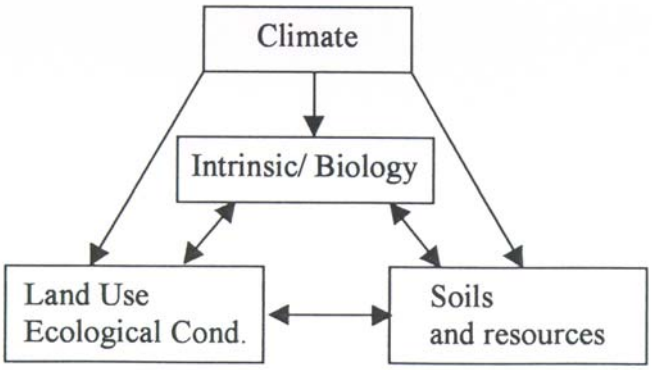

Figure 1: Major ecosystem drivers and interactions involved in plant population expansion and persistence. Extrinsic factors involved in invasion potential are soils, climate and land use. The interplay between intrinsic biological characteristics of the species and the extrinsic drivers determines habitat suitability for invasive species.

Extrinsic and Intrinsic Factors. Explanations and descriptions of invasions have been the focusof weed ecology for several decades (Cousens and Mortimer 1995). By characterizing the manner in which invasions occurred in the past, it is possible to gain knowledge about future weed invasions and expansion rates. Although the ecology of the species and the ecosystem vary across the world, there are some similarities that span taxonomic and geographic boundaries. Understanding these generalities and their relationship to intrinsic (biological) and extrinsic (environmental) factors of invasion will enable a better prediction of spread in distinct habitats. Weed species invasions can generally be depicted by a logistic curve distinguished by three phases: introduction, colonization and establishment, (Groves 1986).

Population growth curves can be generated for species given the initial population size, their intrinsic growth rate, and time. Small populations are often undetected during the introduction phase. Individual seeds or small metapopulations may remain undetected for extended time periods. Weed invasions are most likely to fail at this point due to stochasticity (Mack 1995), or to their lack of a minimum critical patch size (Latore et al. 1998) or habitat. Dispersed seeds compete with the established flora that is well adapted to the site; thus few invasions proceed to the colonization phase. Most factors, aside from suitability to the ecosystem, that influence the rate of the introduction are extrinsic to the disseminating seed. Prediction of the introduction phase is strongly related to these extrinsic factors.

Colonization is characterized by exponential population growth. During this explosive growth phase, the weed often becomes apparent and control efforts to halt the spread begin. This phase is closely related to the intrinsic rate of increase for the weed species. Hence, predictions of

colonization rates should focus on intrinsic biology of the species with minor influences from extrinsic factors. At some carrying capacity, K, the population approaches a quasi-threshold density where its population growth may remain near one, i.e., stabilize and not expand very quickly. This phase is termed naturalization. The K density occurs when niche occupancy and available resources limit the rate of spread (Figure 2). This phase is controlled by extrinsic factors so predictions of risk for populations approaching K should also be focussed on extrinsic parameters. Most agencies remove weeds from their target list (e.g., noxious weed lists) in this phase as they are too difficult and expensive to eradicate.

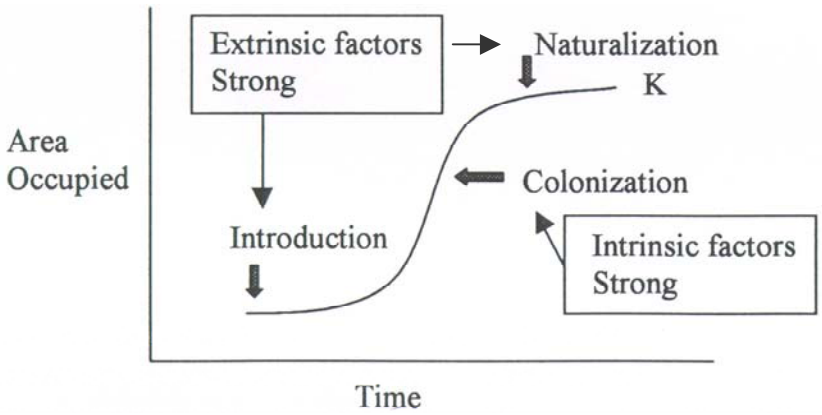

Figure 2: Logistic growth curve depicting the phases of expanding populations

The driving forces (extrinsic factors) most responsible for floristic growth and persistence in habitats are soil, climate and land use. Many studies have shown that both plant growth (e.g., Ecological Site descriptions for Forestland and Rangeland, NRCS 1997, 1998) and weed invasions occur within certain ranges of soil types (Huenneke et al. 1990). Although soil-mapping units often have fuzzy boundaries, usually species are most productive within the boundaries of certain soil types. One criterion that should be used in predictive models is the isolation of soil mapping units that each target species finds suitable. Climate also drives both abiotic and biotic thresholds for growth in ecosystems. For example, the retreat of forests to mountainous areas over the last 10,000 years is a direct result of changing climate (Betancourt et al. 1990). Climate can change habitat suitability over short time scales through drought, seasonal frost and flooding (Nilsen and Muller 1980). Weed species tend to adapt well to a variety of habitats, but usually invade areas with similar climates to their native range first, then adapt to other climates later (Panetta & Mitchell 1991, however notable exceptions also occur, see Mack 1995). Climate is an isolator of suitable habitat for weed invasion. Edaphic processes such as topography and elevation influence climate and the species that can grow at a given location.

Land use and the condition of the environment is a third general driving component in habitat suitability and invasion. Changes in land use are thought to be the single most important factor in species extinction (Cousens and Mortimer 1995) and to have strong influences on invadable sites (Elton 1958 as cited by Hodkinson and Thompson 1997, Radosevich et al. 1997). Humans to some degree have modified most of the world's ecosystems and this has direct affects on

invasion suitability. Some ecosystems are altered by the presence of the weed itself (D'Antonio and Vitousek 1992) through an increase in fire frequency or nitrogen depletion. Other weedy species are adapted for the change in land use where native species are not, i.e. resilience to grazing pressure in the Great Basin (Mack and Thompson 1982).

Source and Satellite Populations. Scaling also plays an important role when considering rate of spread (Collins and Glen 1997) and population growth of invasive species. Regionally, a species may be detected in the late colonization or early naturalization phase and thus be considered a stable population. However, this stable source population may contribute to subsequent local infestations through seed dispersal. The resulting small satellite populations (or foci of infestations) are sinks from the source population and can become further source populations themselves (see "Attachments", figure 3), expanding markedly the original infestation area (Husband and Barrett 1996). Rates of increase for satellites can be extremely high because satellite introductions have a much higher probability of success than initial introductions due to the constant seed flow arising from the source areas. The landscape relationship becomes important for predicting spread from source populations to new locations. Avenues of connectivity (e.g., transportation routes, streams, prevailing winds) between source infestations and suitable, yet unoccupied, habitats may enhance spread and therefore enhance the invasion risk of the unoccupied site. Patch resistance to invasion may consist of many factors, but it is certainly strongly correlated to species richness (Tilman 1997). However, local scales that are often missed by remote sensing techniques (e.g., weeds using native vegetation as nurse crops) are paramount for detecting new source colonies and predicting spread before infestations begin to grow rapidly. Ground surveys remain as the best method for detection of new source and satellite populations. The scale of spatial heterogeneity on the landscape strongly influences spread rates and invasions. Small nacent populations or colonies are the funnel for high spread rates in a given region. These local satellite infestations are more important to contain before they reach their potential growth rates than even the initial source population (Moody and Mack 1998, Cousens and Mortimer 1995). It is important to use both regional and local scales to predict population expansion.

Invasion models. Modeling weed invasions has been attempted in numerous studies over the last decade with varying success. Unfortunately, unquantifiable parameters and overgeneralizations have led to some dissention about further development of more invasion models. Modeling attempts generally use analytical diffusion models in an attempt to apply any weed in any area. The future of invasion modeling should be the interplay between general descriptions of weed biology, potential habitats, and landscape scale connections among ecosystems. Models that are general enough to predict risk for many species, but adaptable enough to changing criteria for different species provide the greatest hope in achieving some predictable success at an affordable cost. Land managers need models that incorporate both specific biological and landscape level inputs. Scales too large for application and too small for use in detecting landscape invasions are, therefore, of limited use to the land manager. Managers also need models that directly aid in the detecting and monitoring of invasive plants while they remain in the small satellite population phase where control and eradication are most successful.

We will investigate both the intrinsic and extrinsic factors that affect plant invasions in this project. Intrinsic factors such as physiological growth parameters, growth rates, and demography will be collected through the literature for the weed species identified in this study. The extrinsic

drivers of plant invasions: soil, climate, and land use are the foundations for assessing invasion risk. We will develop a GIS-based model which will enable land managers to identify land areas with the characteristics needed for noxious weed establishment and survival. The model system should aid managers in triaging their lands into areas of high, intermediate, and low risk of invasion based on factors that add or subtract from the risk of invasion.

METHODS:

The model will involve computer programming a GIS-based system that will interface with a multitude of relational databases. To construct and validate the model we will also evaluate available field inventory data on the presence and absence of noxious weeds on USFS Districts throughout Region 6.

Data Layers and Databases There are 110 noxious weed species in the Pacific Northwest, and a number of plant databases are being constructed by various agencies to address the need for information on exotic species. Current databases will be sources of most of the information for constructing our database. They contain most of the data that our model will require, but often information is nested within narrative sections of the biological description of a weed. In some cases, these databases lack detailed information on each species' establishment and growth requirements. We envision that the model's noxious weed database could consist of upward to 50 fields of information per species, and be a combination of numeric and categorical information for each plant (e.g., Table 1). Metadata will provide citations from which the information came or list the scientist or manager that was consulted. We will work closely with the developers of several of the current databases to assure consistency of data served from our model and among other databases.

Table 1. Example of data for two selected exotic species that will likely be used for determining the potential presence and risk of an exotic species at a site.

Sci. Name	***Comm. Name***	***Grwth Period***	***Seedl. Vigor***	***Seed Spread Rate***	***Veg. Spread Rate***	***Soil Texture***	***Min pH***	***Max' pH***	***Anaerobic Toler.***	***Min. Precip. (in.)***	***Max Precip. (in.)***
Bromus tectorum	Cheat-grass	Wint., Spr.	High	Rapid	None	Fine Med. Coarse	4.8	7.8	None	5	45
Lythrum salicaria	Purple Loose-strife	Spr. Sum.	Mod.	Rapid	None	Fine Med. Coarse	5.0	7.0	High	30	60

For example, we will work most closely with the USDA-NRCS PLANTS database and with the subset database called VegSpec/Plants (Pyke 1999, http://plants.usda.gov and link to VegSpec) during the initial model development. This will allow us to use similar programming rules to those found in VegSpec to expedite development. The spatial data distribution component of our

model will be similar to the Southwest Exotic Mapping Project (SWEMP, http://www.usgs.nau.edu/swemp/) .

Three major spatial databases, climate, soils and surface, will be georeferenced to the study sites using ArcInfo (see "Attachments", Figure 4).

These three general extrinsic components of ecosystems should dictate where an invasive plant might grow. The climate database will be constructed using a statistical-geographic approach to mapping climate data called PRISM (Parameter-elevation Regressions on Independent Slopes Model) (Daly and Neilson 1992, Daly et al. 1994). PRISM uses point climate station data and digital elevation models to extrapolate climate data over large elevation ranges and to incorporate rain shadow and coastal effects into the long-term climate data across the US. PRISM has been produced for the 48 contiguous US states as a 4-km grid map of monthly precipitation (50 states), minimum, maximum and average temperature, and temperature range (http://www.ocs.orst.edu/prism/prism_new.html). Expert peer reviews are being conducted on maps of monthly snowfall, snow water equivalent, growing degree days, heating and cooling degree days, and median first and last frost dates for the for the lower 48 contiguous US states.

We also will contact the USDA NRCS to determine the status of the Soil Survey Geographic Data Base (SSURGO, http://www.ftw.nrcs.usda.gov/ssurgo.html) for locations in Washington and Oregon. SSURGO maps include the Soil Survey data for the location and the Map Unit Interpretations Record (MUIR, http://www.statlab.iastate.edu/soils/muir/) database that provides 25 physical and chemical soil properties. Should these not be available for the areas selected in this project, we will use the NRCS Soils database currently being used in VegSpec. To georeference this database, we will digitize the soil mapping units for the study site using the NRCS base 7.5 min. orthophotoquads; for the area. Table 2 provides a sample of the data available from the VegSpec soils database.

Table 2. Example of some of the soil fields for the database that would be a portion of Invasive Plant Risk Model (from NRCS Soil Survey of Spokane County found in VegSpec)

Soil Mapping Unit	***Depth to Water Table (ft)***	***Hydric Soil***	***Texture Class***	***Min. pH***	***Max pH***	***Flooding Frequency***	***Flooding Duration***
Bridgeson Silt Loam	1.5	Yes	Medium	6.6	7.8	Occasional	Long
Latah Silt Loam	4.0	No	Medium	6.6	7.8	Occasional	Brief

Surface data layers of land use will include digital orthophoto quadrangles, topography (from USGS Digital Elevation Maps, 7.5 and 15 min), transportation routes (roads and trails), fencelines, land uses livestock grazing, military activity, buildings and site improvements (wells, water troughs, etc.), crop production, etc.) and current vegetation. We will use digital data available from the USFS. We anticipate that some of this information will require digitization from maps or files at the agency. Current vegetation communities will be determined using a supervised classification of Landsat Thematic Mapper images for the site. We will use a

vegetation classification technique developed in our laboratories (USGS, FRESC) that has proven successful in determining annual plant communities (Knick et al. 1997).

Data analysis and management will be conducted at Oregon State University and USGS, Forest & Rangeland Ecosystem Science Center (FRESC), Corvallis, Oregon, using networked Windows NT and Unix Workstations. Software to manage and interface with the data includes Microsoft Access™, ArcInfo, and ArcView. The final product will be supplied as an ArcView component program. Final data will be documented with FGDC compliant metadata and will be served, when applicable, via the World Wide Web from one of the FRESC servers. Copies of the risk model and all database files will be loaded and tested on hardware owned by the U.S. Forest Service. Documentation will also be supplied to each location.

Validation. The final validation of the model will use an unsampled section of the study area to predict areas where noxious species will likely occur. We will sample equivalent sized areas where the model predicts occurrence or nonoccurrence of invasive plants. If operating properly, then areas where the model predicts weed occurrence should have significantly higher concurrence of weed presence than would be expected by random chance. We will stratify these comparisons by species and test the agreement between the model and the actual locations using Cohen's κ, a statistical test of agreement (Liebetrau 1983). We will use a one-sided test that tests the K: K <= 0, since we anticipate that when the model provides a predictive capability of locations for noxious plants, then K should be significantly positive.

MEASURES OF SUCCESS:

Standard of Success: A scientifically defensible Invasive Plant Risk Model is operational and validated at a sub-Regional test case.

Expected Outcomes: A scientifically defensible Invasive Plant Risk Model will be used by EIS ID Team in developing and evaluating Invasive Plant Management alternatives for the PNW Region.

Implementation of Products/methods: In addition to use by the PNW Region EIS team, the model will available to Cooperative Weed Management Areas, and federal, state, and private landowners who need to analyze invasive plant risks and management activities across western wildlands.

PRODUCTS AND DUE DATES: The project will provide GIS-based modules of the program to allow users to identify new weed populations before or as they occur, and to plan monitoring and treatment for such populations. The final product, including data layers, will be supplied as an ArcView component program. All files will be loaded and tested on hardware operated by the USFS.

DUE DATE: December 31, 2002.

PUBLICATIONS: Additional publications in scientific journals are planned that describe model development, data layers, and the model's utility.

TECHNOLOGY TRANSFER The investigators will work with the PNW Region Invasive Plant Management EIS ID Team, coordinated with Dr. Nancy Diaz, ID Team Leader. The EIS team will be able to apply the model in evaluation of EIS alternatives, based on a sub Regional test case conducting by the investigator team.

PRODUCT LEVERAGING: NFS, Range provides national guidance and funding for noxious weed management, including the PNW Region EIS team. The EIS project will contribute estimated 0.75 FTE of GIS support to model development, and the participation of team leader Dr. Nancy Diaz in project guidance. The EIS ID Team will be conferring with the investigators during model development, and EIS GIS support will assist model developer and test case application.

Model development and refinement will be coordinated with and use results from current OSU joint venture research with Dr. Catherine Parks, PNW Station on basic plant biology information. This information will be used to refine or produce subregional variants of the model.

LONG-TERM BUDGET REQUEST:

	Item	Requested FHP STDP Funding	Other-Source Funding	Source
FY 2002				
Administration	Salary and OPE	70,083	$75,000 (0.75 FTE GIS)	USFS, PNW Region, NFVW $
	Overhead		$32,083	OSU
	Travel	2,000		
	Tuition		$ 7,941	OSU
Procurements	Contracting			
	Equipment Services	4,725	In-kind: GIS equipment provided. (est. $10,000+)	USFS, PNW Region, NFVW $
	Supplies	500		
YEAR TOTALS		$77,308	>$125,000+	

BENEFITS: The short-term benefit is enabling the PNW Region to implement an Integrated Invasive Plant Management program with relative invasion risk estimates for planning and prioritizing the most effective survey, prevention, control, and monitoring program. The long-term benefit is the improved protection of ecosystems across all land ownerships within the PNW from the introduction and establishment of community-replacing invasive plants by providing a risk model to support planning and prioritization of efforts.

LITERATURE CITATIONS

Baker, H.G. 1986. Patterns of plant invasion in North America in Ecology of Biological Invasions of North America and Hawaii, eds: Mooney, H.A., and JA. Drake. Springer-Verlag, New York, NY.

Betancourt, J.L., T.R. VanDevender, and P.S. Martin. 1990. Fossil packrat middens: The last 40,000 years of biotic change in the arid west. Univ. of Arizona Press, Tucson.

BLM. 1994. Noxious weed strategy for Oregon/Washington. BLM, Oregon/Washington State Office. Report BLM/OR/WA/PT-94/36+4220.9, Portland, OR

Castillo, E. and Alvarez, E. 1991. Expert Systems: uncertainty and learning. Computational Mechanics Boston, MA and Elsevier Applied Science, New York, NY.

Collins, S.L. and S.M. Glenn. 1997. Effects of organismal and distance scaling on analysis of species distribution and abundance. Ecological Applications 7(2): 543-551.

Cousens, R. and M. Mortimer. 1995. Dynamics of weed populations. Cambridge University Press, New York, NY.

Daly, C. and R.P. Neilson. 1992. A digital topographic approach to modeling the distributions of precipitation in mountainous terrain. Pgs. 437-454, *IN* Anonymous (ed.), Interdisciplinary approaches in hydrology and hydrogeology. American Institute of Hydrology.

Daly, C., R.P. Neilson, and D.L. Phillips. 1994. A statistical-topographic model for mapping climatological precipitation over mountainous terrain. J. Appl. Meteor. 33:140-158.

D'Antonio, C.M. and P.M. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual Review of Ecology and Systematics: 23: 63-87.

FICMNEW. 1997. Pulling together: National strategy for invasive plant management. http://bluegoose.arw.r9.fws.,gov/FICMNEWFiles/NatlWeedStrategyTOC.html.

Franklin, J. 1995. Predictive vegetation mapping: geographic modeling of biospatial patterns in relation to environmental gradients. Progress in Physical Geography 19:494-519.

Groves, R.H. 1986. Invasion of Mediterranean ecosystems by weeds in Resilience in Mediterranean type ecosystems, ed. B. Dell, A.J.M. Hopekins and B.B. Lamon, pp. 129-145. Dordrecht: Junk.

Hodkinson, D.J. and K. Thompson. 1997. Plant dispersal: the role of man. Journal of Applied Ecology 34:1484-1496.

Huenneke, L.F., S.P. Hamburg, R. Koide, H.A. Mooney and P.M. Vitousek. 1990. Effects of soil resources on plant invasion and community structure in Californian serpentine grassland. Ecology 71(2): 478-491.

Husband, B.C. and S.C.H. Barrett. 1996. A metapopulation perspective in plant population biology. Journal of Ecology 85(6):743-753.

Ignizio, J.P. 1991. Introduction to expert systems: the development and implementation of rule-based expert systems. McGraw-Hill, San Francisco, CA.

Jacono, C.C. and Boydstun, C.D. 1998. Proceedings of the Workshop on Databases for Nonindigenous Plants, Gainesville, Florida, September 24-25, 1997. http://nas.er.usgs.gov/publications/plants/plant_workshop/npwrkshp/.

Kalkhan, M.A., R.M. Reich and T.J. Stohlgren. 1998. Assessing the accuracy of Landsat Thematic Mapper classification using double sampling. International Journal of Remote Sensing 19(11): 2049-2060.

Knick, S.T., J.T. Rotenberry and T.J. Zamiello. 1997. Supervised classification of Landsat Thematic Mapper imagery in a semi-arid rangeland by nonparametric discriminate analysis. Photogrammetric Engineering & Remote Sensing 63:79-86.

Latore, J., P. Gould and A.M. Mortimer. 1998. Spatial dynamics and critical patch size of annual plant populations. Journal of Theoretical Biology: 190 (3):277-285.

Liebetrau, A.M. 1983. Measures of association. Sage University Paper 32, Sage Publ., Newbury Park, CA.

Mack, R.N. 1981. Invasion of *Bromus tectorum* L. into western North America: an ecological chronicle. Agro-Ecosystems 7:145-165.

Mack, R.N. 1986. Alien plant invasion into the Intermountain West: a case history. Pages 191-213, *IN*: Mooney, H.A. and Drake, J.A. (eds), Ecology of biological invasions of North America and Hawaii. Springer-Verlag, New York, NY.

Mack, R.N. 1995. Understanding the processes of weed invasions: the influence of environmental stochasticity. Pp 65-74, *IN*: Stirton, C.H.. (ed.), Weeds in a changing world: Proceedings, British Crop Protection Council (BCPC) Symposium, BCPC Symp. Series no. 64.

Mack, R.N., and J.N. Thompson. 1982. Evolution in steppe with few large, hooved mammals. American Naturalist 119:757-773.

Moody, M.E., and R.N. Mack. 1998. Controlling the spread of plant invasions: the importance of nascent foci. Journal of Applied Ecology 25:1009-1021.

Moore, D.M., B.G. Lees, and S.M. Davey. 1991. A new method for predicting vegetation distributions using decision tree analysis in a geographic information system. Environmental Management 15:59-71.

Nilson, , E.T. and C.H. Muller. 1980. A comparison of the relative naturalization ability of two Schinis species in Southern California. Bulletin of the Torrey Botanical Club 107: 51-56.

NRCS. 1997. National Range and Pasture Handbook. USDA, Natural Resources Conservation Service Grazing Lands Institute, 190-vi-NRPH, September 1997, Washington DC.

NRCS. 1998. National Forestry Manual, 190, September 1998, http://nsscnt.nssc.nrcs.usda.gov/nfm/index.htm.

Panetta, F.D. and N.D. Mitchell. 1991. Homoclime analysis and the prediction of weediness. Weed Research 31:273-284.

Perry, J.N., and J.L. Gonzalez-Andujar. 1993. Dispersal in a metapopulation neighborhood model of an annual plant with a seedbank. Journal of Ecology 81(3)453-463.

Pyke, D.A., P.H. Smith, J.M. Patterson, K.A. Ticknor, J.F. Henson and S.D. Warren. IN PRESS. Selecting Native Plants Using VegSpec - A Web-based Expert System. Pages ?-? *IN*: Haase, D. (ed.) Proc. of native plants: propagation and planting. Oregon State Univ. Corvallis.

Radosevich, S.R., J.S. Holt and C.H.. Ghersa. 1997. Weed Ecology: Implications for Vegetation Management 2nd Edition, John Wiley and Sons, New York. 600 p.

Rejmanek, M. and D.M. Richardson. 1996. What attributes make some plant species more invasive? Ecology: 77(6):1655-1661.

Rice, P. 1999. Invaders Database System. The University of Montana. http://invader.dbs.umt.edu/

Tilman, D. 1997. Community invasibility, recruitment limitation, and grassland biodiversity. Ecology 78(l): 81-92.

ATTACHMENTS

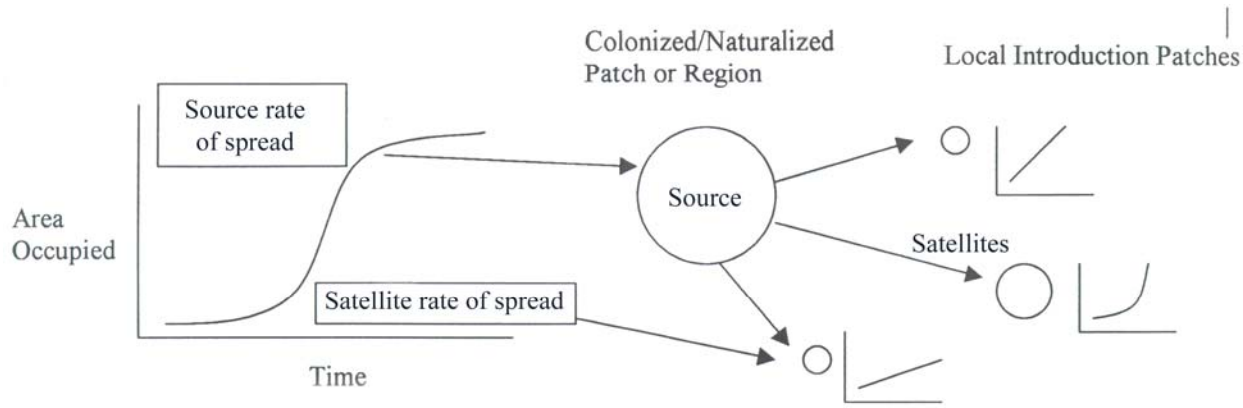

Figure 3: Source and satellite model of invasion spread. Size of circles depicts relative population size, while graphs depict the phase of population growth. The source population is experiencing dampened growth rates but is also the source for satellite populations that will experience linear or exponential growth.

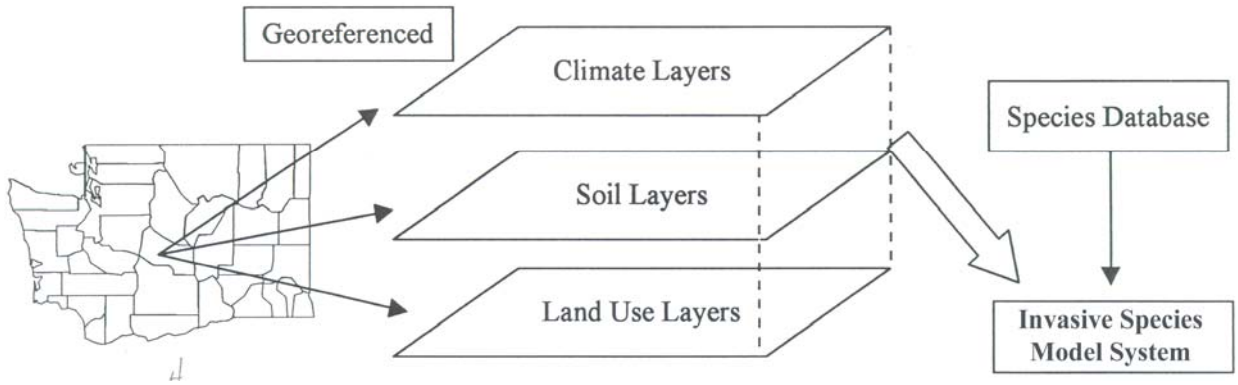

Figure 4: The relationship between georeferenced database layers and the species database for the weed assessment model.