

Direct Application of Invasive Species Prioritization: The Spatial Invasive Infestation and Priority Analysis Model

Deborah Stone and Michael Andreu


ABSTRACT

Effective and efficient prioritization of invasive species treatments is an important aspect of land management and ecological restoration, as the number and distribution of invasive species increase and budgets decrease. Land managers have a multitude of prioritization frameworks from which to choose, but the vast majority only consider entire species across a landscape rather than individual populations. Here, we discuss the Spatial Invasive Infestation and Priority Analysis (SIIPA) model (built in ESRI ArcGIS software), a customizable tool for rapid application of a prioritization framework to known invasive populations within a preserve, management area, or region. The SIIPA model is based on the framework provided in The Nature Conservancy's Draft Weed Management Plan and prioritizes invasive species based on four characteristics common to many other schema: 1) current extent of the species; 2) current and potential impacts of the species; 3) value of habitats the species infests; and 4) difficulty of control and establishing replacement species. We describe how the model can be customized to have different classes for each characteristic, different weights for each class, and include other characteristics. To demonstrate how the model performs at different scales and for different land management objectives, we consider the application of this model in three different case studies: the Nature Conservancy's Disney Wilderness Preserve in Kissimmee, Florida; the U.S. Forest Service's Apalachicola National Forest near Tallahassee, Florida; and the Heartland Cooperative Invasive Species Management Area in central Florida. The SIIPA model provides land managers with an adaptable, easy-to-utilize decision support tool for making critical prioritization choices.

Keywords: adaptive management, Florida, GIS, invasive plants, land management, SIIPA

Restoration Recap

- Invasive species often impede the success of restoration projects, both during implementation and long-term maintenance. There are often more populations to control than managers have the time or money to treat.
- The Spatial Invasives Infestation and Priority Analysis (SIIPA) is a GIS-based tool that can assist managers in prioritizing treatment of their invasive species populations using a customizable framework to suit their particular land management goals.
- We applied the SIIPA model at three different scales for different agencies to demonstrate how it works in different situations. Characteristics used in these scenarios to prioritize invasive species include: Impacts, Extent, Habitat Quality, Available Control Methods, Proximity to Roads, and Proximity to Protected Species.
- The SIIPA model can be downloaded from The Nature Conservancy's Conservation Gateway at: www.conservationgateway.org/ConservationByGeography/NorthAmerica/iln/Pages/siipa-model.aspx.
- We recommend that managers involve core stakeholders in the planning process and document their prioritization framework.

 *Supplementary materials are freely available online at:*
<http://uwpress.wisc.edu/journals/journals/er-supplementary.html>

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Invasive species control is one of the fundamental activities of natural lands management and is often a major precursor to ecological restoration. Restoration of degraded systems often requires the removal of invasive species, and even intact systems may need preventative management to slow or stop the establishment of noxious weeds and to maintain natural resilience (D'Antonio and Chambers

2006). Invasive species can potentially alter intact native habitats and their processes at both the ecosystem and population levels (Gordon 1998, D'Antonio and Chambers 2006). They can complicate restoration efforts by helping create resilient alternative states with positive feedbacks that require more intensive and expensive restoration techniques for a project to obtain success (Suding et al. 2004). Systems can sometimes be so degraded by long term invasions or structural changes that the removal of one invasive species may have negative or unintended consequences, such as the subsequent invasion of another invasive species or the inability of native species to re-establish (Zavaleta et al. 2001, D'Antonio and Meyerson 2002). While they frequently impede restoration projects, invasive species can sometimes be used in the restoration process, as in the planting of non-native *Acacia* species in southeast Asia to help restore forested systems that have been degraded by the invasive grass, *Imperata cylindrica* (cogon grass; D'Antonio and Meyerson 2002).

Invasive species are hypothesized to be the second greatest threat to endangered species after habitat loss (Brooks and Esque 2002). They can negatively impact ecosystem services and processes including, but not limited to, prescribed fire, soil nutrient cycling, and biodiversity (Vitousek et al. 1996, Wilcove et al. 1998, Tilman 1999, Mack et al. 2000, Davis 2003, Ehrenfeld 2003, Brooks et al. 2004, Hejda et al. 2009). In addition, they can have major economic impacts, including the introduction of agricultural pests or negative effects on human health (Mack et al. 2000, Millennium Ecosystem Assessment 2005). A 1999 study estimated the total impact of invasive plant, animal, and microbe species in the United States to be 123 billion dollars per year (Pimentel et al. 2002).

Given these negative impacts, there is a general consensus among land managers that actions need to be taken at some point in the invasion curve (Harvey and Mazzotti 2014). While prevention and Early Detection, Rapid Response (EDRR) are much cheaper, detection and eradication at the early stages of invasions is difficult, thus land managers are often left trying to mitigate the damage from already established invaders (Sand et al. 1990, Mack and Lonsdale 2002, Rejmánek and Pitcairn 2002, Hester et al. 2004). Due to the high cost of direct treatment, it is imperative that managers effectively prioritize where treatments occur to maximize treatment effects while minimizing costs.

Many different prioritization systems have been created, such as the Alien Plant Ranking System or the California Invasive Plant Council (CAL-IPC) framework (CAL-IPC 2003, USGS 2016). However, the vast majority of systems only provide broad scope in planning, often considering invasive species as a whole across a landscape, when most land managers are primarily concerned with only a handful of properties. These systems are useful when thinking in general terms, but do not help in detailed planning

or on the ground decisions for invasive species control actions. Many of these assessments require a substantial time investment or thorough data analysis to produce a list of species based on the priority for control efforts and potential damage in the region of concern, but they may not consider all of the factors involved in each situation. These lists can assist a manager in making a first draft of a control plan, but often the resources are not available to control every known population of even the "short list" of priority species. At this point many managers are still faced with decisions such as focusing on a particular species or area to determine which invasive species populations will be treated during that time frame. None of these systems provide a spatial component, a framework that is easy to implement or adapt, or a way to distinguish between different populations of the same species.

The need for spatially explicit, locally focused prioritization has been addressed to some degree in recent years (Yager and Smith 2009, Darin et al. 2011, Hohman et al. 2013). These systems employ a range of techniques, from a straight forward framework in ArcGIS software that considers one species and one treatment strategy at a time, to an analytical hierarchy process involving several software applications with some characteristics prioritized in ArcGIS software. These prioritization systems provide a spatial component that considers individual populations rather than the species as a whole, but are not necessarily easy to use or adapt for different situations. Given that "a single set of assessment criteria is unlikely to satisfy all of the listing objectives relevant to different organizations" (Fox and Gordon 2009), many land managers could benefit from an adaptable tool to assist them in rapidly applying their individual prioritization framework to all the known invasive species populations that they must manage. While one of these tools is available for online use and several of the other authors often mentioned making the systems available to others for use, to the best of our knowledge, they are not currently available for download on the internet and subsequent customization for land managers.

The objective of this study was to create an easy to use and easy to customize tool for land managers, the Spatial Invasive Infestation and Priority Analysis (SIIPA) model. Many of the characteristics and how they are weighted are parameters that can be adjusted when the model is run as a tool, allowing managers to easily change the weight of different characteristics to see how that affects prioritization outcomes. Land managers, or others applying this model, have full capability to determine the inputs and prioritizations so that the model will meet their individual needs. Other characteristics, such as proximity to threatened and endangered species, can easily be added to the model as well, so that different prioritization frameworks can be applied to suit the needs of different agencies or landowners. Some of the inputs can also incorporate the results of other invasive assessments, data from the literature,

or expert opinion to provide the level of documentation needed for different scenarios. Here we describe this prioritization system, then examine its application and illustrate its potential use at three different sites and scales.

Description of the SIIPA Model

The Spatial Invasive Infestation and Priority Analysis model is a GIS based prioritization tool that ranks invasive species populations on the four characteristics outlined in The Nature Conservancy's Draft Weed Management Plan (2001): 1) current extent; 2) current and potential impacts; 3) value of habitats the species infest or could infest; and 4) difficulty of control and establishing native replacement species (Table 1). These four characteristics are also commonly used in many other prioritization frameworks. In Fox and Gordon's (2009) review of 17 different invasive species prioritization systems, the extent of the species was considered in nine (52.9%) of the frameworks, ecological impacts were considered by 17 (100%), the communities invaded by six (35.3%), and difficulty of control and economic impacts by 11 (64.7%). Each characteristic is ranked according to a set of guidelines in the plan. This framework was designed so that a high priority species or population obtains the lowest weights, or the higher the weight, the lower it appears on the priority list. Each species is given a weight for each characteristic (i.e., for current extent: 1 = species not yet in the area; 2 = species that are just beginning to establish; 3 = species that are well established and continuing to spread). Then the four weights are summed to provide a total score; those species with the lowest total scores are the greatest priority for removal.

We built the SIIPA model using ArcGIS software, originally in version 9.3, but finished the applications in version 10.3 (ArcGIS, v. 9.3 and v. 10.3, ESRI, Redlands, CA). It contains two tools: Infestation Analysis and Priority Analysis. The Infestation Analysis tool was designed to show the most infested areas of a preserve and to compare

management success over multiple years. It uses only the current extent and impacts of the species characteristics and the required data includes a shapefile of known invasive population locations, and a species table that contains a list of all known species and a field for ranking the impact for each species. The Priority Analysis tool was designed to assist in planning annual invasive species management activities. It incorporates the previous characteristics but also considers habitat quality and available control methods; the required data for this tool includes the invasive species shapefile, the species table (which also includes additional data on control methods), a habitat quality shapefile, and an optional survey history shapefile, if available (Table 2).

The SIIPA GIS model Priority Analysis tool (Figure 1, page 259) uses eight general steps to obtain a prioritized list of invasive species populations. The first is simply a sequence of adding the necessary fields to the shapefile for giving a weight to each characteristic as well as final score for the population, and then it joins the invasive population shapefile to the invasive species table that contains the prioritization data on species impacts and available control methods. Step two scores each population on species impacts using the Select by Attribute tool to choose the populations that belong in the most important species impacts class and then applies the Calculate Field tool to give those populations the weight selected for that class. This sequence is repeated for the next impacts class until all the classes have been given the appropriate weight. The third step in the model follows this same process, using the Select by Attribute tool followed by the Calculate Field tool for each class, to give each population a weight for the control methods characteristic. Next, it calculates the infested acreage and uses the same tool sequence to score each population based on extent. The fifth step compares the invasive shapefile to a habitat quality shapefile and uses a similar process, this time using the Select by Location tool rather than the Select by Attribute tool, to give

Table 1. Characteristics used in the different applications of the SIIPA Model. The SIIPA model can be adapted to use diverse characteristics based on the prioritization goals for different land management scenarios as long as either tabular or spatial data is available. For example, Apalachicola National Forest has a management objective of protecting rare species, and so this characteristic was included in addition to those used in the original framework. The Heartland CISMA members were concerned with land uses such as various recreational activities or agriculture introducing or spreading new exotic species and so we included the number of potential vectors in that model.

Characteristic	Site			
	TNC Draft Weed Management Plan	Disney Wilderness Preserve	Apalachicola National Forest	Heartland CISMA
Impacts of Species	X	X	X	X
Extent/Number of Populations of each Species	X	X	X	X
Available Control Methods	X	X	X	X
Habitat/Proximity to Protected Areas	X	X	X	X
Proximity to Protected Species	—	—	X	X
Vectors	—	—	—	X
Proximity to Roads	—	—	X	—

Table 2. Data used in the different applications of the SIIPA Model. These data inputs were used to select for and rank each characteristic in the different applications of the SIIPA model. For example, specific habitat quality data based on stands or burn units was available for both the Disney Wilderness Preserve and Apalachicola National Forest, but the Heartland CISMA used protected lands boundaries as a proxy for habitat quality.

Required Data	Site			
	Disney Wilderness Preserve-Infestation Analysis Tool	Disney Wilderness Preserve-Priority Analysis Tool	Apalachicola National Forest	Heartland CISMA
Invasive Species Polygon Shapefile	X	X	X	—
Invasive Species Point Shapefile	—	—	—	X
Habitat Quality Map	—	X	X	—
Species Table	X	X	X	X
Land Use Map	—	—	—	X
Protected Species Shapefile	—	—	X	X
Protected Lands Shapefile	—	—	—	X
Roads Shapefile	—	—	X	—
Survey History Shapefile	X	X	X	—
Grid Shapefile	X	X	X	X

each population a weight for value of habitat invaded. A final score is calculated in step six based on a weighted average of all characteristics, producing a ranked list of all the known invasive plant populations. Table 3 shows a sample population from the Disney Wilderness Preserve and corresponding weights for the characteristics and final score. The weights for each class in each characteristic, as well as the methods for defining extent, habitat quality, and the weights of the individual characteristics in the final score, are all parameters, so they can be easily adjusted when the SIIPA model is run as a tool. Further analysis in step seven combines the shapefile with a grid of the area of study to find the highest priority areas, and then the final step uses the Select by Location tool to compare that product with survey history (if available) to differentiate between absence data and areas where the invasive spread is unknown.

The Infestation Analysis outputs a raster map where each cell has an infestation level score. The Priority Analysis tool produces a similar raster map with a priority score, and also a shapefile where each population has its own final score, allowing a land manager to “work down the list” of their highest priority populations as long as their budget allows. The Priority Analysis raster map can be used to locate areas that contain many high priority populations to target invasive species by section rather than simply individual populations.

Here we provide three case studies in which this model was used to prioritize control efforts. These case studies span multiple spatial scales and incorporate varying prioritization goals and available information and, in doing so, aim to illustrate the flexibility of this model.

The SIIPA Model at a Local Scale— The Disney Wilderness Preserve

The SIIPA model was originally designed for use at The Nature Conservancy’s (TNC) Disney Wilderness Preserve (DWP) in Kissimmee, Florida. The DWP was owned by Candler Lumber Company until the 1940s and then became a cattle ranch until the early 1990s, when it was purchased as a wetland mitigation project. Many different conservation organizations marked DWP as important for land conservation in Florida due to the wide variety of habitats present on the land, its connection to the Everglades ecosystem, and the presence of several endangered species. It was preserved as a large-scale, off-site wetland mitigation project for Disney and the Greater Orlando Aviation Authority in a large multi-agency effort. The Nature Conservancy manages the land and its restoration to provide wildlife habitat and connectivity. It encompasses a wide variety of plant communities, including wet and dry flatwoods, hardwood swamps, marshes, and scrub and totals approximately 4,650 ha. We developed the SIIPA model at DWP to assist with treatment decisions and to better utilize the data from a relational geodatabase (the Weed Information Management System, see below) that was implemented in 2009.

The invasive species staff at DWP, a total of two people, determined which characteristics were important for invasive species treatment prioritization and found that TNC’s Draft Weed Management plan framework (Impacts, Extent, Control Methods, and Habitat Quality) aligned very well with our own system. We felt these characteristics captured the most important threats of an invasion and could be analyzed using data we were already collecting. We then adapted this framework to accommodate the type of data and attributes that were available as well as to better represent the specific priorities and goals at DWP (Table 1).

Table 3. Example population descriptions and associated scoring. A sample population at the DWP with the specific attributes considered for each characteristic, and how it would be scored accordingly, which is then combined into a final score based on the average of all four characteristics. Weight variable range from one for the highest priority to nine for the lowest priority.

Characteristic	Population Class Description	Weights
Impacts of Species	Cogon grass (<i>Imperata cylindrica</i>)—Locally Important	2
Extent	0.3 ha	9
Available Control Methods	Likely to be controlled	1
Habitat/Proximity to Protected Areas	Highly disturbed area	9
Total Score	n/a	5.25

A more detailed table appears in [Supplementary Table 1](#). We used a polygon shapefile that contained species and percent cover class data, a habitat quality polygon shapefile, a table containing an invasive species list with impacts and control methods rankings, and a survey history shapefile to run the model. We utilized a relational database that tracks populations using a point shapefile and then subsequent assessments and treatment polygon shapefiles that track changes in each population over time. We modified a burn unit map to create habitat quality and survey history shapefiles.

We first applied the SIIPA Model to the DWP in 2011, ran it annually through 2013, and compared the three model outputs for 2013: the Infested Areas map; the Priority Areas map; and the Priority Populations map (Figures 2A–C). The use of the model here was essentially a “hindsight” tool that allowed us to see how our recent decisions aligned with the stated prioritization goals and then re-evaluate the treatment plan for the upcoming year since data was only collected as the invasive plant control treatments were being made, and the model was run at

the end of the year. A relational GIS database, the Weed Information Management System (WIMS) and invasive plant survey program were first utilized in 2009, providing two years of invasive species treatment data without use of the SIIPA model. Once we implemented the SIIPA model in 2011, the priority scores lowered somewhat, indicating that use of the model allowed us to make treatment decisions that were more in line with our stated priority system, although the difference may not be significant (Figure 3). Using the SIIPA model helped us hone our prioritization even further by encouraging more critical thinking about our data and prioritization framework. As part of the adaptive management process stimulated through application of the SIIPA model, we updated a few data inputs in 2012 to better reflect our management actions (we improved the habitat quality map, added an EDRR species category, and adjusted the weights of the different infestation size classes). For the most part, application of the model showed that day-to-day treatment decisions aligned with the goals; however, some projects did not meet the standards and were eliminated after that year’s analysis. One example

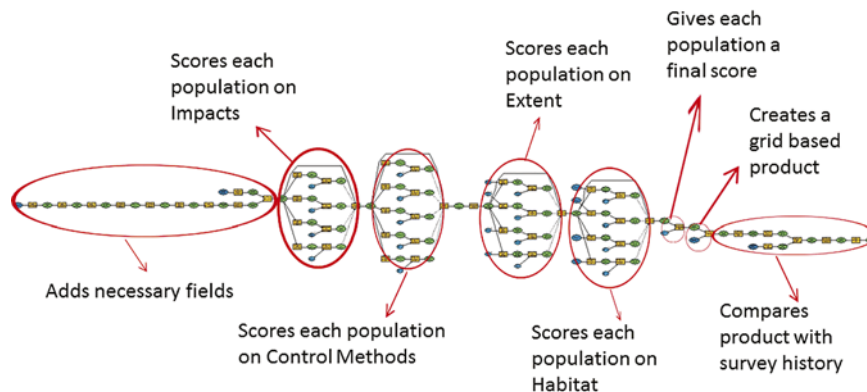


Figure 1. The SIIPA Model Diagram. These are the eight major steps in the SIIPA Priority Analysis tool—each step selects invasive populations based on their different classes for that characteristic, gives each population a weight, then proceeds to the next step. Then the model gives an overall score based on the relative weights of each of the characteristics as input by the user, compares the prioritized invasive species shapefile to a grid shapefile, and combines that with survey history (if available) to differentiate between absence data and unknowns. The dark blue ovals are data inputs, the yellow squares are individual tools from the ArcMap toolbox, the green ovals are outputs, and the light blue ovals are the parameters for the SIIPA tool.

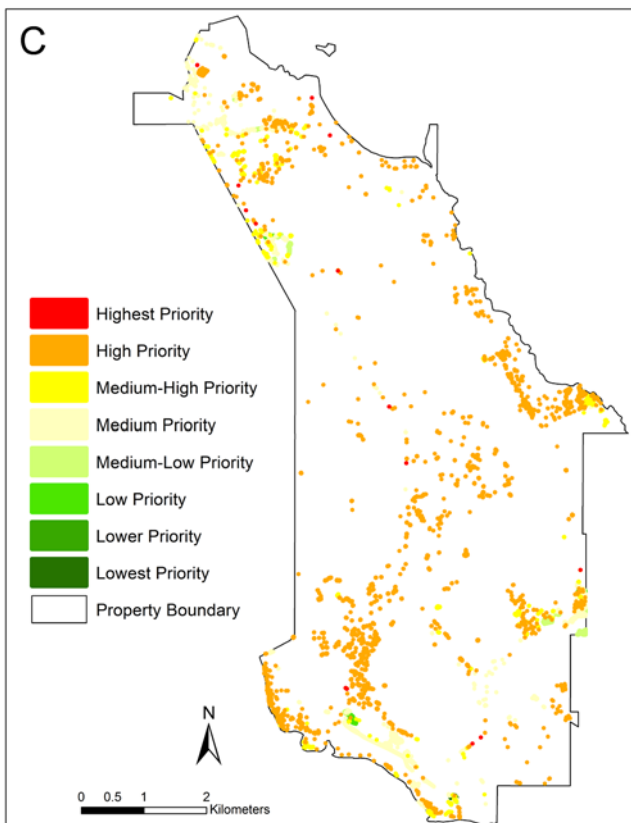
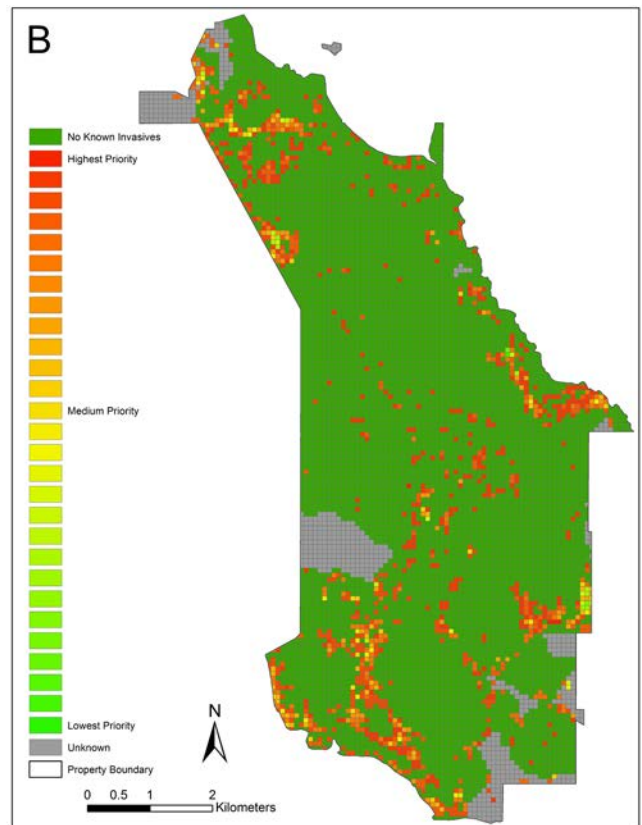
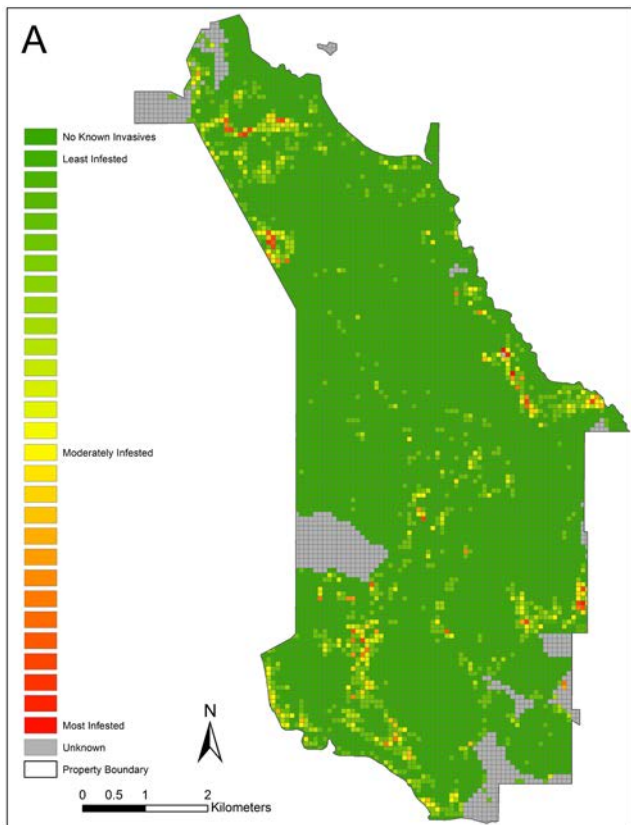


Figure 2. The SIIPA Model Outputs for the Disney Wilderness Preserve in 2013. The Infested Areas map (A) is based on impacts and extent and can be used to show the change in invasive species coverage over time, and therefore evaluate success or failure of treatment efforts, as the tool is run over successive years. The DWP Priority Areas map (B) also considers habitat quality and available control methods and shows the highest priority areas at DWP while differentiating between areas with no known invasives and those that have unknown status. It can be used to plan invasive species treatments by area to maximize efficiency. The Priority Population map (C) shows all the known populations of invasive species at DWP, with each population given its own priority score. It can be used to plan treatment activities by simple order of priority, or can be combined with the Priority Populations map for a hybrid approach.

is the treatment of *Panicum repens* (torpedo grass) and *Paspalum notatum* (Bahia grass) in a restored pasture in 2010. The yearly analysis showed that these invasive and non-native populations were actually lower priorities than originally thought. This insight from application of the SIIPA model allowed us to alter the work plan for the upcoming year and to focus our limited resources on higher priority populations.

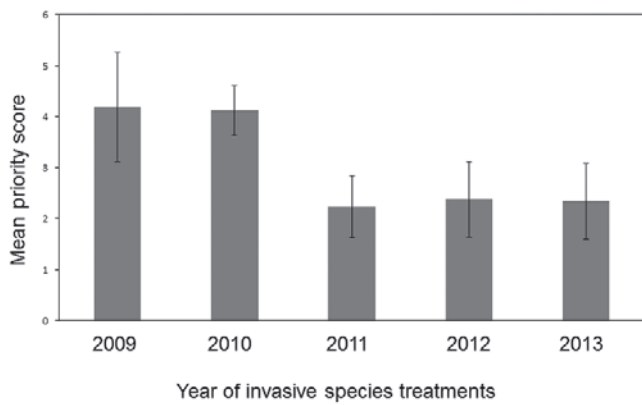


Figure 3. Mean Priority Scores by Year from the Disney Wilderness Preserve. In the SIIPA model, the highest priority populations have the lowest scores. Treatments in 2009–2010 were completed before application of the model; treatments from 2011–2013 utilized the outputs from the SIIPA model in creating the annual work plan, indicating that the SIIPA model enabled us to make treatment decisions that were more in-line with our stated prioritization framework. The model also assisted with our adaptive management process by highlighting data needs and allowing us to improve the data inputs and rankings in 2012 and 2013. Error bars indicate standard deviation for each year.

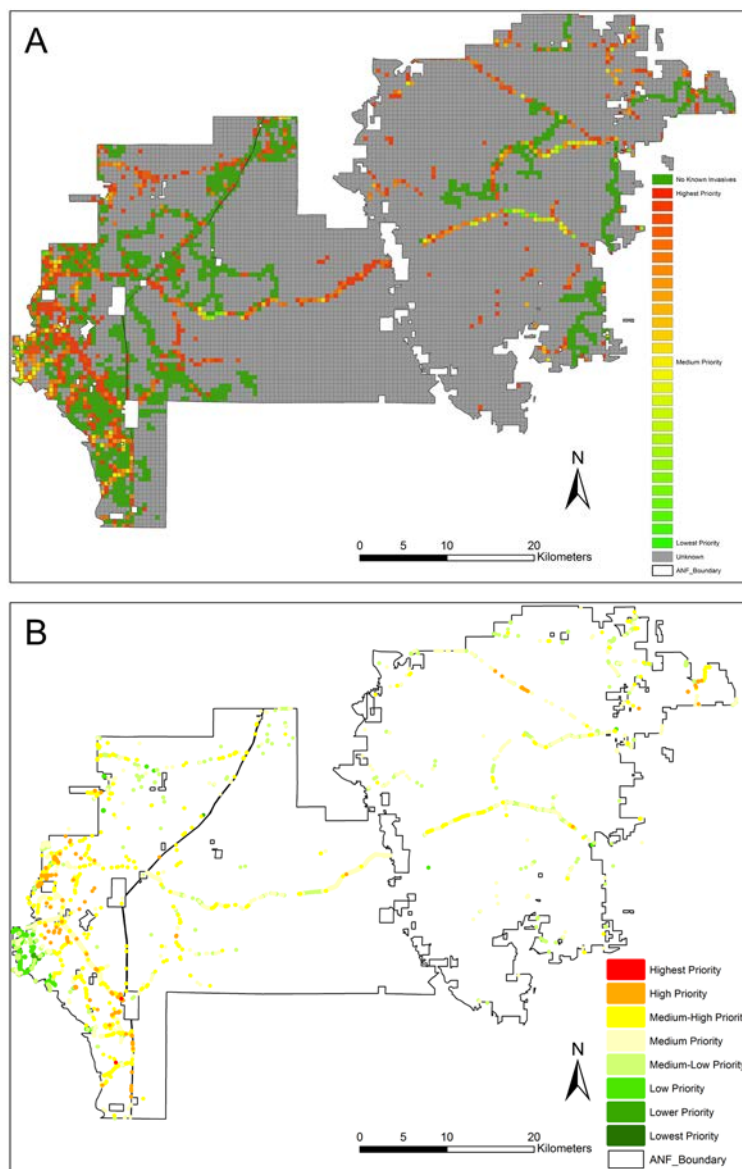


Figure 4. SIIPA Model Outputs for Apalachicola National Forest. The Priority Areas Map (A) for ANF is a function of the Priority Populations map (B) and the survey history, and shows the invaded areas by priority ranking, or no known invasives or unknown status. It can be used to plan treatment or survey projects, such as planning surveys in the western portion of the forest where there are many high priority areas and small gaps of unknown status. The Priority Populations map shows the individual invasive species populations at ANF and their associated priority score, which could be used to target the most important populations first and then nearby invasions.

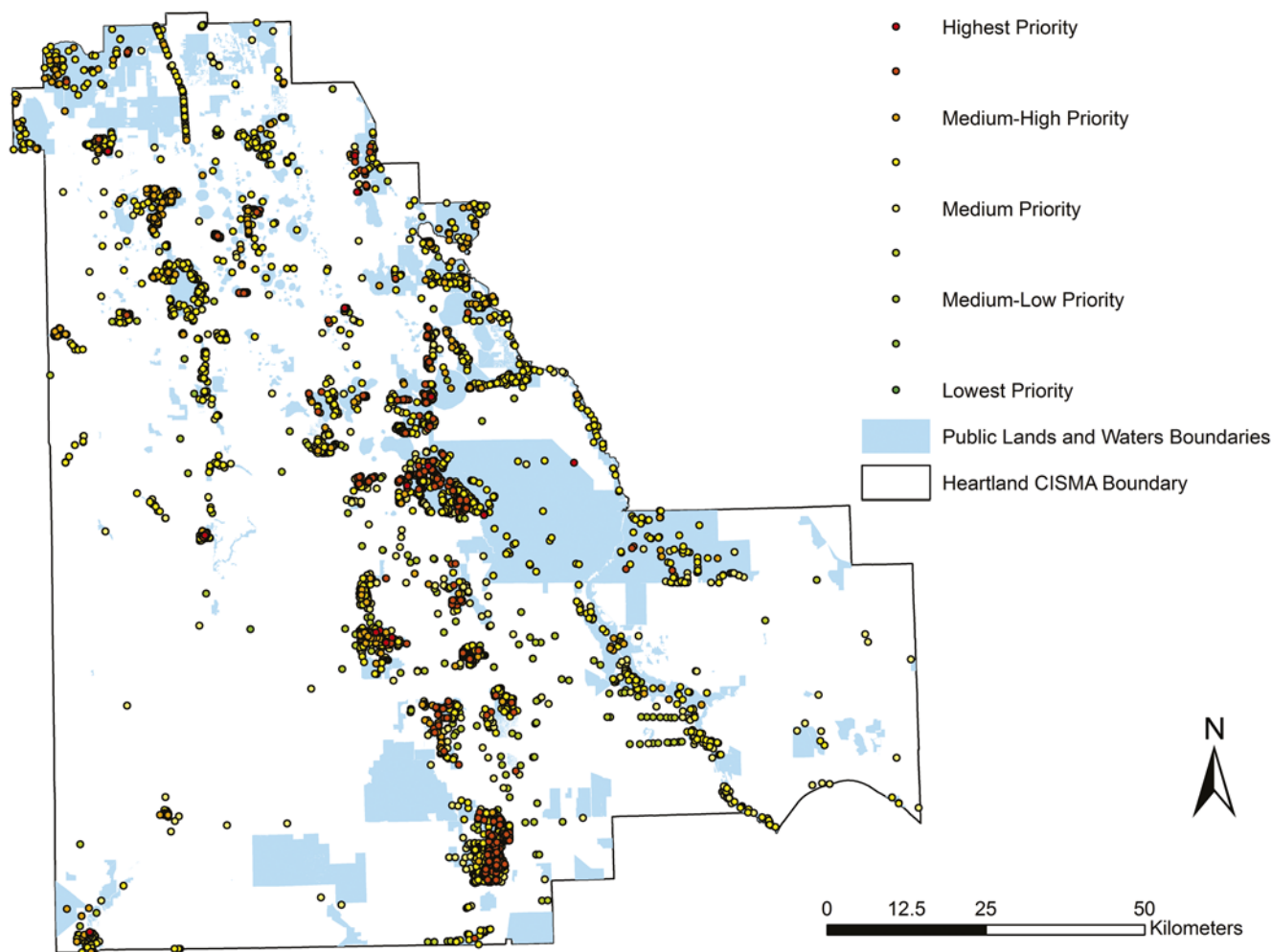


Figure 5. SIIPA Model Output for the Heartland Cooperative Invasive Species Management Area. The Priority Populations map for the Heartland CISMA shows each population ranked by its priority score, with a collection of high priority populations falling in the center of the map along the Lake Wales Ridge, which contains many protected plant species (an important characteristic for the CISMA). The model can be used at a regional scale to aid in planning and prioritizing invasive species treatment projects, such as targeting populations or areas for CISMA workdays or a regional funding program, or targeting private landowners for outreach efforts for education or participation in invasive species treatment cost share programs.

The SIIPA Model at a Landscape Scale—Apalachicola National Forest

We applied the SIIPA model at the U.S. Forest Service’s Apalachicola National Forest (ANF) to assist with their invasive species prioritization decisions and to examine how the model works on a larger landscape. The Apalachicola National Forest is located in the Florida panhandle and consists of approximately 230,600 ha of a matrix of flatwoods, sandhill, and forested wetlands plant communities (United States Forest Service 2013). It is managed for a variety of uses such as conservation of rare species, recreation, hunting, and timber. Forest Service staff asked TNC for assistance in applying the SIIPA model to help guide their own invasive plant treatment plans and we were interested in seeing how the model worked at a larger scale.

The application process at ANF involved an on-site meeting in 2013 between staff to determine the characteristics to use and how to rank each characteristic, where we discussed the different classes for each characteristic already in the SIIPA model, as well as possibly including other characteristics that were important at ANF. Apalachicola National Forest staff decided to use the same characteristics and a similar ranking system to DWP, and to include two new characteristics: 1) distance from roads and, 2) proximity to rare and protected species (Table 1). These characteristics represented the importance of protecting rare species, and treating populations that are not as visible from the roads and therefore might not be prioritized. These characteristics are calculated using a similar method to the other characteristics—a sequence of the Select by Location tool followed by the Calculate Field tool for each class in the characteristic’s prioritization

framework. The group also decided to wait to implement the model for the completion of a habitat quality monitoring project so we could utilize that data in the SIIPA model and enhance the quality of the product. Any subsequent issues were addressed via email. We used the following data for the SIIPA model at ANF: an invasive species shapefile with species and cover class data, an invasive species table with impact and control method rankings, a polyline shapefile of roads, a polygon shapefile combined from different rare species shapefiles, a polygon shapefile of habitat quality adapted from a raster layer of Ecological Condition Monitoring by ANF staff, and a polygon shapefile of survey history. Apalachicola National Forest maintains a thorough geodatabase that contains detailed data for invasive species, various protected plant and animal species, roads, invasive species surveys, and treatments. Survey data was recorded from regularly traveled roads as well as contracted surveys. The maintenance of these data in a comprehensive geodatabase increased the efficiency of the model application for ANF, as management and quality control of the data can be a time-consuming process.

We completed the SIIPA model application at ANF in November 2015. The priority areas map indicated that the western portion of ANF had the highest priority areas for treatment, but that there was a substantial amount of area with unknown status throughout the property (Figure 4A). The final prioritized population shapefile had two populations considered the highest priority score, both of which were EDRR species in close proximity to rare species, but in less visible areas farther from the roads; one hundred ten populations received the second highest priority score, with most of these populations occurring on the west side of ANF (Figure 4B). Staff will use the model outputs to plan invasive species treatments for the upcoming year. One model output is the priority population shapefile that ranks each population and can essentially be used as a priority list to plan the order of treatments so that the highest priority population is treated first, then the next, and so on until treatment funds are no longer available. The maps of the priority populations and priority areas can be combined to locate the areas that have the highest concentration of high priority populations, allowing for a reduction in travel time and costs while still focusing on the higher priority populations. The model outputs will also be used to help plan future invasive species survey efforts.

The SIIPA Model at a Regional Scale—The Heartland Cooperative Invasive Species Management Area

Finally, we applied the SIIPA model to the Heartland Cooperative Invasive Species Management Area (CISMA) to see how the model performs at a regional scale and how this could benefit larger scale management efforts. The Heartland CISMA encompasses five counties in central Florida

(Polk, Hardee, DeSoto, Highlands, and Okeechobee); it originated from the invasive species committee of the Lake Wales Ridge Environmental Working Group and includes local, state, and federal agencies, non-profits, educational staff, and concerned citizens. Land uses throughout the CISMA include agriculture, cattle ranching, orange groves, and residential. Natural areas include scrub, sandhill, flatwoods, cypress swamps, marshes, forested wetlands, and dry prairie. The Lake Wales Ridge, a ridge reaching up to approximately 90 m in elevation, contains over 23 threatened and endangered plant and animal species (Guthrie 2016), making it an obvious target for conservation efforts.

The implementation of the SIIPA model for the Heartland CISMA was more complex and time consuming, which was expected considering the number of managers and agencies involved and the greater spatial scale of the target area. Initial application began in 2013 but was put on hold until 2015. The characteristic and ranking decisions were made at a general CISMA meeting, with approximately 20 members present. A subcommittee of three members assisted with further decisions on the quality control process for the data. During customization of the SIIPA model for the Heartland CISMA, we changed the ranking systems for a few characteristics to fit the available data and needs of the CISMA (i.e., number of populations of each species was used as a proxy for Extent), and two new characteristics, proximity to rare species and potential vectors, were added (Table 1). Many managers were very concerned with protecting the large number of rare and endemic plant species found in this area, as well as watching for emerging invasive species that might be introduced through the many different agricultural activities near protected lands. Incorporation of these two characteristics into the SIIPA model followed a similar process as in the other characteristics—the Select by Location tool followed by the Calculate Field tool for each class within the characteristics. The gathering and quality control of the required data was the longest part of the process. We gathered the required data from Florida Natural Areas Inventory (rare plant locations and protected areas boundaries), the Florida Geographic Data Library (land use maps), Florida Fish and Wildlife Conservation Commission (public water bodies), the Early Detection and Distribution Mapping System website (EDDMapS, invasive species locations) and the websites for the various protected lands (number of public uses as potential vectors).

We completed the Heartland CISMA SIIPA model in February of 2016. Given the scale of the CISMA project and the lack of any comprehensive survey data, the priority populations map was the only output for this application (Figure 5). The final prioritized invasive species shapefile yielded interesting results, with 19 populations of ten different species spread across the center of the CISMA receiving the highest priority rating. Three of the populations were on their EDRR species and the rest were categorized as

invasive by the University of Florida Institute of Food and Agricultural Sciences (IFAS) Assessment; all populations were located in conservation lands and close to protected plant species. Several of the populations were the serious invaders that are quite common in the region but were given higher priority scores in the extent category due to not being commonly reported in the EDDMapS database. This underscores the importance of the quality of the initial dataset in providing a reliable high-quality product. The product builds upon many of the available invasive species prioritization lists for the region or state by incorporating a spatial component as well as several other characteristics that are important to the land managers in the area. The map can be used to help prioritize partner workdays within the CISMA, prioritize projects in regional level funding programs, or to identify private landowners for outreach efforts regarding cost share programs for invasive species treatments.

Discussion

The main purpose of the SIIPA model is to assist land managers with making day-to-day prioritization decisions by providing them with a tool to quickly apply their own prioritization framework to the known invasive species populations on their property. As illustrated in the first case study, our model can also be used as an adaptive management tool to evaluate the success or failure of current treatment methodologies; and as a means of preserving institutional memory of invasive species locations, treatments, and goals. The map products are also effective ways to communicate the current invasive situation to stakeholders and allow managers to understand and justify decisions and allocation of resources. The SIIPA model could potentially be used in a wide variety of situations, from considering different geographic areas to including other characteristics such as impacts on wildlife, prescribed fire, hydrology, and treatment costs based on species or location, although these situations have not been tested yet.

Benefits of the SIIPA model include its relative simplicity, adaptability and specific map products. The SIIPA GIS model can be utilized through ESRI's ArcGIS software, which is commonly used in many fields, including conservation. Many land managers will already have access to ArcGIS and therefore would not need to purchase any special software. The SIIPA model will also be available as part of the EDDMapS website in the near future through a Florida Forest Service project for invasive species prioritization, funded by the U.S. Forest Service Landscape Scale Restoration program. We began work in fall 2016 on adapting the SIIPA model to become a "dashboard" style tool, making the model available to private and public landowners without ArcGIS software. While application of the model requires ArcGIS experience, it is not overly complicated to implement, and once the initial setup has

been completed, it can be easily run as a tool for any future uses. Also, it was designed to encompass some of the most commonly utilized prioritization criteria but still be easy to apply, to make it more appealing to the ever-busy land manager. The model metadata contains detailed instructions, comments, and common trouble shooting suggestions to aid land managers in applying it for the first time (found in the description when viewing the model in ArcCatalog or in the Tool Help). The outputs are easy to interpret maps that can be shared with many stakeholders and assist with creating annual work plans. Finally, it can be customized to include a wide variety of prioritization characteristics or concerns as long as some sort of spatial or tabular data is available for the characteristics under consideration. This flexibility provides great utility, as one prioritization framework is highly unlikely to meet the management needs of various agencies or individuals. Adding more characteristics will require greater ArcGIS skill and a larger time commitment, but once the model has been customized for that particular entity, it can be easily run by less technical staff as needed in the future.

We realize that this is by no means a perfect tool that will solve all prioritization problems. The outputs will only be as good as the data used and the quality of the criteria that are used to run the model. Also, this is not the most complex prioritization tool and often relies heavily on local expert opinion rather than scientific or published data; but given that the information needed to make fully informed prioritization decisions is not always available in published literature, this model allows managers to apply their experience to inform future management in its absence. Incorporating more in depth analysis or standardized criteria for characteristics can increase the robustness of the model, such as at ANF with the habitat monitoring project for habitat quality or with the Heartland CISMA using published invasive species lists for impacts. Plus, a simpler tool is not always undesirable, as avoiding "analysis paralysis" can be key to actually performing the intended management, and it is not certain that considering more characteristics would actually affect the model products in a large manner.

It is important to note that the application of the model will be improved if managers create a prioritization framework, if one is not already available, and they are allowed to review the rankings. Applying the model for the first time can be somewhat complex and should involve staff that have reasonable GIS experience as well as staff that have invasive species knowledge. Transparent, objective, and consistently applied criteria are critical to a good prioritization framework and may help to remove bias. The data collection and quality control will take the greatest amount of time. Finally, good documentation will assist in revisiting use of the model in the future, allow others to review your decisions, and aid in thorough planning.

Effective and efficient invasive species prioritization can greatly assist land managers in accomplishing their restoration and maintenance goals, and aid in maximizing treatment impact under budget constraints. The SIIPA model can help managers in moving their weed management plan from an “often dusty folder on the shelf” to an annual work plan directing the day-to-day invasive species management actions that readily facilitates adaptive management.

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Deborah Stone, School of Forest Resources and Conservation, University of Florida, FL 32611.

Michael Andreu (corresponding author), School of Forest Resources and Conservation, University of Florida, PO Box 110410, Gainesville, FL 32611–0410, mandreu@ufl.edu.
