GIS and the Management of Invasive Species

Tiffany-Lane Davis

An invasive species is a non native organism that has the potential to cause harm to the economy, the environment, or human health (NISC 2009). They cost the United States billions of dollars annually and consist of plants, animals, and pathogens. Introductions are managed very little at the federal level other than the USDA. The majority of the effort is handled by state and local agencies. The way that these species are handled is dependent on a variety of information. GIS is utilized to some extent, but has the potential for widespread implementation.

Because the number of introductions doubles every hundred years, prevention is of primary importance in the management process (NISC 2009). Once the species is here, however, the focus is on gathering information about the species in order learn how to best keep its population under control and reduce the impact of the species on the ecosystem. If the problem is addressed at the early stages it may be possible to eradicate the organism before it takes a firm hold on the environment. Another important part the process is prediction. If we understand the distributional and dispersal behavior of a species then perhaps we can foresee where they will invade next and take precautions to stop their spread. Worst case scenario, the exotic species establishes and spreads because it has found a prime habitat for itself. Now, measures must be taken to manage the new addition. GIS can be used throughout the entire management process.

The first priority is prevention. If the invasive species can not make it to new habitats then all of the time and money spent on control, eradication, and restoration could be reallocated to other parts of our economy. In order to do this successfully, vectors and pathways by which species arrive must be identified. GIS accomplishes this by mapping the vectors and pathways, established as points and lines in a map, which lead to a high probability of invasion. Four pathways that are likely to lead to unintended introductions are contaminant, stowaway, corridor, and unaided (Hulme 2009). Several analyses have been done on these areas specifically and have produced some promising results. For example, when considering contamination, unprocessed logs are one of the largest sources of invasions. The attributes that might be combined in a GIS map might consist of the origin of the resource, the time of shipment and quantity of logs, how long it was stored at its place of origin, where it is stored at its new location, and the proximity of the storage to forested areas. A three component model was used that “described local pest population dynamics at the storage site (a function of demographic parameters and timber import volumes), likelihood of escape, and the probability of colonizing suitable habitat (a function of distance and dispersal ability” (Hulme, 2009). Surprisingly the temporal and volume aspects of shipment were the factors that affected chance of species spread the least (Hulme 2009). The most influential aspect was the distance between storage houses and forested areas. With this information now available,
maps of high risk areas can easily be mapped in GIS. Buffers can be created to see where the dispersal area from the facility would overlap with the tree line. Storage too close to prime habitat can then be focused on, perhaps by knocking them down and rebuilding further away or making the building less escapable. Unintentional introductions can be reduced drastically and will be the most efficient way to spend money in this particular area.

There are many factors that affect the establishment and spread of a nonnative species. These include, but are not limited to, soil type, elevation, aspect, disturbance, proximity to a body of water, and local vegetation (Murray 2009). With this data, maps to predict the risk of a certain area to invasion can be produced to narrow the focus of the search for the species. Early detection and rapid response reduce the time and cost associated with the eradication of a species. If you know where to look for a species it can be found and eliminated in the shortest time possible preventing further harm to the environment. Formerly forest managers have been using the Forest Site Quality Index to narrow down the hunt for an invasive species, but by being able to make predictions with a higher success rate it can make the process much simpler by defining habitat of high priority (Murray, 2009).

When an exotic species makes it through prevention measures and has managed to establish and spread before it can be detected, control and management are the next steps in the process (NISC 2009). One way that some species are managed is through biological control. By mapping the distribution of the pest species, the best areas for release of the bio-control can be determined. When placing the agent into the field you might want to start in areas that have high concentrations of the species you are trying to reduce. This can be determined by mapping the distribution of an invasive and performing statistical analysis to determine a high number of individuals per area to give you the density. Another consideration might be to put the bio-control in areas that supply it with pathways to new populations of the exotic. GIS can also be used to track the distributions of both the native and nonnative species and in this manner evaluate the success or failure of the bio-control agent.

A variety of data and GIS tools can be used for all of these situations. Often, Data Elevation Models (DEM) provides a lot of information about the environment of an area (Holcombe et al 2007). Temperature and moisture content both change as elevation increases. The zonal statistics function of ArcGIS is helpful in providing the averages, maximums, minimums, and ranges for both large and small scales making analysis of habitat possible when dealing with specific or broad areas (Holcombe et al 2007). Buffers are used when the known range of an invasive species must require a specific land feature, such as a river. This gives the land manager an area of focus when searching for a species (Holcombe et al 2007)). Species Environmental Matching (SEM) is a useful statistical analysis that gives the predicted spread of a species. While not yet completely reliable, it does give managing agencies early warning signs. This technique is constantly being worked on by researchers to hopefully progress the technology for its widespread use (Holcombe et al 2007).
While GIS can be used to alleviate some of the issues with invasive species, it is not utilized to its fullest potential. It is mostly put into effect on a case by case basis and not for the overall management of species. More development of the Species Environmental Matching would make land managers' lives easier and might increase successful eradication. Another issue is the gap between federal, state, and local agencies. The federal government leaves most of the issue up to the states to figure out, but if there was a synergy across the United States it would make for a better program. Finally, there is still no way for data to flow up the chain from local to state to federal. This leads to repeat data collection, which taxpayers are funding. This is a waste of time and energy. The most prominent reason for the lack of GIS usage in invasive species management is that it is still maturing. There needs to be more proof that modeling and mapping works when handling this issue.

Reference not included in annotated bibliography:


This paper is a specific example of how remote sensing and GIS have been used congruently to map and analyze the seed productivity of the invasive plant Jack in the Bush. The use of this technology for this purpose was really innovative for research because they had only been using remote sensing for canopy species. By combining the known variables that the shrub likes the best, like light intensity and the biomass of the location, they were also able to determine factors that they did not yet know how they affected the productivity of the species. This plant occurs in the environment in reproductive and non-reproductive populations. The amazing discovery that resulted from this experiment was that the reproduction is affected by light intensity. Now that this is known, the reproductive populations can be isolated as risk areas and management can be focused on them. This reduces the cost and energy focused on individuals that will not even reproduce.


This paper talks about how globalization is the main causes of the introduction of new species. As trade and transport increase so does the frequency of unintentional species movement. The best part of the paper is towards the end when specific examples of GIS involvement are described. One circumstance was dealing with the spread of a marine tunicate. Through a combination of factors such as the amount of traffic, the means by which it can be transported, and environmental suitability, a risk map was generated pointing out the areas that should be focused on for management first.

Murray, D. P. 2009. Spatial Distribution of Four Exotic Plants in Relation to Physical Environmental Factors with Analysis using GIS. Thesis submitted to the Faculty of the Virginia Polytechnic Institute and State University.

In this paper Murray shows how environmental factors affect the location of new invasions of nonnative species. By increasing the accuracy of prediction, time and cost can be reduced for forest managers in particular. Previously they had been using an index to choose sites in the property to look for new populations. With Murray’s analyses, the sites were predicted at a higher accuracy. This shows factors, such as disturbance, elevation, aspect, and other environmental characteristics can be utilized to help with detection and rapid assessment of invasive species. By mapping these factors in GIS, layering and prioritizing them, hotspots will direct the management process. By showing people that prediction modeling is more beneficial than former methods, hopefully GIS will be used more in this way.

This is a great paper about the many different aspects of GIS and how they can be used when analyzing the environment. The authors range from the simple to complex. They explain how just viewing data in picture form on a map can give you vital information before you even start performing statistical equations. Simple, statistical, environmental envelope, and regression models can give you every side of the story that you are trying to investigate. The paper also explains the different types of data that are used for each GIS tool. I found this paper to be a really useful summarization of the tools of the GIS program. It also was the easiest to understand in terms of the technology and models involved in managing invasive species.


This paper addresses the link between the attributes possessed by the invasive species and how this affects its distribution as well as how environmental factors affect the richness of invasive species in an area. They used a 10 x 10 km Universal Transverse Mercator grid and counted the number of occupied cells to determine the density of the invasion. Then topology, climate, and other factors were averaged so that each cell encompassed all of this data. This was a very interesting approach since I had not read any other articles using this method. When these cells were placed on a map of Spain there were several clear hotspots on the coast where species richness was the highest for nonnative organisms. A visual such as this is very helpful because with one click of the cell you receive a host of information about that particular site.


An innovative idea, this paper focuses on propagule pressure. Dispersal and how suitable the environment is that the propagule is introduced to are the first factors that lead to a full fledged invasion. GIS was used to show the water pathways that the species fanwort might travel to invade new lakes. Other factors used in this process included the chemical properties of the bodies of water as inputs into models to determine habitat suitability. Predicting new invasions is not easy to do since nature is always evolving, but apparently with the addition of propagule pressure and climate features the result has been improved upon.