Development of a Geographical Information System for the Wildcliff Nature Reserve

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This project entails reproducing and expanding upon a series of existing maps which illustrate key points in the conservation and research strategy for the Wildcliff Nature Reserve in the Western Cape of South Africa. A comprehensive GIS of the reserve will be created to include important biotic and abiotic spatial datasets such as soils, vegetation boundaries and topography.

Wildcliff Nature Reserve

Wildcliff is a 955-hectare wilderness preserve in the Langeberg mountain range of South Africa's Western Cape. It is centered at about 33º57'S, 21º2'E with elevations from 290m to 1130m. The boundaries lie between 20º58.9'E on the west to 21º3.0' on the eastern side, and 33º58.5'S on the south to 33º55.9' at the northernmost point.

The reserve offers an outstanding example of the flora of the renowned Cape Floristic Region, which represents less than 0.5% of the area of Africa, but is home to nearly 20% of the continent's flora. Its plant species diversity, density and endemism are among the highest worldwide, and it has been identified as one of the world's 18 biodiversity hot-spots. Of the world's six floral kingdoms, it is the smallest and richest per area unit.

Wildcliff serves as a powerful display to the ecological and biological processes associated with the Fynbos vegetation, which is unique to the Cape Floral Region. The range of topographical features and altitudinal gradients present also provide habitats for an array of vegetation types including pockets of Afromontane forest. The dominant vegetation biomes of the reserve include Mountain Fynbos, Afro-Montane Forest and Renosterveld, with an array of invasive species on its lower, southern slopes.

Because the fynbos biome thrives in nutrient-poor soils, they only provide limited nutrition to large vertebrates. However, the diverse mountain fynbos on the reserve, in addition to the valleys and crevices, harbor distinctive pockets of vegetation, supplying food and shelter to a variety of fauna.

In the past, portions of Wildcliff were used for farming. In 2007, Ian and Jennifer Giddy purchased the property on behalf of the Wild Cape Nature Trust from Jeanne and Gordon Hewland who had lived there for fifteen years, farming cattle. The goals of the trust include conservation, restoration, research and education. As such, Wildcliff will be maintained as a nature reserve in perpetuity for these purposes.

Geographical Information Systems (GIS)

Almost all ecological research is inherently spatial and needs to be put into a local or regional context. Maps are conceivably the most direct route to understanding research results and the status of the wildlife and natural resources at Wildcliff.

On the other hand, a map lacks particular information of importance, regardless of how detailed it is. We can follow every twist and turn in a road, but what is the name of the road? How long is it? Paved or unpaved? These kinds of detail require tabular data 'underneath' the geographical features. When the mirror reflection of reality that we see in

maps is combined with facts and measurements, then we have a Geographical Information System, or GIS.

GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps. Some of the earliest applications of GIS were driven by the need to quantify environmental attributes and processes. Today they empower researchers and ecologists to expeditiously acquire, analyze, and display spatial data on organisms and their environment (Johnston 1998, Wadsworth and Treweek 1999).

The development of these technologies is ideally suited to furthering the conservation efforts at Wildcliff, allowing researchers to access and utilize current, historical and time series information relevant to conservation and ecological research.

Objectives

GIS software is the an ideal tool to further Wildcliff's objectives of conservation, restoration, research and education, allowing researchers to merge data from many different sources, scales, and dates and recombine them in a powerful display and analytical environment. The main objectives of this project will be to:

- Provide baseline ecological data for resource managers and researchers
- Provide opportunities for future inventory, monitoring, and research activities

The central task of this GIS project will be to create layers of environmental features on the reserve, beginning with and drawing on the mapping that has already been done. This information will be included with current layers such as contour lines and reserve boundaries to create a comprehensive GIS which will improve the quality and usefulness of maps and spatial environmental data of Wildcliff available. Later research will be expanded to include spatial datasets involving current and completed research, as well as the progress of alien vegetation eradication on the reserve.

The resulting Wildcliff GIS from these studies will allow researchers to combine all of the available data so they can begin to explore it and ultimately test hypotheses in ways that were not possible only a decade ago. As new research is conducted, the data can be entered into the system, which constantly enlarges Wildcliff's database and thereby enables researchers to compare data over time.

Components of the Wildcliff GIS

Software

Software is essential for creating, editing and analyzing spatial and attribute data. For purposes of this project, the ArcView (ArcMap) program of ESRI ArcGIS9 will be used. ArcView is full-featured GIS software for visualizing, managing, creating, and analyzing geographic data.

Hardware

Hardware comprises the equipment needed to support GIS data collection and analysis. This will consist of:

- A workstation which runs the GIS software and serves as the connection point for supplementary equipment. For this the researcher's Toshiba Satellite laptop will be used.
- A Garmin 76S, a waterproof handheld GPS with 24 MB of memory, a 10,000 point track log, an electronic compass and a barometric altimeter. Used to collect location data in the field.
- A waterproof digital camera, used to take digital images of high resolution. This camera will be utilized primarily for vegetation studies.

Data

In a GIS, every geographical layer contains the location details for all of the features of that layer. So, a layer of soil survey points, for example, will hold the latitude and longitude information for every point, but every GIS file format also has the capacity to maintain a table of information regarding those points. A soil layer may contain every soil survey point's soil classification, composition, etc. in addition to the point locations. The familiar GIS 'shapefile' format is actually a compilation of digital files; one containing the geographical data (file extension .shp), another containing the tabular data (file extension *.dbf) and the third containing the index between the first two (file extension *.shx).

Each GIS layer, or theme, represents a category of information, such as forest cover or trails. The themes integrated into the Wildcliff base GIS will be organized as follows:

Layer: Reference
Map use: Location finding
Representation: Map grids, labeled tics at map edge

Layer: Cultural
Map use: represents cultural features and landmarks
Representation: Points, lines, areas, and annotation

Layer: Boundaries
Map use: Admin and legal boundaries of the reserve
Representation: Lines with areas to support annotation

Layer: Hydrogeography1
Map use: Rivers and streams
Representation: Lines

Layer: Hydrogeography2
Map use: Ponds and dams
Representation: Areas

Layer: Hyspogeography
Map use: Represents terrain
Representation: Elevation points, contour lines, TINs, DEMs, and hillshades

Layer: Soil
Map use: Represents distribution of soil types

Representation: Raster surface

Layer: Soil survey locations
Map use: Displays the location of soil survey points
Representation: Points

Layer: Vegetation
Map use: Representation of major as well as minor vegetation types: montane fynbos, renosterveld, afromontane forest, wetlands, and clusters of alien species
Representation: Areas and rasters

Layer: Image Base
Map use: Map background and reference
Representation: Raster

Multiple datasets will be imported into the GIS from previous studies both at Wildcliff and in the general region. These include:

- A theme database with topographical 20m contour lines created by Jim Cory, a scientist in Wisconsin.
- A theme database containing the location of existing buildings, structures, and roads on the reserve (also compiled by Jim Cory).
- Shapefiles of general South African geology and vegetation regional boundaries.
- Theme databases representing results of studies already conducted at Wildcliff, such as the mammal survey, baboon troop movements and areas of alien vegetation removal.

Methods of data acquisition

After compiling existing geographic data layers into a GIS project, new data will be assembled in the field using a handheld GPS with a built in altimeter. This GPS will be used to accurately and efficiently find locations of environmental features not previously mapped at Wildcliff. Data from the GPS will later be uploaded on to the computer and assembled as shapefile data layers using ArcGIS software.

Additional notes about attribute features will also be taken in the field. This data will be handwritten in a chart which also includes the attributes' corresponding GPS position so that they can later be placed into their appropriate feature class attribute tables. For this a personal geodatabase will be created containing attribute data for existing and accumulated data pertaining to the reserve.

Data to be collected in the field over the course of study will include theme databases of vegetation, soil and wetlands. These will be organized as follows:

A.) Vegetation Dataset

After a vegetation classification system is decided upon, vegetation boundaries will be mapped via GPS and later imported into ArcGIS as shapefiles. Attribute information gathered in the field will consist of the classification label, at least four associated species, and a confidence estimate. If necessary, the researcher will note and additional vegetation classifications within the plot and their relative percent cover.

Tables of the multiple vegetation classes will be merged into a single table using Microsoft Access software, and then used with the JOIN command in ArcView to assign attributes to the GIS vegetation coverage. The result will be a single GIS coverage depicting

the location and extent of vegetation on the reserve. This layer will be duplicated and the copy rasterized for possible future spatial analysis which may require it.

The resulting vegetation map and database will allow easy access to vegetation data, detect change, and allow determination of underlying influences of vegetation distribution. It will also afford systematic updating of the map in the future.

B.) Soil Dataset

A soil survey will be undertaken during the course of research in order to create a complete database and map of the soil characteristics at Wildcliff. The locations of these survey points will be recorded using the GPS then imported into ArcGIS under the 'soil' feature dataset.

Core samples (using a handheld soil auger) and surface soil samples will be collected and labeled according to their location on the GPS receiver. The samples created during the survey will later be analyzed in the lab in order to create feature classes based on soil texture, pH and classification.

Soil will be classified according to the guide on the South African Agricultural Geo-referenced Information system (AGIS) website, provided by the ARC Institute for Soil, Climate and Water. This includes classification of topsoil as well as subsoil layers. This soil classification system was created specifically for South Africa, published first in 1977. It uses unique combinations of topsoil and subsoil horizons (layers) to place a soil into a specific soil form. Other characteristics within the soil form are then applied to define the soil series.

Back at the lab, surface soil samples will be tested for texture (% sand/silt/clay) and pH. To test for pH, a handheld pH meter will be used (supplied by the researcher).

Data from the soil survey will be contained entirely in 2 tables, Soil and SoilSurvey, and related by common fields. Data entry in the Soil table will be saved in the dBase IV file format (.dbf). SoilSites data will be entered in the attribute table of the collection sites shapefile, which is automatically saved into a separate dBase file by ArcMap.

The Soil table fields will include:

SoilID – Indexed identification number assigned to each soil classification, formatted as S001, S002, etc. This field is used as the primary key of the table, so there can be no repetition of records.

Description –Brief description of the classification according to the ARC Institute for Soil, Climate and Water.

The SoilSurvey table will originate as the attribute table of the survey collection sites shapefile. Fields will include:

SiteID – Indexed identification number assigned to each collection site. This field has no duplicates, and is used as the primary key of the table.

SoilID – Individual soil type identification number, related to the field of the same name in the Soil table.

Sand – Percent composition of sand in the surface soil sample.

Silt – Percent composition of silt in the surface soil sample.

Clay – Percent composition of clay in the surface soil sample.

pH – Measured pH of the surface soil sample.

Comments – Description of any unique components of the soil sample.

C.) Hydrogeography Datasets

Wetlands comprise a relatively small proportion of the terrain at Wildcliff, but their unique flora and fauna as well as their role in the reserve's ecosystem will make them an important aspect of the Wildcliff GIS. A map containing the approximate location of the three locations of natural wetlands on the reserve will be taken into the field and groundtruthed using the GPS device. This information will also be uploaded as polygon shapefiles and integrated into the GIS. Locations of dams on the reserve will also be included with this dataset in the same matter.

The existing files containing the locations of rivers and streams will be included in a second hydrogeography dataset. These locations will be groundtruthed to ensure their accuracy and provide more locational definition.

Products

Basic maps produced by this project will include soils, vegetation boundaries, hydrogeography, and a DEM (digital elevation model). Overlays of roads and structures will be included on all maps for reference. More detailed maps will be created depending on their relevance to research at Wildcliff. These may include an interpolated surface map of pH or a soil texture map.

The resulting map layers of the digital Wildcliff base map can be superimposed in any combination and can be used by researchers to easily create digital distribution maps from collection lists for dissemination and analysis. This system will make it possible to carry out a number of analyses and visualizations. For example, researchers would be able to:

- plot the distributions of particular species and use overlays to visualize coincidence of distribution patterns with geographic and environmental features
- map values for morphological characters onto the distribution points in order to examine character variation over the range of the species
- quantitatively analyze spatial statistics (such as plotting plant height to see elevation or soil patterns)

Cited

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