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Tools for assessing and recognizing wetlands values
Paper 4

Applications of a user-friendly GIS to wetlands conservation at the site level

By **Suzanne Palminteri, George Powell, R. Glenn Ford, Janet Casey**

1. The protection and informed management of a wetland requires a knowledge of the geographic relationships among key components, including water, soil, vegetation, animals, and human infrastructure. Having the capability to spatially represent and analyze your information facilitates and strengthens your ability to make planning and management decisions. In this talk, I will discuss how user-friendly geographic information systems can improve the ability of site-level managers to assimilate and interpret data to help them answer management questions.

What is GIS?

2. **Definition:** A Geographic Information System (GIS) combines computer software with hardware to access, view, manipulate, and display a wide range of geographically-oriented information, such as land uses, soil types, vegetation types, rainfall, elevation contours, human infrastructure or species distributions – anything that can be mapped.

3. **Simple Concepts**: The concept of GIS is not difficult: its basic methodology is equivalent to overlapping two sheets of clear acetate, each containing geographic information about an area. When these different sets of data from the same geographic area are overlayed and viewed together, patterns and relationships between them often emerge that may otherwise have remained hidden. To demonstrate how layering of data in a GIS works, I provide a series of maps, the first of which shows the range of vegetation types on the western side of Lake Manyara in northern Tanzania. A second map of the area presents the boundary of Manyara National Park, with the escarpment, or rift, leading down to the lake area. When overlapped, these two sets of data provide greater information: for instance, together they show which vegetation types are protected by the park and which fall outside the park.

4. A composite map of the park and its vegetation would be useful as a base map for studying migrations between wetlands along the lake and other adjacent habitat types both in and

outside the Park, or as a promotional tool for communicating with government officials, tourists, or the public to demonstrate the habitat variety protected by the Park.

5. **Obstacles:** Despite its value and conceptual simplicity, GIS has remained out of reach for many field conservationists due to high startup costs, a steep learning curve, and lack of awareness of its value to conservation. This need not be the case, as a standard computer and an investment of about US$750-1,000 in software, a smaller digitizing tablet, an ink-jet printer, and a hand-held GPS will provide most groups with sufficient GIS capability to produce maps and carry out basic ecological analyses.

6. For more than a decade, there have existed a number of high-tech and powerful GIS options that will classify and analyze large satellite images and/or carry out advanced modeling routines. This high-end technology, in the hands of computer experts, has been extremely valuable for global, continental, and regional analyses. However, another level of GIS is now emerging that allows field-level managers and conservationists with minimal computer skills to apply the same types of analyses for the protection and management of a wetland site.

7. In this talk, I will focus on making GIS technology available to managers working at the site level. Simpler systems exist that require only a few days, rather than months, to learn, cost a few hundred dollars, rather than thousands, to purchase, and can provide a majority of the functions required by users in the natural resource conservation and management field. These systems run on standard computers, which are available to most conservation groups.

8. Of course the scope of your project, as well as your analysis and presentation needs, will dictate the scale of your investment in computer hardware and software. Nevertheless, it is important to recognize that many of the basic functions, especially at the level of the reserve or research site, can be carried out with standard equipment by the managers or researchers themselves.

The value of gis to wetlands conservation

9. The utility of a user-friendly GIS to wetland conservation depends on the needs of the resource manager. One might create a map showing the location of a proposed road or factory in relation to an existing wetland, while another might determine how an area's hydrology corresponds to the locations of wading bird colonies or vegetation communities. Still another might want to create maps of wetland vegetation from different years to show the spread or decline of a particular species such as periphyton or cattails (*typha*).

10. A user-friendly GIS can help conservation professionals protect and manage wetland resources by: (1) communicating a situation or relationship; (2) carrying out simple analyses such as measuring and intersecting map elements; (3) analyzing distributions of species and habitats; (4) modeling potential variations in or changes to habitat such as the flow of water-borne pollutants; and (5) guiding resource and land use planning, by answering management questions through data layering.

11. To demonstrate how these procedures can be done with a relatively simple GIS program, I will use example maps created in an easy-to-learn GIS called CAMRIS. However, the applications presented in these case studies can be executed in various programs.

The Communication Power of Maps

12. One of the most basic and important uses of GIS for conservation is the communication of information to decision-makers, donors, the press, neighbors, and the public at large. As an example, I provide a simple map of the Florida Everglades which shows the relative positions of one of the major "head waters of the wetland", Taylor Slough, and expanding agriculture where increased drainage was being proposed. While the potential impact of the agricultural development is painfully obvious to any wetlands advocate, a simple demonstration like this can go a long way towards helping the less informed decision-maker understand the threats of such an action to a wetland. If a picture is worth a thousand words, then an annotated map showing the relative positions of sensitive components of a wetland and proposed destructive activities is worth many thousands. GIS allows one to quickly assemble the relevant components of an issue and present them in a compelling manner.

13. The capacity of a GIS to show information at various spatial scales helps property owners, site managers, and others recognize the role of their property or site in the larger landscape. Because connections between wetlands in a region may not be obvious to politicians or the general public, it may be helpful to show your information in maps at different spatial scales. For example, viewing this same map at a broader spatial scale demonstrates that Lake Manyara and its associated wetlands are not functioning in isolation, but are part of a larger wetland complex. This larger area includes the streams and wetlands of neighboring Tarangire National Park that are essential dry season water sources for many animals of northern Tanzania. Looking at the data this way can help the Park managers or conservationists justify protection or limitations on human use of the lands connecting the wetlands systems in these two parks.

Simple Analyses

14. Maps in a GIS are useful not only for showing others but also for determining research or conservation priorities among the research or conservation team itself. Simple geographic analyses, such as measuring, buffering, and intersecting map elements, allow one to determine distances, such as that between a building site and a wetland, or areas, such as the extent of a stand of flooded forest or a continually-flooded area.

15. I provide a base map of the Celestún Reserve (also called Parque Natural Celestún) located on the western side of the Yucatan Peninsula in Mexico. The advantage of dividing your data into layers using a GIS is that it allows the user not only to pick and choose which information layers you want to view at any given time, but also to update your map quickly and then print more copies when necessary. For example, if a researcher at Celestún wanted to locate specific vegetation types in the Reserve, without having to look at towns and roads, s/he would remove the roads and towns layers and add the layer containing vegetation data.

16. The Celestún Reserve manager might have additional concerns that would require viewing the human infrastructure. S/He could, for instance, load the simple base map with or without the vegetation information and then quickly see and print an expanded view of a specific sector of the Reserve, such as the North end. This capacity would be useful if, say, there was a proposal to upgrade a small dirt road located in that sector. By updating the layer containing the road, the manager could then measure the length of the road that would occur inside the Reserve.

17. If you were the site manager, you might also want to identify the areas of particular vegetation types, or of the salinas, estuary, and shoreline that would be affected by the enlargement of the road. To do this, you might highlight the areas that would be affected if the impact from expanding the road stretched one kilometer in each direction. A simple buffer routine will provide you with that information.

18. What if impact from the road was really going to extend 2 kilometers in each direction? The same basic layering characteristics of a GIS would also allow you to create multiple versions of a map by using the same basic information and changing only the layer containing the impact area of the road, without having to recreate all the layers each time. By using a GIS to overlap the layer containing the impact or buffer zone with a layer containing the area's vegetation types, you would know how much of each vegetation type would be impacted by the road.

19. This knowledge is essential for discussing the situation with government officials, other property owners, the road constructors, and the public. The road builder will likely use a GIS to determine the cheapest and most effective site for expanding the road, but perhaps with additional information from the Reserve manager, the environmental impact will factor into the decision as well.

Distribution Analysis

20. Analyses of distributions, such as habitat types or seasonal movements of individuals or groups of animals, can be accomplished in a user-friendly GIS. Official vegetation or life zone maps or satellite images can be combined with data collected in the field that is entered into the GIS from either a Global Positioning System (GPS) or plots on printed field maps.

Habitat Distributions

21. I provide a satellite image showing different types of flooded forest, or Varzea, in the Mamiraua Reserve in the Brazilian Amazon. The different colors pertain to different vegetation types distinguished by their varying levels of inundation, as the waters of the Amazon and its tributaries rise and fall up to 10 meters each year. This reserve is home for part of the year to thousands of wading birds, including cormorants and anhingas, storks, egrets, and several species of herons. The great numbers of birds arrive as the water level drops, concentrating fish in smaller and more isolated bodies of water.

22. Satellite images provide broad-scale information about the vegetation types and current land uses of an area at a given moment. For work at a finer scale, aerial photos and higher-

resolution satellite images are also useful for locating and determining distributions of particular communities, such as swamp forest or submergent vegetation.

23. An expanded view of the image shows specific lakes within the Mamiraua Reserve. While this image shows the sizes and locations of the lakes at a given point in time, one could compare it to an earlier or later image to show any vegetation changes that might indicate changes in water quality or quantity. In addition to viewing the different types of Varzea vegetation, as well as sand and water, a GIS system can help you calculate the amount of area in each vegetation type. Using images from two different years would allow the reserve manager to compare the total area comprised by each habitat type.

Seasonality of Animal Distributions

24. Another helpful feature for the site manager is the capacity to import individual points, either from a database, referenced with a GPS, or from plots on field maps. If the points represent observations, such as these observation sites of a radio-tagged crocodile in the Mamiraua Reserve, the GIS user can calculate a basic minimum convex polygon around those points, as well as polygons representing 50% or 95% of observations of the animal, thereby establishing home range size.

26. If these observation points are overlapped with the Mamiraua image, the user can estimate not only the size of the home range, but also the vegetation types in which this particular animal is likely to be found. These calculations provide the user with information on space use of specific species that can guide protection efforts.

27. Data collected along a linear transect, such as a shoreline, can be presented graphically as a linear series of polygons for easier viewing. The wetlands along the Delaware Bay on the New Jersey coast, USA, are a world-class shorebird stopover. Segments of the shoreline transect are assigned numeric values based on the densities of different shorebird species (birds per kilometer) in that segment during spring migration. The scientist who made this map created a buffer zone around the actual shoreline to produce a polygonal shoreline. Darker colored bands represent areas with higher densities of shorebirds.

Modeling

28. While a site-level GIS program is often used primarily to make maps and present information, it can also be useful in predicting future situations, depending on current activities. As a wetlands manager, you might be interested in the effects of changes in land use to the streams of a particular watershed or the rate and direction that water might carry oil or pollutants to the shore or to another body of water.

29. For wetlands, such as those along Delaware Bay, that are located near urban or commercial centers, the wetlands manager may want to model the impact of such a spill on shorebirds or water quality. As an example, I provide a view of the overlay of the shorebird density map with output from the NOAA Hazardous Materials oil spill model, which shows the movement of oil based on a 48-hour spill scenario.

30. In the case of the wetlands of the Mugu Lagoon in California, which are located near established pollution sources, a transport model of the pollution output was interfaced with the GIS. I provide a map showing the results of the pollutant transport model, which indicates the pollutant sources, areas of the lagoon with higher and lower densities of pollutants, and the direction and intensity of the flow of water throughout a tidal cycle on a grid.

Planning

31. Planning for conservation of wetland sites may include one or more of the following activities: determining priority sites for connecting natural areas, negotiating on the site selection for a new reserve or a new construction or agricultural project, or making site-level policy recommendations to decision-makers. To carry out any of these activities, conservation professionals must consider a variety of natural and human factors, such as the slope, soil type, water table, endangered species distribution, land price, and habitat cover of the site, as well as its distance from other natural habitat, transportation corridors, and population centers. Overlapping data such as these provide information on the interactions and relative geographic locations of these different factors. This information is critical to be able to answer management questions, such as: (1) Which areas stay flooded year-round? (2) Which unprotected zones are critical for maintaining water flow to a wetland area? (3) Which zones are most heavily used by wading birds? (4) Which sites require restoration? (5) Which areas contain endangered plants? (6) Which areas both contain both endangered plants and require restoration?

32. Answers to questions like these inform the wetland manager about relative locations of conservation opportunities and threats, indicate sites that require priority attention, and help strengthen conservation arguments regarding the siting of construction or the development of policies favorable to areas surrounding wetlands.

33. For example, data on the distribution of wading birds were collected over several months in the Sian Ka'an Biosphere Reserve in southeastern Mexico. Using overflights to follow predetermined transects and entering observational data into the GIS, researchers from the NGO Amigos de Sian Ka'an developed a database of wading bird densities based on density values assigned to two-minute grid quadrants. Using the GIS, the researchers generated density curves based on these quadrant values.

34. These density data show where groups of wading birds congregate, but the curves can also be generated for specific species of interest, such as rare or endemic species. These data can be applied to several management questions, including: where to locate core protected zones within the Biosphere Reserve, where to focus research and protection efforts, or where tourists should or should not visit. Knowledge of the bird preferences can also be used in the future as a preliminary indicator of the respective distributions of vegetation or inundation, which would allow Reserve managers to react appropriately to changes in either of these factors.

Why use a user-friendly GIS?

35. Using a GIS can benefit virtually everyone involved in the fields of research, ecological monitoring, management and conservation of wetlands. All of these activities have a strong spatial component, and therefore, can be facilitated through geographic information processing.

36. From our experience training environmental groups, students, protected area administrators, and researchers in developing countries, we have found that to be effective for these on-the-ground conservationists, a GIS must be easy to learn and use, as well as to teach.

37. Furthermore, it must allow the user to input, update, view, analyze, and display information – all using standard computer equipment. This is especially true for field personnel and groups based in smaller communities that lack access to commercial or institutional geography and data processing departments. These groups often do not have the technical capability of a full-time GIS analyst nor the funds to contract GIS specialists to produce maps for them.

38. In some countries, GIS users can purchase specific data files – such as the political boundaries, protected areas, roads, and rivers of a region – in digital format, which saves a project considerable data entry time. However, in many cases, these data are often derived from coarse-scale sources, and they are often unavailable in the developing world. In many developing countries, access to digital data is limited to non-existent, and many groups must enter all basic data from their area of interest into the GIS themselves. And of course a typical research project will be continually generating new data, which can then be added to the information base.

39. Even where digital data or a satellite image is available for your site or region, there is no substitute for ground-truthing and knowing your area. The resource manager who knows his or her project site and species of interest can detect errors found in paper maps and coarse-scale images and can use the GIS to update geographic information if necessary. I provide two maps showing the collection of locational data for areas of taller, drier forest (restinga) in the Mamiraua Reserve in Brazil using overflights. The distribution of these restinga areas were analyzed and incorporated into the GIS, where they could be compared to the vegetation types indicated by the satellite image of the area.

40. Therefore, a GIS that allows easy entry of data from paper maps, Global Positioning Systems, compass and distance readings, and database files will allow an organization or research project to compile the basic geographic information it needs to begin analyzing and presenting information. A user-friendly and low-cost system also encourages a wider range of the organization's or project's staff to use the program, thereby ensuring continuity of access to the data even if a principal GIS user leaves the group.

41. By allowing the user to carry out operations such as those we've just reviewed on a system that is easy to learn and use, the site-level GIS can help smaller field-based organizations and studies use their limited conservation resources as efficiently and effectively as possible.