AN OPERATIONAL GIS FOR FLATHEAD NATIONAL FOREST

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ABSTRACT

Flathead National Forest is utilizing Geographic Information System techniques to establish an updateable, forest-wide, geographic database. Hungry Horse Ranger District, discussed in this paper, is the first of five ranger districts to be completed. GIS data layers for the Hungry Horse District include: digital terrain data (elevation, slope and aspect); Landsat data classified by spectral class and then stratified by elevation and aspect to depict vegetation associations; timber compartments; timber harvest history; land types; land ownership; administrative areas such as wilderness areas, recreation areas, wild and scenic areas, and experimental forest boundaries; mean annual precipitation; drainage basins; streams, rivers, lakes and islands; roads and trails; as well as data planes depicting distances to water and distances to roads. Techniques used to compile the database are discussed; various data planes are depicted through illustrations; and, applications of the GIS database are described.

INTRODUCTION

Flathead National Forest (FNF) encompasses approximately 2.6 million acres in northwest Montana (Figure 1) with Forest headquarters in Kalispell. Bordered on the north by Canada and on the northeast by Glacier National Park, FNF is confronted with the problem of managing an area with diverse concerns. To balance the needs of timber, wildlife, and recreation in an economically and ecologically sound manner, it is increasingly important that map and tabular information be available to resource managers. FNF has adopted the use of a Geographic Information System (GIS) as one means of supplying information in a timely and economical fashion.

Primary data compilation for FNF's GIS database started in 1982 in the Hungry Horse Ranger District (HHRD). The completed HHRD database has served as a demonstration of GIS capabilities to other ranger districts and regional Forest Service offices. In 1984, Forest managers scheduled the establishment of 17 to 25 primary data planes for each of FNF's four remaining ranger districts over the next three years. Management problems differ from one ranger district to the next. As such, GIS data planes will be compiled to meet the needs of each individual ranger district.

Among Forest Service GIS efforts, this project is unique in two respects: the Forest Service has not acquired any additional computer hardware or software to reach the present operational stage; and, Forest Service personnel perform all project work rather than having the project contracted to an outside service agency. Personnel at FNF headquarters perform Landsat classification, map digitization, data management, project implementation coordination and applications through data plane manipulation. As the database for each ranger district reaches the operational stage, ranger district personnel receive training in data plane combination and query techniques enabling data manipulation capabilities at the ranger district office. During the planning and startup stages, the overall project design and guidance with implementation techniques required collaboration with data processing and image analysis consultants at Washington State University Computing Service Center (WSUCSC). The need for consulting from WSUCSC staff diminishes steadily as Forest Service personnel gain skill and familiarity with the systems.

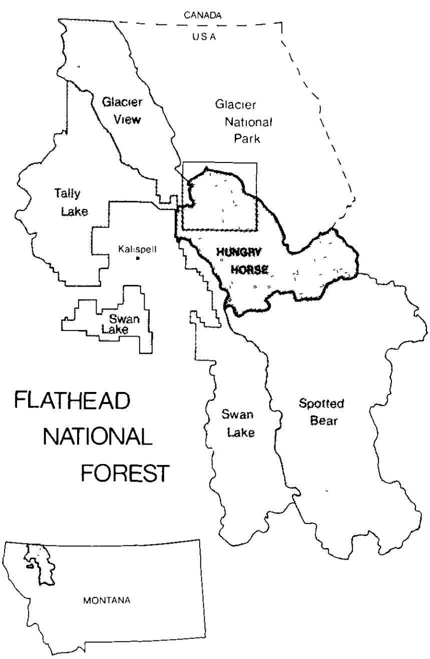

Figure 1: Flathead National Forest. The boxed area at the north portion of the Hungry Horse Ranger District delineates the area shown in the remainder of the figures.

METHODS

Processing and manipulation of the database is accomplished through the facilities in the Digital Image Analysis Laboratory (DIAL) at the Computing Service Center in Pullman, Washington. DIAL systems include Video Image Communication and Retrieval/Image Based Information System (VICAR/IBIS), a batch oriented system, which runs on an Amdahl 470/V8 mainframe; and, an International Imaging Systems-System 511, an interactive system, which is resident on a dedicated PDP 11/34 mini-computer. The FNF's Data General NV8000 is used as a Remote Job

Entry/Remote Job Output station via teleprocessing to WSUCSC's mainframe environment.

VICAR/IBIS, the primary processing system used in this project, utilizes raster-based GIS techniques. Raster format data can be conceptualized as a two-dimensional matrix of data elements called pixels. Each pixel stores one data value and the location of the pixel in the data matrix denotes its geographic location. The GIS data planes, a collection of spatially corresponding raster files, are manipulated mathematically using digital image processing algorithms (Jaffray, Hansen & Hart, 1984).

Data Acquired in Digital Form

Defense Mapping Agency (DMA) digital terrain data and Landsat Multispectral Scanner (MSS) data were acquired in computer compatible format on magnetic tapes. Both DMA and Landsat datasets are standard products distributed by U.S. Geological Survey and National Oceanographic and Atmospheric Administration respectively. For compatibility with VICAR/IBIS, the format of each dataset was restructured with specialized VICAR/IBIS "logging" programs (Hart & Wherry, 1984).

Digital Terrain Data Processing. Four 1 x 1 degree DMA digital elevation blocks were geometrically corrected to a Universal Transverse Mercator (UTM) map projection and mosaicked into a 2 x 2 degree, 50 by 50 meter pixel image encompassing the HHRD. Best results were achieved in subsequent processing when DMA 16 bit pixel accuracy was preserved during this process.

Images depicting slope magnitude and slope direction (aspect) were modelled from the DMA elevation mosaic. Slope and aspect models were compressed to 8 bit pixel accuracy for storage efficiency and data generalization purposes. Data were represented as 40 vertical feet per pixel value; 1 degree of slope per pixel value; and 5 degrees of declination per pixel value on the final elevation, slope, and aspect GIS planes.

Landsat 2 MSS Data Processing. Landsat acquisition 22354-17420 (03 July 84, EDIPS format) encompasses all of the HHRD and Glacier National Park. This scene exhibited no cloud cover or data anomolies. Landsat classification and subsequent stratification procedures were performed by FNF personnel in cooperation with Glacier National Park researchers who are developing a GIS database in parallel with FNF (Haraden, 1984, and Key, et al., 1984).

The multispectral classification techniques employed in this project most nearly resemble the multi-cluster blocks technique described by Hoffer (1979). Numerous training areas of known cover type were processed through a clustering algorithm and the consequent spectral statistics were evaluated and compared. From several hundred original spectral classes, 99 were chosen for the final classification statistics set. The resulting classification of the entire Landsat scene did not adequately discriminate between land cover types. The spectral classes contained confusion between water and shadow, inadequate distinction between agricultural classes and natural grasslands, and confusion between certain timber categories and shrubs.

The 99 spectral classes were combined with elevation and aspect data forming 3,600 unique spectral-elevation-aspect categories. Contingency tables were constructed to correlate spectral-elevation-aspect categories with ground data and each spectral-elevation-aspect category was assigned to one of 189 land cover classes. This stratification process alleviated the confusion problems inherent in the multispectral classification and improved the quality of the classified Landsat product.

The southern two-thirds (the United States portion) of the classified, stratified Landsat scene was geometrically corrected to a UTM map projection at a 50 by 50 meter pixel resolution. A set of 38 control points (approximately one control point per 7-1/2 minute quad area) were selected in the DIAL facility by FNF and Glacier National Park personnel. Figure 2 shows a black and white rendition of the 189 land cover categories in the geometrically corrected, stratified, Landsat classification.

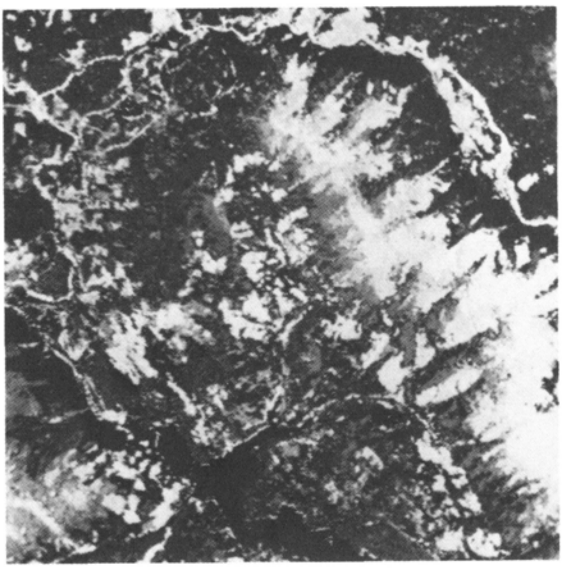

Figure 2: Landsat Classification. Stratified by elevation and aspect, registered to UTM map projection; 189 classes.

Data Digitized from Maps

Maps are digitized at the FNF headquarters offices in Kalispell using a Numonics model 2401 coordinate digitizer which is on-line to the Data General computer. Line segments are recorded in tablet inches, converted to latitude/longitude and subsequently to UTM coordinates, then edges are matched between separate quad sheets. The data files are mailed to WSUCSC on computer tape for incorporation into the GIS database. All but two data planes originated from 1:24,000 USGS quads.

Timber Harvest History. Records of timber harvest in the HHRD date back to 1943. The timber harvest data plane identifies each area by year and type of activity (thinning, selective cut, clearcut, etc.). For purposes of manipulation, summation, or display, data can be grouped as needed by any permutation of year and type of activity. Examples of year/type combinations are: all clearcuts of 1982; all areas which were thinned between 1970 and 1980; or, all types of logging operations for 1954.

Landtypes. Landtypes, outlined in Table 1, identify the opportunities and limitations associated with the physical characteristics of FNF. The landtype classification system is based on geologic processes (as reflected by physiography), soil types, and the factors which determine the behavior of ecosystems (i.e., climate, vegetation, relief, parent materials, and time) (Proposed Forest Plan, 1983). The Landtype data was derived from 1:63,360 scale maps.

Table 1: Landtype Classification System

Group 1	Flood Plains
Group 2	Wetlands
Group 3	Avalanche Fans, Talus
Group 4	High Alpine Basins
Group 5	Mass Failure Lands
Group 6	Alluvial Fans, Outwash Plains, and Reworked Tills
Group 7	Silty Glacial Tills
Group 8	Sandy Glacial Tills
Group 9	Clayey Glacial Tills
Group 10	Steep Glacial Tills
Group 11	Residual Soils, 20 to 40% slopes
Group 12	Residual Soils, 40 to 60 % slopes
Group 13	Alpine Ridges and Rocklands
Group 14	Glacial Trough Walls
Group 15	Fluvial Breaklands
Group 16	Structural Breaklands

Land Ownership. The Land Ownership data plane delineates private land holdings within the FNF boundaries. In the HHRD there are 16,600 acres of private land.

Administrative Areas. The Administrative Areas data plane delineates areas such as the Coram Experimental Forest (8,020 acres), Wild and Scenic River System (13,838 acres), and wilderness and primitive areas. The HHRD shares administrative responsibilities with other ranger districts for the Great Bear Wilderness (286,700 acres) and the Jewel Basin Hiking Area (15,368 acres).

Precipitation. Mean annual precipitation data derived from snow surveys and Soil Conservation Service historical records were drafted on a 1:63,360 scale map. The precipitation isolines were then digitized and entered into a GIS data plane. Precipitation in the FNF ranges from 20 inches to 120 inches per year.

Timber Compartments. Timber Compartments (Figure 3) are management units of timber stands used for timber inventory purposes. Boundaries of these units were determined by ridges and streams. The Timber Compartments data layer correlates this database to the Forest Service Timber Stand Database at Fort Collins, Colorado.

Drainage Basins. The Drainage Basin data plane shows the watershed boundaries in the HHRD (Figure 4). Information from the GIS database is often summarized by watershed area using a polygon overlay process.

Roads and Trails. Figure 5 illustrates the road network in the HHRD. Line segments denoting segments of road are classified by seven different schemes as shown in Table 2. Trails occupy a separate data plane as do each of the seven road classification schemes.

Figure 3: Timber Compartments. Management units for timber inventory.

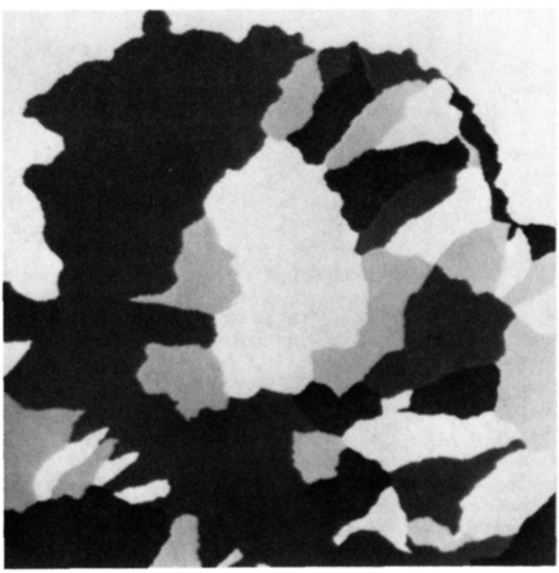

Figure 4: Drainage Basins. Watershed boundaries.

Figure 5:
Road System.
All existing roads.

Table 2: Road Classification Schemes

Road Function Class		Road Service Level	
1	Other	1	paved, double lane
2	Arterial	2	gravel, double lane
3	Collector	3	gravel, single lane
4	Local	4	dirt

Road Management Reason		Road Management Jurisdiction	
1	public safety	1	County
2	resource protection	2	State
3	soil and watershed	3	Forest Service
4	management direction	4	State forest
5	wildlife	5	private
6	administrative	6	Class D permit

Road Management Device		Road Management Date	
1	Barrier	1	closed year long
2	Controlled gate	2	closed 4/1 - 7/1
3	Service barrier	3	closed 10/15 - 11/30
4	Gate	4	closed 12/1 - 5/15
5	Signed	5	closed 10/15 - 5/15
6	Controlled by sign	6	closed 10/15 - 7/1
7	Controlled by barrier	7	closed 9/1 - 7/1

Road Maintenance Level	
1	custodial care only
2	limited passage
3	low usage/care
4	moderate usage/care
5	maximum usage/care

Hydrology. Streams are recorded as first through fifth order, perennial or ephemeral. Line segments denoting the South and Middle Forks of the Flathead River are given different values; and, islands are differentiated from lakes. Figure 6 illustrates the hydrology data plane.

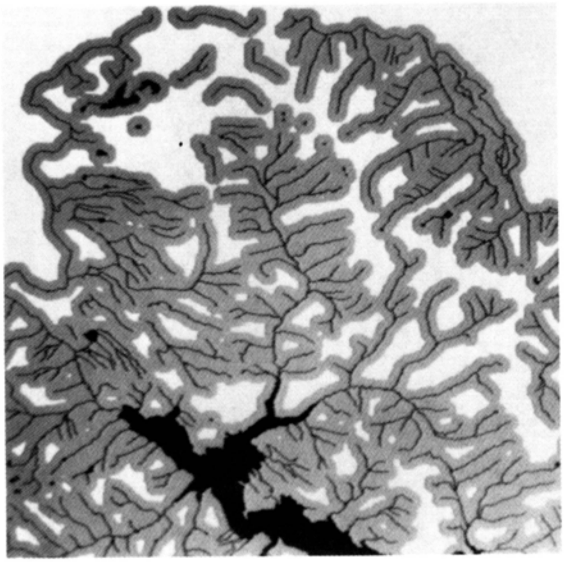

Figure 6: Hydrology. Streams, rivers, lakes and islands; 600 meter distance to water is shaded.

Distance Function Data Planes. Graduated distance corridors were modelled from the hydrology and roads data planes. Pixel values in the distance corridor image indicate how far any pixel is from a road or hydrologic feature. The distance modelling is accomplished with iterative applications of a convolution filter to the data plane of interest. Corridors identify distances between 0 and 1,200 meters.

APPLICATIONS OF THE GIS

In one application utilizing the HHRD database, a data plane depicting distances of zero to 600 meters from water was digitally overlaid with another data plane delineating timber harvest areas. The resulting image and acreage summary quantifies areas which present erosion hazards in that particular watershed.

A road viewshed plan presently being constructed will be used by the FNF landscape architect to design scenic and recreational qualities along a heavily traveled reach of highway. In this application, a distance corridor around arterial roads is superimposed with information from the data planes delineating hydrology, timber harvest, and generalized Landsat classification. Information from these images will be used to plan management of timber harvest methods along the road to enhance the recreational and visual experience and provide a pleasing spatial arrangement to the traveler.

Generation of a map showing areas critical for elk calving habitat is a good example of the utility of the FNF GIS. Modelled after Langley

(1983), Table 3 outlines the selection criteria used in manipulating the HHRD data layers. An acreage summary of the three suitability categories revealed 253 acres of Optimum, 1,798 acres of Acceptable, and 94 acres of Marginal elk calving areas in the HHRD. The data plane depicting elk calving areas will be used in conjunction with the distance to road data plane to evaluate road closure in areas of critical habitat.

Table 3: Elk Calving Criteria

Optimum
- elevation: 4,000 - 4,800 feet
- aspect: flat or south facing
- proximity to water: less than 300 meters
- vegetation: non-forest; less than 50 acres in size

Acceptable
- elevation: 3,500 - 5,000 feet
- aspect: southwest or southeast facing
- proximity to water: 300 - 750 meters
- vegetation: non-forest; greater than 50 acres in size

Marginal
- elevation: above 5,000 feet
- aspect: west or east facing
- proximity to water: 750 - 1,200 meters
- vegetation: timber

CONCLUSIONS

The demand for information from the FNF GIS database grows steadily with each successful application of manipulation and query capabilities. The implementation of this GIS has passed the all important test of user acceptance and is becoming an integral part of strategies for accessing resource management alternatives.

The resolution and accuracy of the GIS database meets or exceeds the quality of FNF databases constructed by traditional methods. In addition, the computer assisted GIS approach affords FNF personnel a quicker and more economical means of updating the database. Manual cartographic updates are replaced by data file editing and rerunning a series of computer jobs.

FNF personnel estimate that the GIS will save a significant amount of money and time and provide the ability to explore a larger variety of management alternatives. The GIS will allow planners and managers to analyze alternatives on critical lands where vegetative manipulation and other project proposals can achieve the desired objectives of land management economies and efficiencies.

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BIOGRAPHICAL SKETCH

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