Invasive plant mapping : a standardized system
by Diana Irene Cooksey

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Land Resources and Environmental Sciences
Montana State University

Abstract:
Public and private land managers are becoming acutely aware of the negative impacts of invasive plant species, and efforts to minimize their effects are underway. Management of invasive plants depends on availability of accurate information about location, size and severity of infestations. Data collected by invasive plant surveys can help scientists and land managers to develop, implement, and evaluate integrated invasive plant management plans; assess the economic impacts of plant invasion and alternative management strategies; and increase public awareness. Standardized invasive plant surveying and mapping methods are critical because they provide consistently uniform information that can be compared over time and incorporated into a geographic information system (GIS) for production of regional maps for management planning.

In response to the need for a consistent protocol for surveying and mapping invasive plants, guidelines and standards were developed and a statewide invasive plant GIS was created. Educational materials were distributed and training workshops were presented to invasive plant managers throughout Montana. The system was planned, developed, implemented and evaluated by personnel at Montana State University-Bozeman, in cooperation with private, county, State and Federal land managers, using an outcome-based logic model approach. A method for gathering complete statewide data at a generalized scale to provide immediate information about invasive plant distribution was also developed, and a plan to create a self-sustaining future for the system and statewide database was devised.

This system has been adopted by invasive plant managers in Montana and throughout the U.S. The statewide invasive plant database now has a permanent home with the Bureau of Land Management and leadership is provided by the Montana Department of Agriculture, Stillwater County, and an advisory team of agency, industry, and private representatives. Its data have been used for local and statewide invasive plant management, and for public education. Future efforts should focus on developing Internet-based update and retrieval capabilities, educating users, and increasing participation in the system. Additional uses for standardized invasive plant data could include research on invasion biology and ecology, invasive plant spread, and predicting areas potentially subject to weed invasion; verification of invasive plant maps generated using modeling and remote sensing; and Internet-based multimedia public education.

INVASIVE PLANT MAPPING:

A STANDARDIZED SYSTEM

by

Diana Irene Cooksey

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Land Resources and Environmental Sciences

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 2002

APPROVAL

of a thesis submitted by

Diana Irene Cooksey

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

Dr. Gerald A. Nielsen Gerald A. Nielsen 7-19-02
Date

Approved for the Department of Land Resources and Environmental Sciences

Dr. Jeffrey S. Jacobsen Jeffrey S. Jacobsen 7/19/02
Date

Approved for the College of Graduate Studies

Dr. Bruce R. McLeod Bruce R. McLeod 7-22-02
Date

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the Library shall make it available to borrowers under rules of the Library.

If I have indicated my intention to copyright this thesis by including a copyright notice page, copying is allowable only for scholarly purposes, consistent with "fair use" as prescribed in the U.S. Copyright Law. Requests for permission for extended quotation from or reproduction of this thesis in whole or in parts may be granted only by the copyright holder.

Signature Diana Irene Cooksey

Date 7/19/02

ACKNOWLEDGMENTS

I would like to thank Dr. Gerald Nielsen for being a constant source of inspiration, and for encouraging me to document this work. Thank you to Dr. Roger Sheley for his enthusiasm, creativity, and encouragement, and for providing an understanding of invasive plant management. Thank you to Dr. Jeffrey Jacobsen for his continuous support of this project and for his guidance over the last 15 years.

I appreciate the assistance of Barbra Mullin of the Montana Department of Agriculture, Hank McNeel, Kathie Jewell and Donna Degner of the Bureau of Land Management, and Jim Larson of Stillwater County for helping to make this project successful. Thank you also to Elizabeth Roberts, Shana Wood, and the many student workers who helped to implement the invasive plant mapping system. Thanks to Lee Faulkner for providing survey research expertise.

Finally, I would like to thank Gary and Lucas Clutter for giving me the time and support needed to complete this project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

TERMINOLOGY

Weeds are plants that interfere with the management objectives of a given area of land. *Noxious weeds* are those weeds that society has declared we are legally responsible to manage because of their negative impacts (Sheley et al., 1998). *Invasive plants* is a more descriptive term than *weeds* or *noxious weeds* because it reflects the tendency of certain non-native plant species to reproduce and spread rapidly, often crowding out existing vegetation. Although the term *invasive plants* is preferred, *weeds* and *noxious weeds* are used throughout the text where they are in common usage among managers involved in the activity or product being described. All three terms are intended to be synonymous.

ABSTRACT

Public and private land managers are becoming acutely aware of the negative impacts of invasive plant species, and efforts to minimize their effects are underway. Management of invasive plants depends on availability of accurate information about location, size and severity of infestations. Data collected by invasive plant surveys can help scientists and land managers to develop, implement, and evaluate integrated invasive plant management plans; assess the economic impacts of plant invasion and alternative management strategies; and increase public awareness. Standardized invasive plant surveying and mapping methods are critical because they provide consistently uniform information that can be compared over time and incorporated into a geographic information system (GIS) for production of regional maps for management planning.

In response to the need for a consistent protocol for surveying and mapping invasive plants, guidelines and standards were developed and a statewide invasive plant GIS was created. Educational materials were distributed and training workshops were presented to invasive plant managers throughout Montana. The system was planned, developed, implemented and evaluated by personnel at Montana State University-Bozeman, in cooperation with private, county, State and Federal land managers, using an outcome-based logic model approach. A method for gathering complete statewide data at a generalized scale to provide immediate information about invasive plant distribution was also developed, and a plan to create a self-sustaining future for the system and statewide database was devised.

This system has been adopted by invasive plant managers in Montana and throughout the U.S. The statewide invasive plant database now has a permanent home with the Bureau of Land Management and leadership is provided by the Montana Department of Agriculture, Stillwater County, and an advisory team of agency, industry, and private representatives. Its data have been used for local and statewide invasive plant management, and for public education. Future efforts should focus on developing Internet-based update and retrieval capabilities, educating users, and increasing participation in the system. Additional uses for standardized invasive plant data could include research on invasion biology and ecology, invasive plant spread, and predicting areas potentially subject to weed invasion; verification of invasive plant maps generated using modeling and remote sensing; and Internet-based multimedia public education.

CHAPTER 1

INTRODUCTION

Public and private land managers are becoming acutely aware of the negative impacts of invasive plant species. Invasive species have dramatic effects on the structure and function of ecosystems making them a major threat to earth's biodiversity (Binggeli, 1996; Simberloff, 2001). Invasive plants can reduce forage (Hein and Miller, 1992), increase soil erosion (Lacey et al., 1989), alter soil chemistry and nutrient cycling (Pokorny, 2002), reduce habitat for native and endangered species (Lesica and Shelly, 1996), create fire hazards (Whisenant, 1990), and interfere with recreational activities (Westbrooks, 1998). Invasive plants infest 100 million acres (40 million hectares) in the U.S., spread at about 14 percent per year, remove 4,600 acres (1,840 hectares) of wildlife habitat per day on public lands, and cause losses to crop and rangeland productivity exceeding $7 billion annually (Babbitt, 1998). Pimental et al. (2000) estimate annual economic costs associated with invasive plant species to exceed $34 billion in the U.S. alone.

The challenge now before the public is to prevent further damage to natural and managed ecosystems caused by invasive species (Pimentel et al., 2000) to all lands, public or private. Federal efforts to minimize these effects of invasive species are underway. On February 3, 1999, a Presidential Executive Order creating a new federal interagency Invasive Species Council charged with producing a broad management plan for biological invaders was signed (Clinton, 1999). The Federal Interagency Committee

for the Management of Noxious and Exotic Weeds has developed a strategy for management of invasive plant species (FICMNEW, 2000a; FICMNEW, 2000b). From a land management perspective, prevention and early detection followed by eradication are the most practical methods for managing new introductions, whereas containment, control and restoration are appropriate strategies for managing large-scale invasive plant infestations (Sheley et al., 1999). Early detection and immediate control depend upon the availability of information that keeps pace with new invasion threats (Ricciardi et al., 2000). Standardized invasive plant mapping and monitoring programs can provide critical information needed to meet future challenges and evaluate progress of invasive plant programs.

Data collected by invasive plant surveys can help scientists and land managers to develop, implement, and evaluate integrated management plans; assess the economic impacts of plant invasion and alternative management strategies; and increase public awareness, education, and management efforts. Invasive plant management plans are important working documents used by land managers to guide invasive plant control and land rehabilitation. Management plans should be reviewed and updated annually (Goodall and Naude, 1998; Sheley et al., 1999). A critical component of these plans is an accurate and complete invasive plant inventory of the management area (Sheley et al., 1999). Mapping can be used to target control efforts, document activities, monitor change over time, and evaluate the plan's success. Accurate maps that are updated regularly can provide reliable area (acres, hectares) estimates, from which economic costs associated with nonindigenous plant invasions can be calculated. Documenting economic and

environmental impacts of plant invasions is important for obtaining funding for management programs. In addition, documentation of these costs can help increase public awareness of the magnitude and complexity of plant infestations. Even though the negative impacts of invasive plant species are well-known among scientists and land managers, the general public remains largely unaware of the problems associated with biological invasions by plants, partly because they have not been told about their distribution and impacts. Without public support, local invasive species control efforts can be hindered because of complacence or even opposition (Colton and Alpert, 1998). Maps showing areas infested by invasive plants can be used to educate the public by illustrating the extent and severity of the problem.

Standardized weed surveying and mapping methods are important because they provide consistently uniform information that can be compared over time to document progress in management. Our previous experience with attempting to compile invasive plant maps revealed a serious lack of consistency in the way invasive plant managers were collecting and reporting data. Some mappers carefully outlined the boundaries of infestations on paper maps, while others simply marked entire sections or townships as being infested. Others reported points representing the centers of infestations rather than outlining the infested area. Some mappers collected percent cover as an attribute to denote severity, and others collected density. Several different scales and types of base maps were being used, resulting in vastly different levels of detail. These inconsistencies make it nearly impossible to combine data from site to site and year to year, and to

compare changes. There is clearly a need for a standardized system for invasive plant mapping and monitoring to produce reliable data.

A standardized system would allow invasive plant survey data to be incorporated into a geographic information system (GIS) for production of regional maps showing the distribution and severity of infestations. This type of database would provide consistent and accurate information for local, statewide and regional invasive plant management plans.

In response to this need for a consistent protocol for surveying and mapping invasive plants, representatives from federal, state and county agencies, as well as industry and private individuals, developed guidelines and standards for a statewide invasive plant survey and mapping system for Montana. The system was implemented by personnel at Montana State University-Bozeman, in cooperation with private, county, state and federal land managers. In Chapter 2 we describe the processes we used to develop the standardized system. Our approach to creating a self-sustaining future for the mapping system and statewide database is discussed also. Chapter 3 describes the invasive plant mapping system in detail, including guidelines and standards for data collection, and the structure of the statewide spatial database for invasive plant management. Chapter 3 also includes a method for gathering complete statewide data at a generalized (public land survey section) scale to provide immediate information about invasive plant distribution.

CHAPTER 2

DEVELOPMENT, IMPLEMENTATION AND EVALUATION PROCESSES

Introduction

Accurate inventories of invasive plant infestations are essential for their effective management. Standardized methods are necessary to collect consistently uniform infestation data that can be compiled into a region-wide database for mapping and analysis. Analytical information provided by the database can be used for developing management plans, assessing the economic costs of plant invasion, and increasing public awareness of the negative impacts of invasive plants. In addition, assessing the effectiveness of management requires repeated collection of accurate data, and is rarely done. In Montana and throughout the western U.S., previous attempts to implement invasive plant mapping standards were unsuccessful. In response to the need for a consistent protocol for mapping invasive plants, a standardized system was developed using a process that increased the likelihood of adoption. The objective of this chapter is to discuss the process of developing a standardized system for invasive plant survey and mapping that 1) ensures its successful implementation and 2) creates a self-sustaining future for the program. The system itself is described in Chapter 3.

Critical factors for successful project management have been identified by researchers and project managers. Several of these factors were used in developing the invasive plant mapping system.

First, we knew it was important to have a clear vision of what we wanted to accomplish, and a clear strategy for achieving defined project outcomes. A systematic process for developing the program would help to define our strategy.

We also felt that a project coordinator was required to provide leadership, develop education and training materials, and communicate with our target audience--invasive plant managers throughout Montana. In order to generate support and ownership among the groups who would eventually use the system, and to benefit from their expertise, we arranged a "working group" meeting to develop a set of mapping standards that would work for everyone. The group also determined the basic format of a comprehensive statewide database. We invited representatives from all county, state and federal agencies, as well as industry and private groups, involved in invasive plant management. Individuals were chosen based on their knowledge, experience and interest in invasive plant issues.

The first meeting was held in May of 1995. Participants were asked to bring ideas and samples of mapping and monitoring systems they felt were worth considering. The meeting was led by a facilitator whose job was to manage the discussion, listen to concerns of all people involved, and build support so everyone had an active role in developing the standards. Each agency provided a description of their current mapping efforts. Issues of data collection methods, data format and scale were discussed. Decisions about standardized base maps, attribute data to be collected, and methods for collecting data were made by consensus. The group decided to adopt a set of standards

that had previously been developed for the Greater Yellowstone Area (Free et al., 1991) with a few modifications.

Once the standards were implemented, we developed educational materials including publications, workshops, a web site and downloadable files to help with data collection and processing. Efforts to market the program included informing our target audience about products and services available, where they could be accessed, and how the program could benefit users. We used language familiar to county weed coordinators, including the term *noxious weeds* rather than *invasive plants*, to avoid the "ivory tower" perception that is sometimes associated with university programs. We also made it clear that the system was developed and implemented in cooperation with private, county, state and federal land managers, not by the university acting alone.

Throughout the development and implementation process, we attempted to remain flexible, responding to challenges such as lack of participation, private landowner resistance, and technology barriers. We viewed development and implementation of the invasive plant mapping system as an interactive process, constantly changing and shaping the program. We saw "stumbling blocks" as opportunities for continual formative evaluation, and attempted to be flexible in responding to problems, while remaining true to the agreed on outcomes. We tried to look ahead, anticipating user needs for specific products. For example, users needed more detail about mapping procedures and GIS data format, so we developed a weed mapping handbook (Roberts et al., 1999). It includes step-by-step procedures for mapping according to the standards. Reflection was also important: looking back, getting feedback from users, and finding ways to improve.

Various models have been developed for planning, managing and evaluating programs. For the invasive plant mapping system, a logic model approach provided an outcome-based framework to guide development and implementation of the program, as well as an avenue for its evaluation. Logic models are graphical depictions of program elements and their relationships with one another, that portray the path toward desired outcomes (Millar et al., 2001). They model or simulate real-life in such a way that the fundamental logic underlying program activities and outcomes is apparent. The logic model tool helps to identify processes and activities that determine program successes, failures, and effectiveness (McLaughlin and Jordan, 1999).

Methods

We designed a logic model (Figure 1), to guide our efforts in creating a successful mapping system that would increase the effectiveness of local and statewide invasive plant management. The model was developed by first identifying project outcomes, and then working back to determine what we needed to do to achieve those outcomes. Logic model elements will be discussed starting from the leftmost column of Figure 1.

Situation

The negative environmental impacts of invasive plant species are well known, and invasion by non-native species has become a priority issue for resource management (Babbitt, 1998; Clinton, 1999; DiTomaso, 2000; FICMNEW, 2000b; Pimentel et al., 2000). For land managers to develop effective invasive plant management plans, accurate

Figure 1. LOGIC MODEL: Montana Noxious Weed Survey and Mapping System development and implementation.

SITUATION: Lack of accurate and complete information on weed distributions to guide management ↑ Need for standardized system for mapping weeds

INPUTS	OUTPUTS		OUTCOMES-IMPACT		
	Activities	**Participation**	**Short**	**Medium**	**Long-term**
MSU, BLM & MDA Staff Partners in development: County weed coordinators Federal and state agency people Time Money (NWTF, MSU-MAES, BLM) Materials (base maps, colored pencils) Equipment / technology (computers, GPS receivers, GIS)	Meetings Advisory team Standards Statewide database Information delivery - Mailings - News releases - Web site Educational materials - Publications - WWW site Training workshops Technical support	Target audience: County weed coordinators Federal and state agency land managers County weed board members Concerned citizens	**Learning** Weed managers become aware of the system, its resources, and its importance Weed managers learn how to map using the standards	**Action** Weed managers use standards to map weeds (Better records for next coordinator) Weed managers submit data to statewide database Increased cooperation among weed managers statewide	**Conditions** Improved local weed management Improved statewide weed management Reduced weed populations, improved environment

ASSUMPTIONS

1. Communications reach intended audience
2. Managers can be trained
3. Once trained, managers will use the system to map weeds and will submit their data to the statewide database
4. Once trained, managers will teach others

ENVIRONMENT

Politics, Noxious Weed Education and Awareness Program, lack of adequate funding, demands on program staff and weed coordinator time, weed coordinator perceptions about mapping (important, costly, time-consuming, easy, too difficult, etc.), capable and dependable people to sustain the system into the future

and complete information on their distribution is necessary. Land managers spend millions of dollars mapping invasive plants, but often the methods being used lack repeatability. A compilation of data from invasive plant managers in 1987 and 1991 produced statewide maps of spotted knapweed (*Centaurea maculosa*) distribution in Montana (Figure 2). Calculations from the maps showed that between 1987 and 1991, the statewide spotted knapweed infestation decreased from 3.5 million acres (1.4 million hectares) to 1.5 million acres (0.6 million hectares). Unfortunately, we know this is not true. Inconsistencies in data collection and reporting produced erroneous results. Differences in the way infestation locations were recorded, types of attribute data collected, and scale of base maps used made it difficult, if not impossible, to compare data over space and time. Tracking changes over time is important for determining the effectiveness of management activities. The data did not include severity of infestations, important information for management planning. Also, there was no way to assess the accuracy of data collected.

Standardized surveying and mapping methods provide consistently uniform information that can be compared over time and compiled into a comprehensive statewide database for use in management planning and evaluation. A set of mapping standards had previously been developed for the Greater Yellowstone Area (Free et al., 1991), but were not widely adopted in the region. A uniform set of standards used by land managers statewide should yield higher quality information, resulting in better local and statewide invasive plant management. Improved management should lead to reduced invasive plant populations and a better environment.