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INTRODUCTION

Background

The Monongahela National Forest spans 10 counties in eastern central West Virginia. Over the past 100 years it has been subjected to a high degree of mining and timbering. Mining techniques in the area include both open-pit and deep mines. Much of the area has been subjected to mining after effects including acid mine drainage, structural remains, gob/spoil piles, garbage piles, run-off ponds, mine portals, and highwalls. Recently the United States Forest Service (USFS) has started to focus its efforts on the reclamation and remediation of these abandoned mine areas. The Abandoned Mine Lands inventorying process was assigned to the U.S. Army Corps of Engineers (USACE) in 1998 by the United States Forest Service (USFS). An initial step in this process required the USACE to conduct a survey of post-mining related features, providing descriptions and georeferenced locations for each encountered feature. Locations were determined using the Department of Defense Global Positioning Satellite (GPS) system. The Global Positioning Satellite (GPS) system receiver can calculate exact coordinates for any position on earth through a series of calculations involving measurements from a group of satellites to the desired position (Trimble 1996a). Four satellites are used to find an unknown X, Y, Z point location; this narrows the desired location to 1 point (Trimble 1996a). *The data was then entered into a geographic information system (GIS). The data from this GIS was then compared with existing 7.5-minute digital georeferenced topographic maps (or Digital Raster Graphics (DRG), Digital Orthophoto Quarter Quadrangles (DOQQ), and Landsat 7 + Enhanced Thematic Mapper (+ETM) data. A problem was however discovered, in that spatial features did not correlate correctly between the various data sets. This paper presents the methods and techniques used to collect and analyze the data, addresses the various problems associated with data, and proposes solutions and future studies to help alleviate the problems.*

Objectives

There were four primary objectives to this research:

- The first objective was to establish the difference, through discussion, between the datum's of the World Geodetic System of 1984 (WGS84). The WGS84 is essentially the same as the North American Datum of 1983 (Trimble, 1996a) as used in this research, and the North American Datum of 1927, as they pertain to data collection of Global Positioning Systems.
- The second objective was to compare the advantages and disadvantages between the use of DRG's and DOQQ's as a base map within a GIS. Additionally, a demonstration the benefits of a high and low resolution Space Borne image such as IKONOS (simulated by DOQQ imagery) and Landsat 7 +ETM, for larger coverage areas was addressed.
- The third objective was to create a Geographic Information System (GIS) database for Geobiophysical Modeling using data previously collected from the Monongahela National Forest Abandoned Mine Lands Inventory. The GIS database included all collected features such as ponds, highwalls, spoil/gob piles, rubbish piles, structures, portals and haul roads with drainage.
- The fourth objective was to create a spatial display of the georeferenced points using USGS DOQQ's and Landsat 7 +ETM. Sample views were also created using Arcview's Spatial and 3D Analyst (ESRI, 1996) containing Digital Elevation Models to perform hillshading, 3-dimensional views, and slope within a selected DOQQ, Snyder Knob NE.

Objective 1 – Discussion of Datums

*The USACE inventory data was collected in the North American Datum of 1927 (NAD27) using a Trimble GeoExplorer II receiver (Trimble, 1996b). T*he NAD27 is used since it complies with United States Geological Survey (USGS) 7.5-minute digital georeferenced topographic maps. However, the use of

NAD27 for data collection or reference maps does not accurately portray the shape of today's earth. The NAD27 datum model was based on the Clarke Ellipsoid of 1866 (USGS, 1999).

The more modern datum, the World Geodetic System of 1984 (WGS-84), was developed to more accurately reflect the current dimensions of the earth (Trimble, 1996a). The North American Datum of 1983 (NAD83) is a "local datum" that was created to reflect the shape of the earth with reference to North America. NAD83 is now based on the WGS-84 model and, to reflect this, has been modified to NAD84 by using corrected GPS positioning on the earth.

NAD83 is the most current datum used for georeferencing satellite, aerial, and related imagery (USGS, 1999). GPS receivers collect data from satellites using the WGS84 datum and then convert this to the desired datum for projection. The USACE inventory was converted to NAD27 internally by calculations made in the GPS receiver, however, an error will still exist (Trimble, 1996a), because even the most accurate conversion programs based on the National Geodetic Surveys NADCON (North American Datum Conversion) leave an error of 0.5 meters (USGS, 1999). This difference is negligible, as larger differences exist depending upon location in different parts of North America (USGS, 1999). Differences between the two datum's, prior to conversion, can measure up to at least 200 meters in the north-south direction (USGS, 1999). For this reason the World Geodetic System of 1984 (WGS84) was developed and should be the primary datum used in all current data collections.

Objective 2 – DRG's and DOQQ's

The USGS 7.5-minute georeferenced digital topographic maps (or Digital Raster Graphics (DRG)), are based on the standard USGS 7.5-minute paper quadrangle maps which were initiated in the 1930's and were initially projected to the NAD27 datum and now to NAD83. Use of these maps as a GIS base map can prove costly based on their date of currency. Original production of USGS 7.5-minute quadrangle maps began in the 1930's and reached peak publishing around 1970. Production of these maps continued until the early 1990's with the average publication date for these initial 7.5-minute quadrangles being 1967. Since the early stages of the USGS map production revisions have taken place. The average date of publication for these revisions is 1979 (Moore, 2000). This information indicates that the majority of these 7.5-minute quadrangles, and subsequent DRG's, are more than 20 years old. Not only has the land surface changed throughout this time, but also other information shown on these maps including demographics, land use, and land classification to name a few have changed as well.

Introduction of USGS Digital Orthophoto Quarter Quadrangles began in 1991. A Digital Orthophoto Quarter Quadrangle (DOQQ) is a computerized image of an aerial photograph which combines the characteristics and quality of an image with the geometric qualities of a map (USGS, 1998b) using color infrared (CIR) photography as basemap source (Moore, 1997). It refers to a 1-meter ground resolution quarter quadrangle representing 3.75 x 3.75 minute area (USGS, 1996a), although most DOQQ's have overlapping edges to allow for edge matching and mosaicking. The amount of overlap differs between DOQQs (USGS, 1996b), from 50 to 300 meters (USGS, 1995). DOQQ's meet U.S. National Map Accuracy Standards, at a scale of 1:12,000, requiring that 90% of the well-defined points tested must fall within 33.3 feet/10.2 meters (1/30 inch or 1/11.8 centimeters), (USGS, 1998b).

The DOQQ's are projected by the USGS using the UTM system on NAD83, and are being updated to WGS84, which is displayed in the header files that accompany each DOQQ. This file also includes the date of the photograph, coordinates, primary and secondary datum, resolution and additional information (USGS, 1995). This digital format can be used as an image basemap in a GIS for the inventory. A GIS is a powerful computer mapping system used as a tool for managing georeferenced information (ESRI, 1998). The implementation of a quality GIS presents many advantages with regard to data management and the spatial distribution of information. A digital GIS creates the inventory presentation with quality maps and allows paper forms of the data to be manipulated and displayed spatially.

Photographs of the study sites were taken between 1996 and 1999 during leaf off periods of deciduous trees (USGS, 1996a). The DOQQ's were originally created using the latest and most accurate NAD83 datum, but are now using the more current NAD84. The DOQQs simulation of data fused IKONOS high resolution imagery represent the quantity and quality of future products that can be derived. Therefore, timely database using these various information can result in a more useful GIS database.

The U.S. Geological Survey and National Aeronautics and Space Administration developed the Landsat program as an initiative to collect accurate Earth imagery through the acquisition of repetitive images of the Earth from space (USGS, 2002b). Landsat 7 was launched in 1999 and is an eight-band multispectral scanning system that collects imagery at a resolution of 15 meters in the panchromatic band and 30 meters in the 6 visible, near and short-wave infrared bands (USGS, 2002b). Additionally, there is available space borne imagery (IKONOS, Quickbird, etc.) at one meter resolution for panchromatic and four meter resolution which, through data fusion, can provide imagery that can be simulated by DOQQ's.

Statement of the Problem

Primary methods of data collection for the USACE/USFS GPS surveys, as they apply to the Monongahela National Forest Abandoned Mine Lands inventory, require that the projection and coordinates be Universal Transverse Mercator (UTM) in NAD27. The North American Datum of 1983 represents a much more accurate depiction of the location of features on the earth's surface. As a result of this, data collection in NAD27 will not correlate correctly with the more accurate NAD83 datum and more detailed imagery, such as the DOQQ's and high resolution space borne imagery, such as IKONOS, without coordinate conversions using appropriate programs such as NADCON (USACE, 1997) or GEOTRANS (USACE, 1997). The level of accuracy of the NAD27 1:24,000 DRG's is less than that associated with the 1:12,000 DOQQ's of WGS83/WGS84. In association with the problem of the use of NAD27 GPS data collection is the use of NAD27 USGS 7.5-minute DRG, or the recently re-projected NAD83, versus NAD83 USGS DOQQ's and high resolution space borne imagery for GIS base maps. This outdated method of data reference was the required digital base map by the USFS (USFS, 1998). However, updated publications by the USGS have re-projected these DRG maps to NAD83, leaving no viable use for NAD27 DRGs(Moore, 2001). Consequently, the use of the USGS 7.5-minute, 1:24,000 scale, topographic map for a GIS base map creates an additional problem. This is addressed in this research. For this reason a more accurate, current high resolution image base map for the development of a GIS database is needed. The USGS NAD83 DOQQs and high resolution commercial space borne imagery (for detailed analysis and for larger synoptic coverage, the lower resolution Landsat 7 +ETM) can be used.

Statement of the Solution

- This research provides a comprehensive GIS database, using the USGS DOQQ's simulating high resolution space borne imagery and Landsat 7 +ETM, as a base map for overlaying the data collected during the inventorying of the Monongahela National Forest.
- The issue of NAD83 versus NAD27 has been addressed in this research and will provide evidence to establish precedence for upgrading GPS data collection to the newer datum, NAD83 or NAD84, when future work is performed.
- The implementation of DOQQ's for this research will simulate high resolution space borne imagery and show their image capabilities, resolution, and detailed features to both the USFS and the USACE.

Defense of Research

To facilitate the objective of creating an accurate and comprehensive GIS, it is necessary to mention the complications and location inaccuracies associated with collecting GPS data using NAD27. The geoid shape of the earth is changed with WGS84. Newer calculations are compensating more and more for these changes across the earth (USGS, 1999). As a result of these changes that are taking place, older datum's used to represent the shape of the earth are becoming more and more inaccurate and outdated. For this reason a global best fit datum was developed by the National Imagery and Mapping Agency of the US Department of Defense (Higgins, 1999). This datum, known today as the World Geodetic System of 1984 (WGS84), has been revised since its initial inception to a level of accuracy better than 2 cm (Higgins, 1999). Based on these measurements, local datum's have been developed to increase the level of accuracy even further. One such datum is the North American Datum of 1983 (USGS, 1999). Differences in NAD27 and NAD83 GPS collection data can be up to 200 meters apart in the north-south direction and up to 30 meters in the east-west direction (USGS, 1999). These differences in datum's, data collections, and GIS database creation with different base maps were the primary focus for this research.

METHODS AND TECHNIQUES

The technique in initializing the inventory collection process creates an abandoned mines data dictionary that summarized all encountered features in the field. In order to conduct the field survey with the greatest likelihood of accuracy it was necessary to perform the inventory during leaf-off period, mid-November to early April, reducing the likelihood of the vegetative canopy acting as a shield and preventing the GPS units from providing an efficient signal to the satellites (Trimble, 1996a). The Trimble GeoExplorer II unit (Trimble, 1996b) was configured to maximize collection accuracy. These parameters were outlined in the scope of work provided to the USACE from the USFS and included in the Trimble handbook (Trimble 1996b). The GPS receiver collected data for a minimum of 100 positions per site. On some occasions due to tree limb canopy cover or satellite positioning it was not feasible for the GPS to reach this many positions. The site position collection of the hand-held units is an average. Therefore accuracy is not adversely compromised when less than 100 positions are collected (Trimble, 1996a).

After all points were checked for numbering accuracy, the locations were differentially corrected using the Morgantown, WV base station maintained by the West Virginia Department of Environmental Protection (WVDEP), to overcome a process known as selective availability. This process purposely degrades the accuracy of GPS units used by the public and has since been discontinued as of 1 May 2000 (Clinton, 2000). The differential correction data was collected from the WVDEP website http://129.71.240.42/gps/cal.html. The base station provides differential correction of rover files which can improve GPS data position accuracy from 10 meters, to 2-5 meters. The process of differential correction, as used in this inventory collection, overcomes the error associated with selective availability by using a static base station and a roving survey station. This differential correction subtracts the measured error at the base station, from the error associated with the roving unit (Wood, 2000). The farther the roving station is away from the base station, the less accurate the positions are. After correction, the file was exported from Trimble Pathfinder Office (Trimble, 1997) into a readable format know as the American Standard Code for Information Interchange (ASCII). This file format was a means of allowing the data to be imported into an Excel spreadsheet (Dodge, et. Al., 1997) and saved as a database, .dbf file**.**

Once the data was collected, post-processed, and imported into spreadsheet format it was integrated into GIS software. ArcView version 3.2a (ESRI, 1996) was chosen to compile and process all collected data for this project. The overview area was represented by selecting various digital datasets to outline the inventoried area. The first two datasets, states and counties, were chosen from the ESRI data included with the Arcview 3.2a software (ESRI, 1996). The view needed to be re-projected to a coordinate system that coincided with the feature data and additional base map imagery, which was UTM 1983, Zone 17, by changing projection on the view properties. In order to focus only on West Virginia, the files were clipped. To do this, the states theme was activated and the theme table displayed. From here the West Virginia feature was found and highlighted and the theme table closed. Next, the states theme, with West Virginia highlighted, needed to be converted to a shape file from the theme drop-down menu. An appropriate name and location was selected and then the shapefile was created and saved in the new projection. The theme could not be added to the view because of this. The counties shapefile was created in the same manner, with the exception of selecting each county within the state at the opened theme table. The newly created shapefiles were then added to their own view along with a boundary of the Monongahela National Forest, obtained from the USFS in shapefile format.

For this research a comparative analysis was made between a representative NAD83 DOQQ and NAD83 DRG for purposes of depicting advantages of upgrading to the more detailed high resolution space borne imagery represented by the DOQQ's. In addition, an overview of the project area was created using the Landsat 7 +ETM coverage of the state. Due to the amount of data in the inventory and the vast coverage area of the Monongahela National Forest digital space borne imagery made it feasible to display a large area. In order to provide an image with even greater resolution (15 meters) a data fusion technique, using ER Mapper 6.3 (Earth Resource Mapping, 2002), was performed. The existing 30-meter resolution Landsat 7 +ETM image was able to be refined, through a process known as data fusion, to enhance the image to 15-meter resolution. Landsat 7 +Enhanced Thematic Mapper mosiacked images, at a scale of 1:50,000 and with a resolution of 30 meters, were acquired for the West Virginia study site. This process required the importation of the appropriate Landsat bands. In order to produce the color infrared image, bands 4, 3, and 2 were used in the raster layes Red, Green, and Blue, respectively. Band 8, a panchromatic band with 15-meter resolution, was added as an Intensity layer. Once loaded into ER Mapper, each layer needed to be manipulated by editing the transform limits in ER Mapper 6.3 (Earth Resource Mapping, 2002) using histogram equalization. The resultant image is a color infrared 15-meter resolution Landsat 7 +ETM.

The most informative image base map that was used in this project was the digital aerial photographs (DOQQ), which represent the high resolution capabilities that can be achieved through space borne images from Ikonos (Space Imaging, 2002) and Quickbird (Digital Globe, 2002) with data fusion techniques. These are accessed from a collected database already compiled or from various GIS data collections such as the website, http://www.dep.state.wv.us/metadata/. These file types, known as MrSID files required an additional extension, available from www.esri.com in order them to be imported into the project. MrSID is an acronym for Multi-Resolution Seamless Image Database For this research, only the DOQQ's that contained the inventoried feature points were imported into the project.

The comparison between the information supplied by the DOQQ's versus the DRG's began with the importation of the Snyder Knob USGS 7.5-minute digital quadrangle. These are the standard maps requested by the USFS because of the amount of text data that they supply. The Digital Raster Graphic (DRG) maps are United States Geological Survey (USGS) digital topographic maps that have been scanned and georeferenced, or placed in their exact location in space based on a standard coordinate system. Typically the referenced datum is North American Datum 1927 (NAD27), however current procedures have changed this to NAD83 coinciding with the DOQQ's and the reprojected data set.

The primary GIS database has been completed to this point of the research, however geobiophysical modeling of datasets provided additional information that may be useful to both the USFS and the USACE in future projects. This process began with the importation of the National Elevation Dataset (NED) Digital Elevation Model (DEM) data set for the entire state of West Virginia. Before importing the grid, Spatial Analyst 1.1 and 3-D Analyst (ESRI, 1992) extensions must be activated. The NED DEM dataset was added to a separate view as a grid data source. Once activated in the view, the NED DEM dataset was clipped to a more manageable area. The output grid was clipped to the boundary of the Monongahela National Forest.

The newly added grid of the clipped area around the Monongahela National Forest allowed for various image analysis processes. Elevation #1 from the color ramp drop-down menu was selected to provide a more appropriate color selection. A 3-D scene was then made with the DOQQ draped on the DEM grid. To accomplish this, both themes were activated and turned on in the view. Then, 3-D scene was selected from the view menu, followed by selecting themes at the Add View to 3D Scene. With the 3-D scene legend open, all the themes were turned off, except for the DOQQ. Next, under Theme, 3-D Theme Properties a base height was assigned to the image to display it in 3-D. Surface was the assigned base height and the newly formed grid file was selected. A Z-factor of 1.5 was applied to the image to allow the features to be more distinguished. The pond inventory features were then displayed on the 3-D DOQQ by the same procedure. The Z-factor was set at 1.55 to place the points slightly above the DOQQ.

Using the Monongahela National Forest grid that was previously created, a slope and aspect analysis was created to help determine areas of steepness, and subsequently, water flow. This was performed by activating the grid theme and selecting derive slope from the surface menu. The newly formed slope grid is automatically displayed in the view. The aspect grid is formed in the same manner by selecting derive aspect from the surface menu. Another spatial analyst feature performed on this data set was the hillshade grid. This was created using the surface menu and selecting compute hillshade to create a relief type map of the gridded area.

RESULTS AND DISCUSSION

Objectives 3 and 4 - GIS Database

The GIS database was created to analyze the various data sets and produce useful output products that can be used to help with remediation efforts by the USFS.

MAP 1 was created using the Landsat 7 +ETM 30-meter resolution mosaicked image of the state of West Virginia, with the Monongahela National Forest boundary. MAP 2 is the same image as MAP 1 with the area of focus on the Monongahela National Forest. This display allows for a more specific look at the area of research. These first two maps provide an overview of the research area.

The result of the data fusion, through ER Mapper 6.3 (Earth Resource Mapping, 2002), can be seen in MAP 3 as a 15-meter color infrared image of an area approximately equivalent to Snyder Knob NE. This 15 meter space borne image provides more detail than that of the 30-meter resolution and still maintains the quality of the Landsat 7 +ETM.

A more detailed summary of the DOQQ inventory placement can be seen in MAP 4 of the Snyder Knob NE quarter quadrangle simulating high resolution space borne digital imagery. The database placement on a DOQQ base map revealed images of the actual strip mine sites, ponds, and related features viewable from the air. Cleared off areas within the image are the actual strip benches, while ponds are the darker (black) features. The majority of the ponds were located at the base of the highwalls.

The improvement in the information provided by the DOQQ base map versus the DRG base map can be seen in MAP 5. MAP 5 shows a side by side view of the USGS 7.5-minute Snyder Knob digital topographic quadrangle and the USGS DOQQ's of Snyder Knob NE/NW. This map provided detailed evidence that the DRG's are outdated and contains less accurate and detailed information. The pond inventory follows the strip mine bench in its entirety as seen in the DOQQ; however, the view of the DRG revealed that the strip bench stopped midway through the pond series. The source date for the DOQQ, as reveled by the header data, shows that the photograph was taken on April 8, 1997. Information provided on the collar of the DRG revealed that the map was first created in 1973 and field checked in 1974. The map was revised from aerial photographs in 1982, not field checked, and then edited in 1989. The twenty-three year difference from the first field checked date (1974) and the DOQQ photograph date (1997) showed dramatic changes in the land cover of the mining areas.

MAP 6 is a comparison of DOQQ images from Snyder Knob NE. The one on the left is NAD27, while the one on the right is NAD83. The inventory data is displayed on each view for a comparison of the difference between the two datums. Calculations to determine the actual displacement of the inventory after conversion to NAD83 from NAD27 can be seen in the following table.

NAD27			NAD83		
	Northing	Easting		Northing	Easting
Point 1	4331082	628224		4331302.48448	628239.82217
Point 2	4224166	553671		4224385.16665	553687.02733
Displacement	106916	74553		106917.31783	74552.79484
	Displacement value between NAD27—NAD83	Northing 1.31783 m	Easting 0.20516 m		

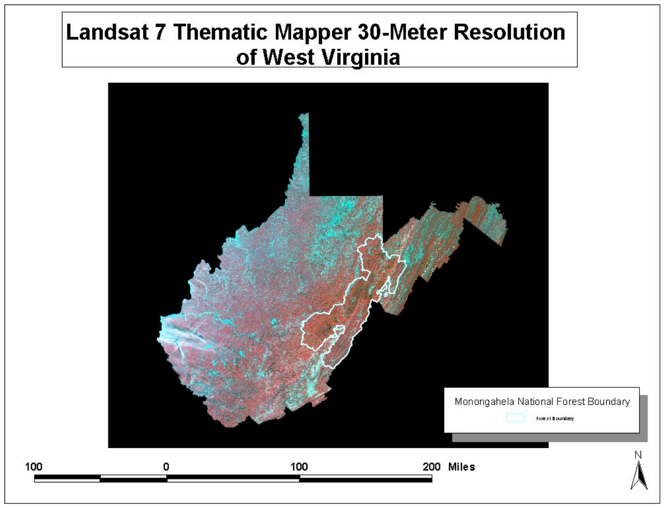
Table 1 Showing displacement of Northern most point (1) and Southern most point (2) before and after conversion with Corpscon from NAD27 to NAD83.

By using the Pythagorean Theorem to calculate the sides of a triangle the actual displacement distance can be calculated through the formula $A^2 + B^2 = C^2$, where A is equal to the Northing distance, B is equal to the Easting distance and C is the actual displacement between the two points. Substituting the values from the table into the formula gives the following:

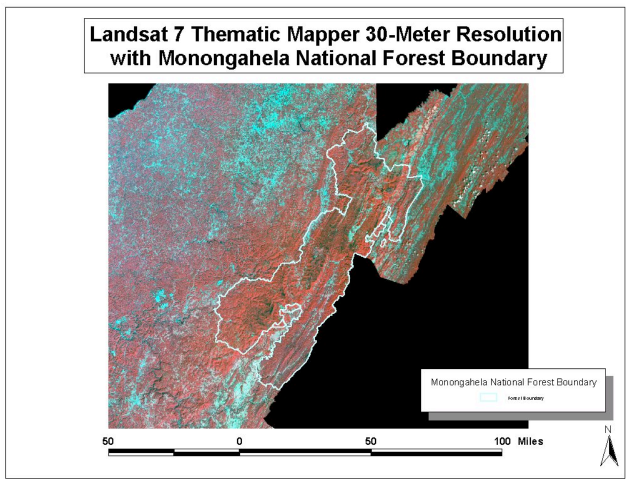
$$(1.31783)^2 + (0.20516)^2 = C^2$$

When this equation is simplified to solve for C, the following equation is derived:

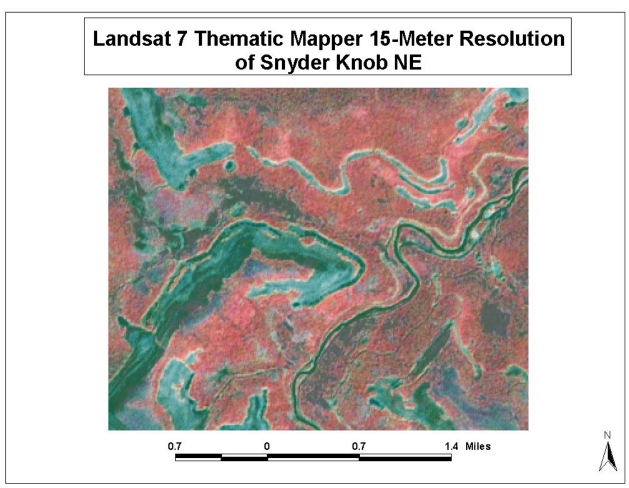
$$C = \sqrt{(1.31783)^2 + (0.20516)^2}$$



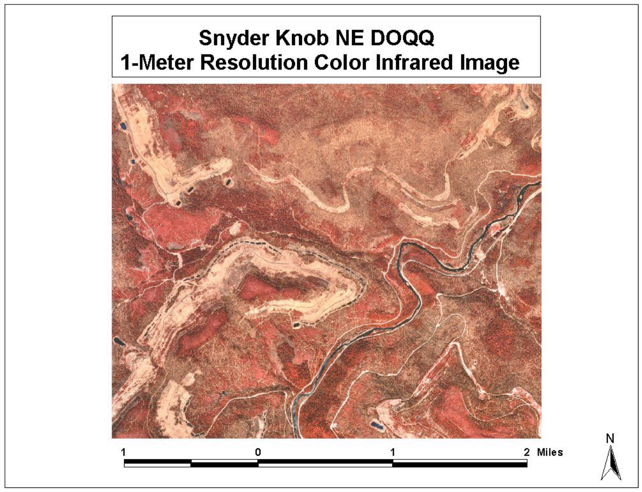
MAP 1



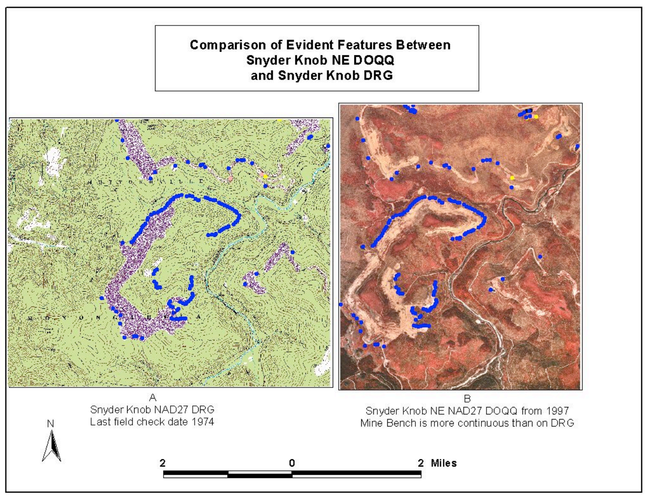
MAP 2



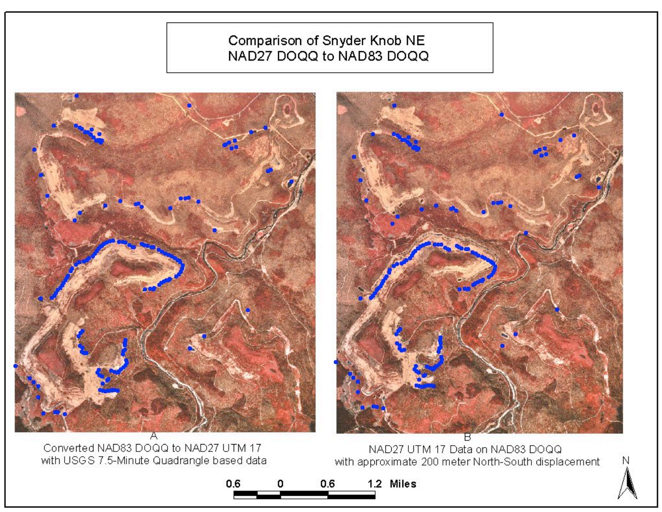
MAP 3



MAP 4



MAP 5



MAP 6

Solving this equation results in C = 1.3337 meters of displacement when performing the conversion from UTM NAD27 to UTM NAD83 of an upper point from the inventory and lower point from the inventory using Corpscon software developed by the Army Topographic Engineering Center, as modified from the NADCON conversion program developed by the National Geodetic Survey (USACE, 1997). The average distance between the two points in the Northing direction from NAD27 to NAD83 was 219.83 meters, while the Easting direction was 15.92 meters.

Additional error is introduced when discussing the location of the WVDEP differential correction base station in Morgantown, which was used as a control reference for the GPS data collection. As previously mentioned the farther away the roving unit is from the base station, the less accurate the differentially corrected positions become, typically 10 ppm, or 10 mm of accuracy degradation for every kilometer between the base station and the rover (Trimble, 1996a). The distance from the Monongahela National Forest inventory areas to the Morgantown base station ranged from about 90 km to more than 150 km, which could equal an accuracy degradation of more than 1.5 meters.

Geobiophysical Modeling

A Digital Elevation Model (DEM) of the Monongahela National Forest area was created as shown in MAP 7. This dataset was projected in NAD83 datum. MAP 7 depicts the location of the inventory features with respect to their elevation. Based on this map, the majority of the features occur within the gray and black sections of the map which represent elevations of 1203-1241 and 1064-1202 meters respectively. Additionally, the DEM allowed for the calculation of a slope grid as seen in MAP 8. This slope map shows the ratio of the vertical rise in the mountains versus the horizontal run and represents this value in degrees. Associated with the slope map calculation is the aspect map calculation, as seen in MAP 9. This map shows the azimuth direction of slope in percentages. The aspect map also shows the path of least resistance of flow, or the direction water may flow down the slope. The final map created from the DEM is the hillshade, MAP 10. This map creates a relief map effect, which is depicted by various shades of gray created by a simulated sun angle of 315 degrees. Using the elevation data provided by the DEM, a NAD83 Snyder Knob DOQQ was draped on top to provide a 3-dimensional view to help capture the actual surface topography of the area, as seen in MAP 11.

CONCLUSIONS AND FUTURE TRENDS

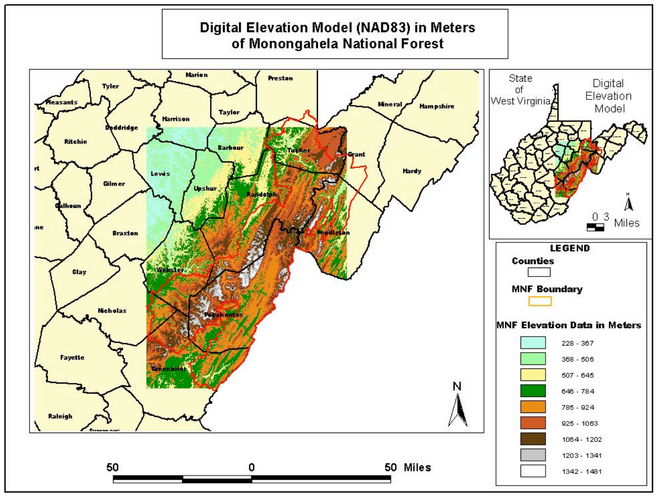
Conclusions

Overview Conclusions

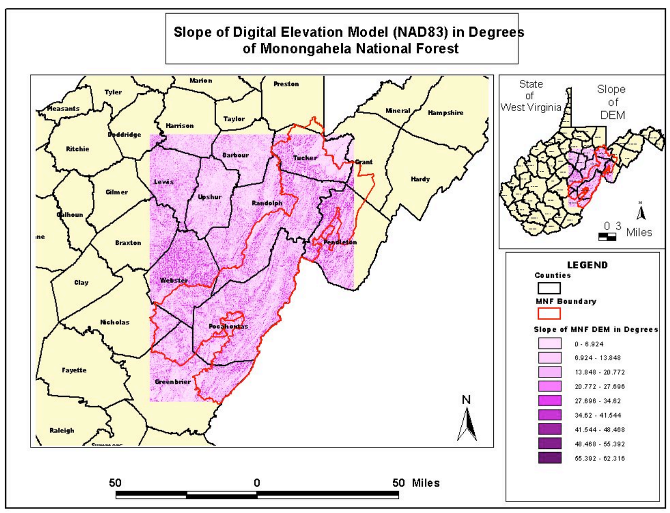
Development of the North American Datum of 1983 (NAD83) was made based on the GRS-80 measurements and for all practical purposes are the same as those for World Geodetic Survey of 1984 (WGS84), (Trimble, 1996a). The geodetic datum used in GPS data collection is the WGS84, from which the calculations for NAD83 are based, because the satellites send the positions to the GPS units based on this datum (Higgins, 1999). Within the United States, these newer datum's have replaced the widely used North American Datum of 1927, which was based on the Clarke Ellipsoid of 1866 (USGS, 1999). USGS topographic maps were created using this older datum of 1927. Subsequently, the USGS DRG's were scanned and georeferenced using NAD27. More recently, this USGS DRG mapping product, has been digitally reprojected to the more accurate NAD83 to make it more compatible with DOQQ's and space borne imagery (Moore, 2001). The USGS DRG's meet U.S. National Map Accuracy standards, at the 1:24,000 scale, with 90% of the tested points falling within 12.19 meters (1/50 inch) (USGS, 2002a). Revisions made to these must be at least equal to the previous version and all features should match within 22.25 meters/73 feet of those on a DOQQ (Moore, 2000) scan resolution of 250 dots per inch (dpi) (USGS, 2002a). The DRG's have been projected on Universal Transverse Mercator (UTM) projection.

Research Conclusions

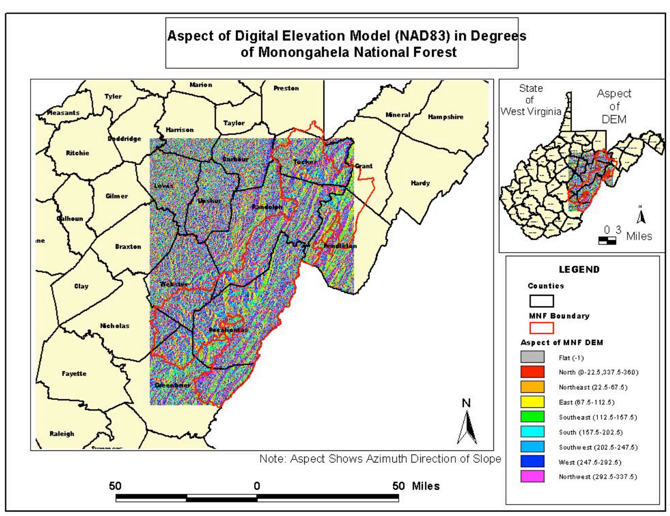
A Geographical Information System (GIS) was used as a compilation and database tool for assembling inventory data and comparing the use of NAD27 to NAD83, DRG's to DOQQ's, and Landsat 7 +ETM as air borne and space borne image basemaps . This powerful mapping system allows the data entered to be updated and maintained with relative ease. A GIS presents the information of a paper map merged with the graphic and visual representation of the real world. Arcview 3.2a (ESRI, 1996) was the chosen GIS software, based on its ease of use and wide distribution among government agencies. Advantages of using the GIS as a tool for managing the georeferenced data include, but are not limited to



MAP 7



MAP 8



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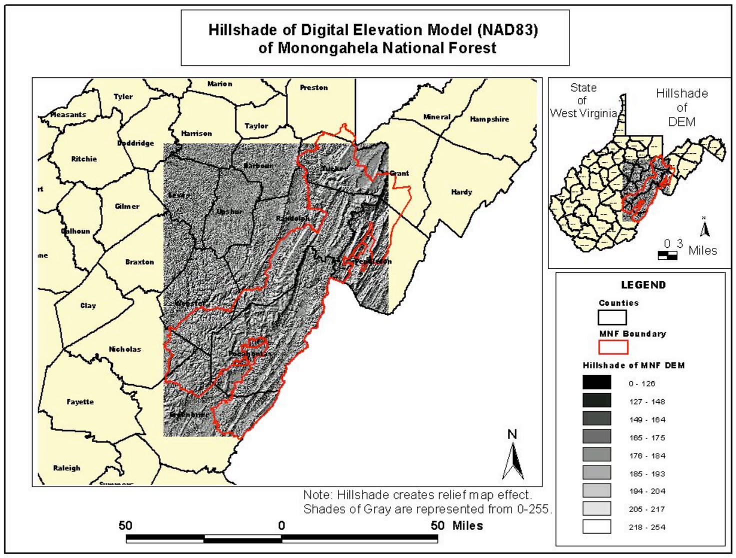
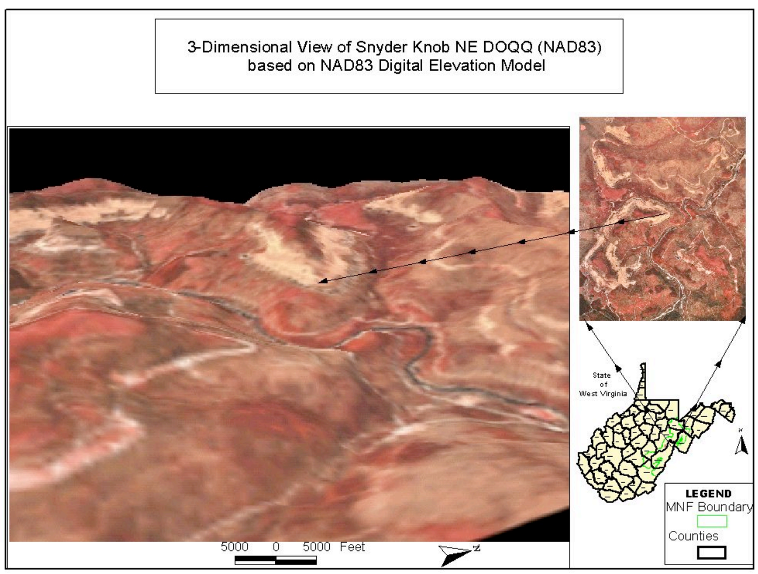
MAP 9



MAP 10



MAP 11

ease of database maintenance, availability of presentation quality maps, visual representation of data, paper map accuracy, and querying tools available with the Arcview (ESRI, 1996) software. These tools allow for features to be selected based on user established parameters. Implementation of a system with this technology saves time and money when dealing with data as large as the Monongahela National Forest Inventory.

The creation of the GIS database was used to demonstrate the objectives of this research, the comparison of NAD27 data versus NAD83, the use of DRG's versus DOQQ's with reference to a GIS database, and the creation of such database using the georeferenced inventory collected by the U.S. Corps of Engineers. Upon review of the accompanying maps, it can be seen that modifications need to be made in regards to the GPS collection techniques from the outdated NAD27 to the more current, accurate, and versatile NAD83 or WGS84, to avoid unnecessary data conversions and confusion resulting in a different datum used. The use of USGS 7.5-minute digital georeferenced, topographic maps as base maps do not provide the level of detail nor GPS accuracy that can be found in USGS DOQQ's. This research has provided the basis for evidence that improvements in both areas need to be made in order to provide a product demonstrating excellence.

Future Trends

The completion of this research through the use of a Geographical Information System creates additional possibilities with respect to managing data with minimal effort and maximum accessibility. One such way to do this is through the implementation of ER Mapper's Image Web Server (Earth Resource Mapping, 2001) or ArcView's ARCIMS (ESRI, 2001). These Internet based servers deliver GIS data through the use of a web browser and allow users with no prior GIS training to access it (ESRI, 2001). The use of this technology creates endless possibilities with data management, such as the geobiophysical modeling inventory of this research. Implementation of the Internet mapping services for inventorying, and related USFS work performed by the USACE, could be made possible through a cooperative agreement between the two agencies and Marshall University.

ACRONYMS AND TERMS

Data Fusion: Data fusion is the seamless integration of data from disparate sources. The data have been integrated across data collection "platforms" and geographic boundaries, and blended thematically, so that the differences in resolution and coverage, treatment of a theme, character and artifacts of data collection methods are eliminated. At present, this is a desirable but unattainable goal. (http://www.ngdc.noaa.gov/seg/tools/gis/fusion.shtml)

DEM - Digital Elevation Model: A DEM (Digital Elevation Model) is simply a digital map of elevation data. These maps, a type of DTM (Digital Terrain Model), are raster data meaning that they are made up of equally sized gridded cells each with a unique elevation.

DOQQ - Digital Orthophoto Quarter Quadrangle: A computerized image of an aerial photograph which combines the characteristics and quality of an image with the geometric qualities of a map (USGS, 1998b) using color infrared (CIR) photography as basemap source (Moore, 1997)

DRG - Digital Raster Graphics: a georeferenced, rectified image of a scanned U.S. Geological Survey (USGS) topographic or planimetric map.

DTM - Digital Terrain Model: A land surface represented in digital form by an elevation grid or lists of three-dimensional coordinates.

GPS - Global Positioning Satellite: A series of Department of Defense satellites used to accurately and precisely locate a position on the earth.

GRS-80 - Geodetic Reference System of 1980: Adopted by the International Union of Geodesy and Geophysics in 1979 as a standard set of measurements for the earth's size and shape. The length of the semi-major axis is 6 378 137 meters. Flattening is 1/298.257. (Clarke, K.C., 1999)

NAD - North American Datum: A set of reference points that describes the position, orientation and scale relationships of a reference ellipsoid to the Earth. The North American Datum of 1927 (NAD 27) uses Clarke spheroid of 1866 to represent the shape of the earth. The North American Datum of 1983 (NAD 83) is based upon both Earth and satellite observations, using the GRS80 spheroid.

NED - National Elevation Dataset: A USGS seamless mosaic of best-available 7.5-minute elevation data for the conterminous United States.

UTM - Universal Transverse Mercator: A projected coordinate system that divides the world into 60 north and south zones, six degrees wide. UTM Zones 17 and 18 North span across West Virginia, with UTM Zone 17 North the majority zone. The majority UTM Zone 17 is the recommended coordinate system for all *projected GIS data sets that cover the entire geographic extent of West Virginia. UTM is utilized for large-scale mapping projects and is the preferred map projection for state government.*

WGS - World Geodetic System: An earth-centred reference system which is a best fit for the whole earth, based on the latest information. The reference system adopted in 1980, known as the Geodetic Reference System 1980 (GRS80) was used by the United States Defense Mapping Agency as the basis for the World Geodetic System 1984 (WGS84), which is currently used for the GPS satellite navigation system. The parameters of the WGS84 ellipsoid "... are identical to those for the GRS80 ellipsoid with one minor exception. The coefficient form used for the second degree zonal is that of the WGS84 Earth Gravitational Model rather than the notation J2 used with GRS80." (DMA, 1987)

BIBLIOGRAPHY

Clarke, K.C., 1999, Getting Stated with Geographic Information Systems, 2nd ed.

Clinton, William J. (2000). Statement by the President Regarding The United States' Decision to Stop Degrading Global Positioning System Accuracy. United States Office of the Press Secretary

Department of Defense, 1987. Department of Defense World Geodetic System 1984 - Its Definition and Relationships with Local geodetic Coordinate Systems, DMA Technical Report 8350.2

Earth Resource Mapping (2002). ER Mapper 6.3. http://www.ermapper.com/

ESRI. (1996) Using Arcview GIS. California: Environmental Systems Research Institute, Inc.

ESRI. (1998).Getting to Know Arcview GIS.(pp.1-2,1-4).CA:Environmental Systems Research Institute, Inc.

Geoscience Australia, Datums and Coordinates, 2002. http://www.auslig.gov.au/geodesy/datums/aboutdatums.htm.

Higgins, Matt. (1999) Department of Natural Resources, Queenland, Australia Commission 5: Positioning and Measurement Working Group 5.5: Reference Frames in Practice, FIG Fact Sheet 5.501-The World Geodetic System of 1984 (WGS84). Available http://www.ps.ucl.ac.uk/fig5_5/FIGFactSheetWGS84.htm

Moore, Larry (1997). United States Geological Survey Mid-Continent Mapping Center. Transverse Mercator Projections and U.S. Geological Survey Digital Products. Available http://mcmcweb.er.usgs.gov/drg/mercproj/index.html

Moore, Larry (2000). United States Geological Survey Mid-Continent Mapping Center. The U.S. Geological Survey's Revision Program for 7.5-Minute Topographic Maps.

Owens, Thomas (1999). *Datums and Projections: A Brief Guide*. United States Geological Survey Geospatial Technology Document: USGS Center for Biological Informatics. Available http://biology.usgs.gov/geotech/documents/datum.html

Schwarz, Charles R. (1989) North American Datum of 1983. NOAA Professional Paper NOS 2, Article 22. pg 249

Trimble (1996a). GPS Mapping Systems: General Reference. California: Trimble Navigation Limited.

Trimble (1996b). GeoExplorer II Operation Manual. California: Trimble Navigation Limited.

Trimble (1997). Pathfinder Office: Getting Started Guide. California: Trimble Navigation Limited.

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United States Geological Survey (2002a). Overview of the USGS Digital Raster Graphic (DRG) Program. Reston, VA: Government Document, Online Edition. Available http://mac.usgs.gov/isb/pubs/booklets/topo/topo.html

United States Geological Survey (2002b). Landsat Program Report 2002. Reston, VA: Government Document, Online Edition. Available http://landsat7.usgs.gov/documents/Second-Landsat-Program-Report--FY-2002.pdf

United States Geological Survey (1998a). The Changing Landscape of Topographic Mapping. Reston, VA: Government Document, Online Edition. Available http://mac.usgs.gov/isb/pubs/booklets/topo/topo.html

United States Geological Survey (1998b). Digital Orthophoto Program. Reston, VA: Government Document, Online Edition. Available http://edcwww.cr.usgs.gov/Webglis/glisbin/guide.pl/glis/hyper/guide/usgs_doq?frame=body

United States Geological Survey (1995). Digital Orthophoto Quadrangles. Reston, VA: Government Document, Online Edition. Available http://edc.usgs.gov/glis/fgdc/doq_qquad.html

West Virginia, The Geodetic Control / Surveying Task Force. Standardization of Coordinate Systems and Datum for Data Exchange by West Virginia State and Local Government Agencies (Draft). http://www.wvals.org/wv_coord_system_nov01.pdf

Wood, Gavin (2000). *Global Positioning Systems*. Silsoe College. Available http://www.redr.org/members/gps.htm