Monitoring Invasive Plants Using Hand-held GIS Technology

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ABSTRACT

Successful control of invasive species requires a clear picture of the spatial extent of infestations. The latest mapping technology involves coupling global position systems and handheld computers running geographic information systems software in the field. A series of workshops applying this technology to mapping weeds was developed and presented to Weed Management Areas across Arizona. Workshops were designed to be robust, flexible, and inexpensive. Participants were strategically selected to enhance material retention and to foster networking outside of formal instruction. Workshop success was due, in large part, to the continued commitment of the participants, especially members of the Tonto Weed Management Area.

INTRODUCTION

Invasions of invasive species can have drastic consequences for ecosystem functional (Vitousek, and Walker 1989, Le Maitre et al. 1996) and structural attributes, including decreased biodiversity of native plants and animals (Wilcove et al. 1998), altered fire regimes (Mack and D'Antonio 1998), and in some cases, extinctions of native species (Pimm et al. 1995). Invasion by exotic species is a major threat to global biodiversity, second only to habitat loss. It has been estimated that invasive plant species cost the United States $34.7 billion annually in economic damages and control costs (Pimentel et al. 1999). This figure does not account for environmental and health costs, which could force the number to be much greater.

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Weed Management Areas are local organizations that bring together landowners and managers (private, city, county, State, and Federal) in a geographical area to coordinate efforts and expertise against common invasive weed species. "The purpose of...a WMA is to facilitate cooperation among all land managers and owners to manage a common weed problem in a common area....WMAs have similar characteristics such as geography, weed problems, climate, common interest, or funding support" (USDA and USDI 2000). The individuals comprising WMAs are often dedicated, hard-working individuals, volunteering their free time in an effort to eradicate a particular noxious plant.

Weed Management Areas typically have strictly limited budgets and time. As such, control efforts must be carefully planned to maximize efficacy and efficiency. Weed control efforts have been likened to fighting wildfire – a clear understanding of the size, rate of spread, and direction of spread of a fire or a weed invasion is necessary to enhance efforts (Dewey 1995). A clear picture of the extent, spread, level of infestation, and other ancillary information can inform management decisions and assist in planning.

One method for increasing weed management efficiency is the implementation of monitoring using digital mapping systems. The tradeoffs for the investment in equipment purchase and education are many. Mapping weeds digitally rather than on paper by hand is much faster and more accurate, eliminates the transfer of data from various paper sheets, enhances sharing of information between agencies, allows for easy updates, and can help users to set management priorities. In addition, digital mapping facilitates information sharing and the transfer of locally relevant files to regional databases such as

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the U.S. Geological Survey's Southwest Exotics Mapping Program (SWEMP, USGS 2004).

Currently in Arizona, ten active WMAs exist, targeting over thirty noxious plant species (Sonoran Institute and The Nature Conservancy 2001). Because WMA members often come from a wide variety of backgrounds, they commonly do not have expertise or even experience with geospatial tools. To address this need, a program entitled, "GIS/GPS for Weeds Mapping" was developed through a University of Arizona/NASA Space Grant Graduate Fellowship. This program, which introduces geospatial technologies to individuals with little or no prior experience, has been developed around the need for weeds monitoring and mapping.

THEORETICAL APPROACH

Our objective of facilitating invasive species management through geospatial technology presented three primary challenges. The most apparent was finding a technological solution to the challenge faced by those currently collecting data on the location and characteristics of invasive species infestations. Next, it was clear that "a good idea" alone was insufficient to encourage the adoption of the technological solutions. And finally, the majority of the potential users were previously unexposed to geospatial technology, and in many cases apprehensive of the perceived steep learning curve it might represent. Social scientists, marketing researchers, and non-formal education practitioners have studied these latter two challenges extensively. We have addressed each from a theoretical framework appropriate to the problem at hand: managing invasive species through the support of volunteers working under the organizational structure of Weed Management Areas.

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Technology Adoption and the Diffusion of Innovation

Futurist John Naisbitt (1982, 1999) demonstrated powerful insight when he suggested, "whenever new technology is introduced into society, there must be a counterbalancing human response—that is, high touch—or the technology is lost. The more high tech, the more high touch." In our approach, we apply translational science (Birmingham 2002) and technology transfer (Lionberger and Gwin 1991), facilitating interaction between technology sponsors (workshop leaders) and users resulting in actual innovation and the adoption of a new product or procedure.

Translational research and technology transfer are personal acts, requiring advocates with keen observational power and insight. Critical to this process are intermediaries between the source of information and the ultimate user, encouraging and supporting the adoption of new technology or innovations to and from his or her clients. Diffusion, or the spread of an idea, method, practice, or product throughout a social system (Rogers 2003), occurs gradually as some users wait to see how it has worked for others before they are willing to adopt a new method. Early adopters, our initial target in this approach, tend to be respected and visible in their community; they provide practical evidence that an innovation actually works, which is important to later adopters. When we reach and equip intermediaries, a much broader audience can be reached by creating an underlying network. By bringing handheld computers and GPS units to groups composed of both early adopters and those less likely to outright use the technology, we applied this theory in the field.

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Technology for Education vs. Educational Technology

The theoretical basis for our educational approach is based on "idea" technologies that de-emphasize hardware and emphasize Earth science ideas, particularly those surrounding invasive species, through a geospatial perspective. The traditional focus on technology for education begins with familiarization and utilization, but generally stops at integration of the technology into application. An alternative approach we have implemented pursues a contemporary perspective of educational technology that focuses on a learner's active construction of the knowledge. This approach allows for evolution of both the student and the learning materials with technological change (Hooper and Rieber 1995). Technology alone will not ensure learning, but it can improve learning if students are engaged and challenged by the task. In this way our workshop participants learn about GPS and GIS through their desire to address a specific need – the management of invasive species.

METHODS

Institutional Infrastructure: Weed Management Areas

The approach we have taken with the "GIS/GPS for Weeds Mapping" program has been to apply technology to an identified need through an existing infrastructure, Weed Management Areas, and an established natural resource education framework, Cooperative Extension. In Arizona it is common for Extension agents responsible for natural resource educational programming to be members of local WMAs. By working with established WMAs, we introduced technology into an existing infrastructure and support group. The link to Extension helped ensure that the educational support necessary

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for the adoption of this technology could be obtained immediately, and that it could be adjusted in the future to address evolving needs.

Field Mapping System

The field system selected for these workshops consisted of a Garmin V WAAS-enabled GPS unit and a Compaq iPAQ 3950 pocket PC running the StarPal HGIS Plus GIS software package. This combination was selected from the wide variety of possibilities due to its relative ease of use for inexperienced users, its low cost (approximately $1,200 in 2003), and field practicality. Of all packages investigated, the iPAQs were the easiest to see outdoors in bright sunlight. Additionally, after attachment to a clipboard, the system can easily be carried and manipulated in the field. However, workshop success was not dependent on the hardware selected. Because this program was developed with flexibility in mind, the content could easily be adapted to work with other comparable packages.

Workshop Design

An introductory workshop, covering basics of global positioning systems (GPS) technology, geographic information systems (GIS) technology, mapping standards, and field data collection, was developed and performed for several groups across Arizona. These initial workshops involved participants from a variety of local, state, and federal agencies, non-profit groups, volunteers, and academia.

Workshops were tailored to meet participants' needs and skill levels. Workshops were designed to meet individual WMA's needs, employing a mix of lecture and hands-on fieldwork. To accommodate different skill levels and learning styles, modules were adapted during the workshops. By including additional instructors and encouraging the

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participation of local experts, we were able to assists individuals past their intimidation or fear of technology. Field exercises, instructional materials and fact sheets were developed in support of the workshops (Mau-Crimmins and Orr 2003; Mau-Crimmins et al. 2003). At the conclusion of each workshop, we met with the participants and asked which program elements were appropriate and which needed modification. In addition, we had all participants fill out evaluation questionnaires providing comments and suggestions. Finally, as new workshops were scheduled, we looked to the participants to dictate what they felt was needed, both in terms of content and support. In this way we adapted our training materials and emphasis as we learned more about the needs of WMA volunteers – our target audience.

Localized "Learning Networks"

Successful implementation of geospatial technology is largely dependent on cooperation between data users, technical experts, and developers. The greater the number of individuals sharing data or technical support across institutional lines, the more likely adoption will occur and the more likely geospatial technology will be viewed as having a positive impact (ARSC 2001). Localized, informal "learning communities" have been particularly important among rural users, where physical distances can impose barriers that are difficult for formal education programs to overcome (Seelan et al. 2003). Recognizing the importance of these localized learning networks, we have made special efforts to help Extension agents and members of WMAs involve as much local expertise as possible in our workshops. In all workshops we have encouraged the WMAs to invite any local GPS or GIS experts with an interest in invasive species management, thereby helping establish the contacts necessary for local data sharing and technical support.

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Advanced Workshops

One component of the workshops that seemed to foster success of the program was our willingness to invest in addressing operational challenges that could have been barriers. By working with participants outside of the structured workshops, we demonstrated our commitment to the group, strengthening the feeling of a support network. To better understand both the utility of this technological solution to invasive species mapping as well as potential barriers to adoption, we decided to work more closely with the WMA that showed the strongest desire to implement the technolology. The Tonto Weed Management Area, based out of Young, Arizona, demonstrated strong commitment to the technology despite very little funding, a poor Internet connection, and a dependence on volunteerism to accomplish the mapping. We established a working relationship with the Tonto WMA and performed several successive workshops covering more detailed hands-on work with the GPS and iPAQ units, downloading collected data into GIS software on desktop PCs, analysis and manipulation of data within a GIS environment, and aerial photo acquisition from the internet.

Our continued investment in the Tonto WMA resulted in diffusion of the technology well beyond our area of influence. We were showered with requests for workshops beyond our initial area of interest; in addition, spontaneous application of the technology to other uses including mapping of water wells and shooting range siting occurred. By fostering connectivity among workshop participants, we observed their desire for the technology expand beyond mere curiosity into management in real applications.

RESULTS

The demand for geospatial data capture system among Weed Management Areas in Arizona has proven quite high. Though we have not advertised the program, we have conducted 11 invasive species mapping workshops involving 312 participants since Fall 2002. The requests for follow-up trainings and introductory trainings from groups in Nevada, Colorado and New Mexico have exceeded the capacity of the program in its current form. Organized programs outside the invasive species realm have also taken interest, including the Cooperative Extension's Master Watershed Steward Program and the Navajo Watershed Research Project. Most recently, a team of 4-H and Youth Development Extension professionals began exploring ways to integrate this technology into their programming.

In addition to the very evident demand for a digital, geospatial alternative to current data capture methods employed by WMA, we have observed three fundamental impacts. First, where local support networks can be fostered, this technological solution can address more than the capture of data. A number of the WMAs expressed the desire to integrate this technology into regular mapping activities with the goal of building a spatial database that can be both used locally and shared with the regional data integration centers such as SWEMP. Second, efforts by groups like SWEMP together with WMAs to streamline the process between data logging, sharing, and ultimately returning derived products from the regional database to the WMAs would benefit from adding the spatial dimension to data logging efforts. Finally, groups addressing other natural resource needs (e.g. watershed, wildfire) either already use or are considering using this kind of field data capture methods. Clearly there is a need for both training and post-training support through local networks.

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FUTURE DIRECTIONS

Our workshops were timely for the Tonto WMA, providing the means they sought for more effective weed management. Outside of our work with them, members of the Tonto WMA obtained grant funds and purchased three Garmin/iPAQ/HGIS combinations. Their level of commitment prompted the continued development of geospatial support. Currently, we are exploring ways to provide WMAs with aerial photographs of their study area in the appropriate format and size for the iPAQs to handle. In addition, project-specific GIS datasets are being assembled for the WMAs, keeping in mind that desktop GIS packages and the iPAQs demand different datasets. Finally, workshop participants are being encouraged to use a web-based bulletin board to ask questions and share findings. Continued information sharing among users with greatly enhances the experience of all involved.

We are working with the Tonto WMA and other weed mapping groups to encourage adoption of common data standards and attributes collected. The Tonto WMA is currently collecting attributes common with Tonto National Forest to facilitate data sharing. We are encouraging the Tonto WMA and other groups to aim to share data with regional databases such as the Southwest Exotic Plant Mapping Project (SWEMP).

The great success of this program suggests that groups with little or no experience can adopt geospatial technology when it is applied to a specific problem. The benefits of this program are that the elements were robust, flexible, and inexpensive, allowing it to be applied to a wide variety of groups and adapted easily. Our program met with success because the participants were ready for the technology and we maintained a core group of committed individuals throughout the consecutive workshops. We are excited by the

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program's success to-date and look forward to expanding the application of geospatial tools to weed mapping into the future.

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