EVALUATING METHODS FOR CHARACTERIZING SLOPE CONDITIONS WITHIN POLYGONS

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(ABSTRACT)

While the applications of Geographic Information Systems (GIS) have progressed from a descriptive tool to a decision making and modeling tool, the understanding of errors and variability of the components of a GIS has lagged behind. Slope is one of these components. This dissertation evaluates different methods for determining and characterizing slope values in polygons and how these methods affect natural resource models.

Eight different previously used methods for determining cell slope values were compared using elevation data from the USGS Big Stone Gap, Virginia, Digital Elevation Model. The 28 pair wise comparisons were statistically different, but for practical applications six of the comparisons were similar with an average slope difference of less than one percent. In a decision model the effect of changing just the slope method used to determine cell slope values can influence the results of a model enough to cause almost a 10 fold difference.

Since usually the smallest administered unit in natural resource management is the stand (polygon), nine ways of describing the slope of a polygon for 240 polygons using an aggregation of cell slope values were investigated. These polygon descriptors were mean, trim mean, median, mode,

first quartile, third quartile, standard deviation, minimum and maximum cell slope value. Also, a new method of determining polygon slope was examined using trend surface techniques, which is not based on aggregation of single cell slope values. The distributions of cell slope values in a polygon cannot be assumed normal since few polygons had a normal distribution. The sensitivity of these polygon slope descriptors to polygon area and surface complexity, based on fractal dimension, was examined and found not to affect these polygon characteristics.

The application and logical decisions required to choose an appropriate slope method and polygon slope descriptor(s) based on model objectives are shown in two examples, a harvesting and USLE model. Automating the process of choosing the appropriate polygon slope descriptor(s) and how to integrate these methods in an operational GIS using an Expert System is discussed.

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Chapter 1 - INTRODUCTION

Geographic Information Systems in Resource Management

In natural resource management, managers link spatial phenomenon and resource attribute information to make decisions based on associations. Using the broadest definition of Geographic Information Systems (GISs), resource managers have been using GISs for many years because they have used maps that contained both attribute and spatial information to make management decisions. It was inevitable that resource managers would become interested in automating a linkage between attribute and spatial information. The modern GIS performs this automation, and allows users to query spatial and attribute information, or a composite of the two, and to create new information that was difficult or impossible to acquire using manual processes. Geographic Information Systems also allow natural resource managers to examine management actions on forest stands in the context of the whole ecosystem, that is, perform cumulative effect analyses (CEA). Computers provide the means needed in GIS to manipulate large amounts of data and perform advanced numerical analyses efficiently. Geographic Information Systems also provide the capabilities to integrate different geographic scales from a single tree in the forest to a country wide forest system.

With tremendous technological advances in computer hardware and software, and the increasing demand for current information and access, GISs are becoming more attractive to natural resource managers. Geographic Information Systems are also becoming more attractive as state and federal laws governing land use and environmental protection increase in complexity, and compliance becomes mandatory. Even a brief review of the literature shows there is a trend toward using GISs by agencies with complex resource management problems and large land areas. These agencies are realizing the importance of incorporating the spatial dimension into natural resource decisions. Geographic Information Systems have opened up new frontiers in how resource managers develop and implement management plans.

Slope: An Important Component of Geographic Information Systems

In natural resource management, many analyses rely on slope as an important component of the decision making process. Slope is the rate of change in altitude at a point on a surface, often called gradient. For example, Kessell (1979) used slope as a component in developing a fire management information system for Glacier National Park. The slope of a land surface proved to be important in determining the erodibility of soils (Meijerink, 1986).

Before Geographic Information Systems, the most common method for determining the slope of a surface utilized information collected in the field at sample points using some type of angle measuring instrument, or slope was calculated from measurements taken on a quadrangle map between two points. In a GIS, slope can be computed using one of several slope models. A slope model uses elevations at different points to determine the slope of a particular area through the application of one of several mathematical algorithms.

Concerns about Automated Slope Calculation in Geographic Information Systems

Using a Digital Elevation Model (DEM) in a GIS, the region of concern is subdivided into exhaustive mutually exclusive subunits (tessellations, i.e., grid cells). Slope is then calculated for each tessellation (cell) using a mathematical slope algorithm. The calculation of slope, and the error associated with it is transparent to the user of the GIS. Geographic Information System developers usually do not document the slope model they use, and different slope models can produce different results for the same area. Some slope models smooth the data, which may not be desirable. Thus, natural resource managers should be concerned about the way in which slope is calculated in GIS.

A second difficulty arises since resource managers are concerned with land areas (polygons), which are composed of many tessellations. Polygons (stands) are usually the smallest administered unit used in natural resource management. The GIS has to combine the slope values for all the tessellations in the polygon of concern to characterize the slope conditions within an entire polygon. No studies have been located that were concerned with evaluating methods for characterizing slope conditions in polygons, or the effects of different tessellation slope algorithms have on the "combined" slope of a polygon.

Application of a Polygon Slope Model

The utilization of slope values in GIS for making resource management decisions would be greatly enhanced by the development of a polygon slope model that describes or characterizes the slope condition in the polygon. A polygon slope model that describes or characterizes slope conditions in a polygon will assist resource managers in making better resource decisions and allow managers the flexibility of using the polygon slope characteristics that are suitable for a particular management application. For example, the Jefferson National Forest Land and Resource Management Plan (USDA, 1985) has distinct slope classes for allowable harvesting methods of forest stands (polygons). Current GISs usually create slope class polygons from elevations, and then the forest stand boundary coverage is overlaid on the slope class coverage to determine the average slope of each forest stand (ESRI, 1988). By a small margin, a forest stand could fall in one slope class based on the average, but the major portion of the stand could be in another slope class. If the resource manager had some information about the characteristics of slopes in the stand or another measure than the average slope of a stand, the stand could be assigned a more appropriate harvesting method. However, there is no slope method or polygon slope descriptor that is applicable in all circumstances. Further there is a problem because slope is a point phenomenon, but, in natural resource management, our unit of concern is areas (polygons).

Next, if information is known about variability of slopes in polygons, this variability could be incorporated into models that use slope as a variable. A polygon slope model that has some form of variability of slopes would allow the propagation of the variability to models that use polygon slope as a variable. This would contribute toward a better understanding of the effect of polygon slope variability in these models. An example would be the Universal Soil Loss Equation (USLE) in which percent slope is assigned to a soil mapping unit (Logan et al., 1987).

Purpose of Study

As the application of Geographic Information Systems progresses from a descriptive tool to a decision making tool, knowledge of the errors and variability of components in a GIS is becoming more important. The first application of slopes in GIS and computerized mapping was as a visual aid to represent a three-dimensional surface on a two-dimensional medium. Hill shading and perspective trace maps (fishnets) are two examples. Quantitative analysis of terrain characteristics is becoming an important component of spatial models used in Geographic Information Systems (Weibel and DeLotto, 1988). Slope is now a variable in many natural resource decision models. The purpose of this study is to evaluate different methods for determining and characterizing slope values in polygons and, ultimately, how these different methods affect natural resource decision models when the models are incorporated into a GIS.

This study has the following four objectives.

1) To evaluate the effects different slope calculation methods have upon slope values of individual cells using a commercially available Digital Elevation Model.
2) To develop and/or select a set of descriptive statistics for characterizing the slope condition in polygons, and determine the effect cell slope calculation method has upon these descriptors.
3) To investigate the effect polygon surface complexity and area have on polygon descriptors.
4) To evaluate the behavior of the polygon slope descriptors across a range of polygon sizes and surface complexities to investigate their applicability to differing operational uses of Geographic Information Systems.

Chapter 2 - LITERATURE REVIEW

This study evaluates methods for determining and characterizing slope values for polygons. These polygon slope values, which are used in many natural resource decision models, are an important component of a Geographic Information System (GIS). Therefore, the definition and history of GIS will be reviewed first. Then, a summary of GISs used for natural resource management is given. The theoretical concept of a spatial data model and the different spatial data models used in GISs are then reviewed. Since GISs utilize a Digital Elevation Model (DEM) to generate slope values, the concept of a DEM is explained in detail. Next, the methods and problems in creating United States Geological Survey (USGS) Digital Elevation Models are reviewed, since these are the most available DEMs. Different methods used to describe surface complexity (roughness, geometric signature, grain) are explained because these methods can be used to categorize polygons, based on land surface complexity. Finally, the different methods used in previous studies to determine a slope value for a cell are discussed.

Definition of Geographic Information Systems

Cowen (1988) recently reviewed the definitions of Geographic Information Systems and developed four general approaches:

- Process-Oriented Approach
- Toolbox Approach
- Database Approach
- Application Approach

The process-oriented approach is based on the idea that the GISs must incorporate procedures for geographic information input, storage, retrieval, analysis and output. The process-oriented approach was formulated in the 1970s (Calkins and Tomlinson, 1977), but this definition includes most computer programs that deal with spatial information. The toolbox approach definition originated with the idea that a GIS is a set of procedures that deal with spatial data. Tomlinson and Boyle (1981) and Dangermond (1983) give examples of what functions should be incorporated in a "true" GIS. This approach is simply a check list. Goodchild (1985) states that a GIS is a system that uses a spatial database to provide answers to queries of a geographical nature. This is the database approach in defining GIS. The application approach defines GISs based on the application of the GIS. Pavlidis' classification scheme describes many different systems based on application (Pavlidis, 1982). After reviewing these different approaches, Cowen (1988) expresses that GIS is best defined as a decision support system involving the integration of spatially referenced data in a problem solving environment.

Burrough (1986), the author of the most comprehensive text on GIS, states that a GIS consists of five technical modules.

- Data input and verification
- Data storage and database management
- Data output and presentation
- Data transformation
- Interaction with the user

Marble and Peuquet (1983) express in the Manual of Remote Sensing that a GIS is computer based and performs the following major functions:

- Data Input
- Data Storage and Retrieval
- Data Manipulation
- Report Generation

This description of the composition of a GIS is similar to Burrough's.

As previously shown, there are many definitions for GISs and different approaches in defining GISs. My view is that GISs are best defined as a technology that processes, stores, analyzes, creates, displays and associates spatial and attribute data. This definition does not constrain the progress of GISs, but does prohibit GISs from being a "catch all" for any spatial data process.

History of Geographic Information Systems

Parent and Church (1987) state that the roots of GISs date back to the mid-eighteenth century with the development of cartography and the first production of base maps. The idea of overlaying base maps with different themes was in use by the time of the American Revolutionary War (Harley et al., 1978). Computerized mapping started in the late 1950s and early 1960s with the development of SYMAP (SYnagraphic MAPping system) by Howard T. Fisher at Harvard University (Sheehan, 1979). Other mainframe programs, GRID and IMGRID developed in the 1960s and 1970s, allowed the computer to overlay maps. This was the start of computerized GIS, as we know it today. This also marked an important turning point from computerized mapping, which describes spatial and attribute data, to GIS that not only describes data but can produce new information based on spatial and attribute data associations.

Natural Resource Applications of Geographic Information Systems

Geographic Information Systems have been used in many areas of natural resource management. Hodgson et al. (1988) used a GIS to monitor wood stork forage habitat. Johnston (1987) used a GIS to develop a natural resource model that integrated visual quality, landscape ecology, fire management, natural vegetation potential, wind management, production and economics. A decision support system for forest management was developed by Herrington and Koten (1988) using a GIS. A GIS was used on the Tongass National Forest for timber sale planning (Bobbe, 1987). Covington et al. (1987) developed an interactive and integrated multiresource decision support system (TEAMS) that utilizes a GIS, a relational database management system, a multiresource simulation model, economic algorithms and a constrained optimization model to evaluate treatment alternatives in the ponderosa pine type of Arizona.

Theoretical Concept of a Spatial Data Model

A spatial data model is a person's conception of spatial reality based on the application in which the model will be applied. To progress from spatial reality to a digital form, there is a series of abstractions through which the data must be passed. Peuquet (1984) describes four levels of abstractions.

- Reality - phenomenon as it actually exists
- Data Model - abstraction of the real world
- Data Structure - representation of the data model
- File Structure - representation of the data in storage

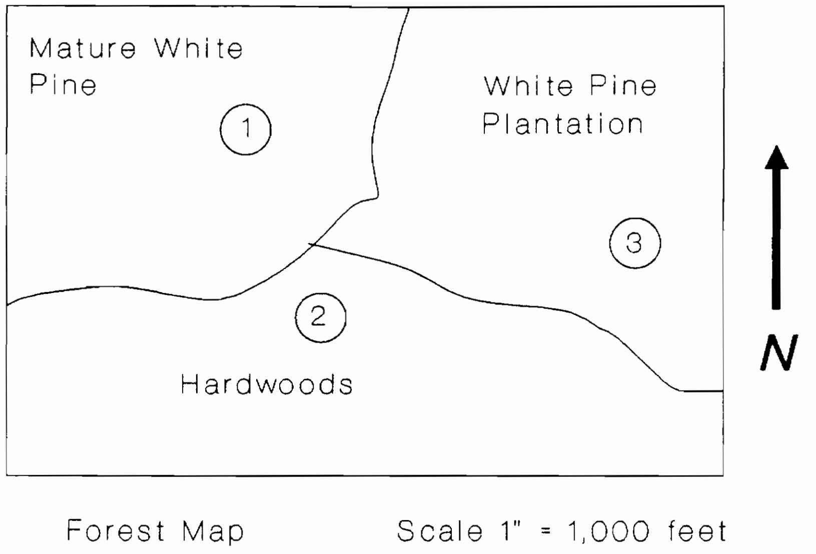
The last three levels are used in database construction.

In the development of a spatial data model, the model cannot mimic reality exactly. When this is attempted the spatial model becomes too complex and exceeds its point of usefulness. Most spatial data models represent the relevant elements of reality for a particular situation, which involves generalization of information.

Spatial Data Models

Geographic Information Systems contain two types of data, spatial data and attribute data, which are linked together by unique codes. The attribute data is stored in a Database Management System (DBMS) and the spatial data is stored in a Spatial Database Management System (Frank, 1988). A simple example would be managing a segment of forest land with three stands (polygons): a white pine plantation, mature white pines, and hardwoods. Each polygon would be linked to the DBMS by a unique code as shown in Figure 1. The DBMS would contain attribute information about each stand, such as forest type, age and acres.

There are basically two types of spatial data models that are used in GIS: tessellation and vector models. Tessellation models, sometimes called polygon mesh models, subdivide a land area into exhaustive, mutually exclusive subunits (cells). The coordinate space is fixed by the size of the tessellation. Tessellations can take on three different geometries: square, triangle and hexagon (Ahuja, 1983). The square tessellation model (raster or cellular) has historically been the most widely used because it is compatible with array data structures, and because most output devices operate in a raster format (Peuquet, 1984). Vector data models attempt to represent a feature on the earth's surface as exactly as possible with X,Y point locations along a line. The basic units of a vector data model are points, lines (arcs) and polygons. The coordinate space is assumed to be continuous. Vector data models record boundaries and linear features. Vector Geographic Information Systems are very popular because they are based on lines to represent features; historically, this has been the method used in maps commonly used by natural resource managers. Figure 2 depicts a land area represented by a tessellation and vector spatial data model.



Spatial Database Management System

Code	Coordinates
1	x,y x,y x,y x,y ....
2	x,y x,y x,y x,y ....
3	x,y x,y x,y x,y ....

link

Database Management System

Code	Type	Age	Acres	....
1	Pine	40	50	....
2	Hardwoods	30	89	....
3	Pine	3	64	....

Figure 1. The Spatial and Attribute Data types in a Geographic Information System

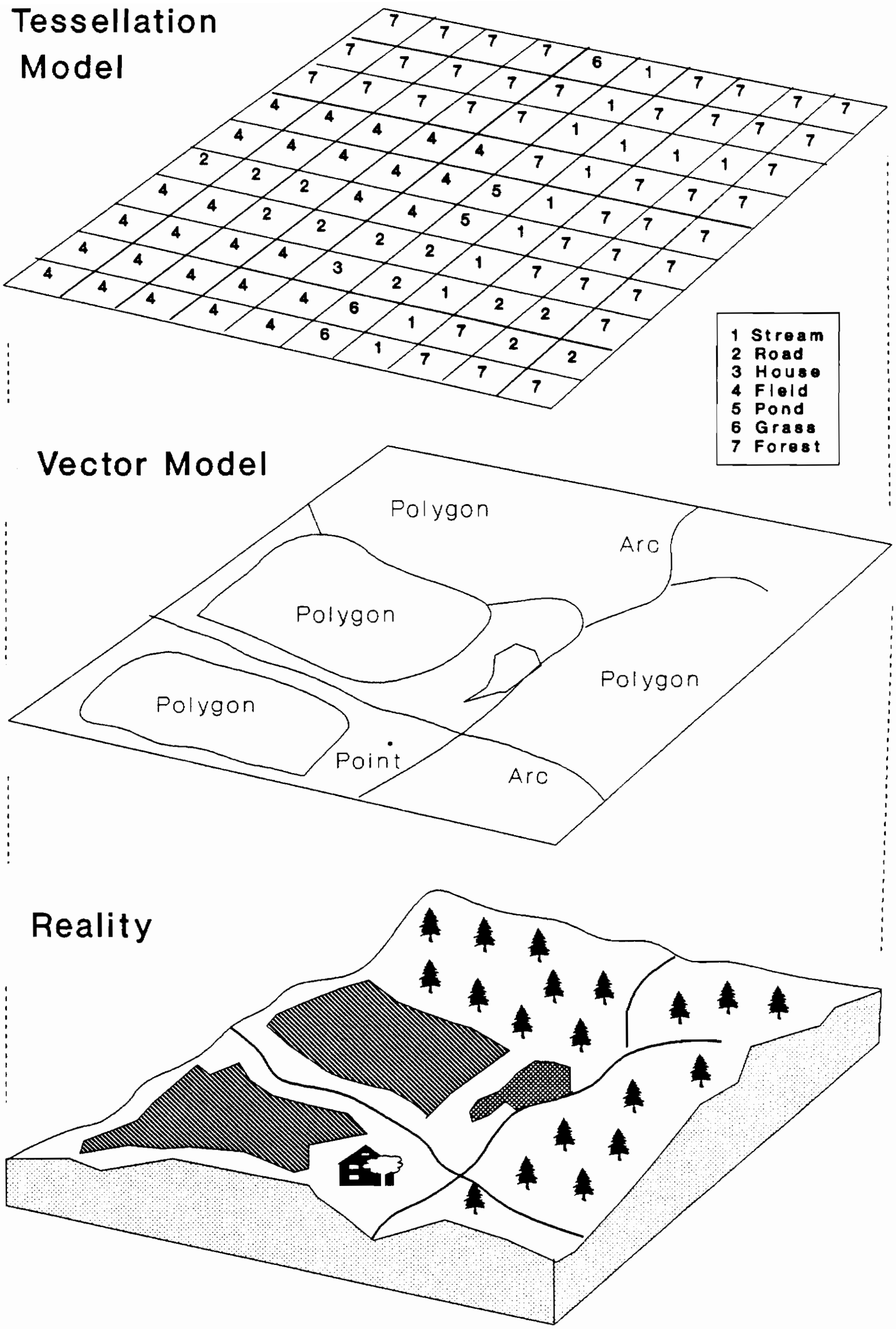


Figure 2. Spatial Data Models used to represent Reality in a Geographic Information System

Maffini (1987) states that "both raster and vector data structures have a place in GIS and will continue to prevail for many years." Both tessellation and vector spatial data models have advantages and disadvantages, which are summarized in Table 1. Peuquet (1984) summarized the difference between vector and tessellation data models with the following statement.

> From a modeling perspective, vector and tessellation data models are logical duels of each other. The basic logical component of a vector model is spatial entity, which may be identifiable on the ground or created with the context of a particular application. These may include lakes, rivers, roads and entities such as "the 20-foot contour level." The spatial organization of these objects is explicitly stored as attributes of these objects. Conversely, the basic logical component of a tessellation model is a location in space. The existence of a given object at that location is explicitly stored as a location attribute.

Because of the advantages and disadvantages of both vector and tessellation spatial data models, most GIS vendors are incorporating both data models into their systems.

Concept of a Digital Elevation Model

An important component of a GIS used for natural resource management is a Digital Elevation Model (DEM). The concept of a Digital Terrain Model (DTM) was proposed over 30 years ago by Miller and Laflamme (1958). Miller and Laflamme describe a Digital Terrain Model as a mathematical representation of a continuous surface by sets of X, Y, and Z coordinates in an arbitrary coordinate field. A Digital Elevation Model is often called a DTM or sometimes a Digital Ground Model (DGM) since there is no standard terminology (Carter, 1988a). A DEM, in the context used in this study, is any representation of continuous relief (elevation) over space. Digital Terrain Model is sometimes used synonymously with DEM, but DEM is appropriately used when the model contains only elevation data and DTM when the model contains topographic data (slope, aspect, etc.) in addition to elevation.

Table 1. Comparison of Vector and Tessellation Spatial Data Models (Burrough, 1986)

Vector Data Models

Advantages

- Good representation of phenomenological data structure
- Compact data structure
- Topology can be completely described with network linkages
- Accurate graphics

Disadvantages

- Complex data structure
- Combination of several vector polygon maps or polygon and raster maps through overlay creates difficulties
- Simulation is difficult because each unit has a different topological form
- Spatial analysis and filtering within polygons are impossible

Tessellation Data Models

Advantages

- Simple data structures
- The overlay and combination of maps with remotely sensed data is easy
- Various kinds of spatial analysis are easy
- Simulation is easy because each spatial unit has the same size and shape
- The technology is cheap and is being energetically developed

Disadvantages

- Volumes of graphic data
- The use of large cells to reduce data volumes means that phenomenologically recognizable structures can be lost and there can be a serious loss of information
- Crude raster maps are considerably less beautiful than maps drawn with fine lines
- Network linkages are difficult to establish
- Projection transformations are time consuming unless special algorithms or hardware are used

A DEM is constructed from sample data points, which are obtained by digitizing existing contours or by photogrammetric methods. Balce (1987a) and Sharif and Makarovic (1989) describe how to determine the optimum sampling interval and method for creating gridded DEMs. Digital Elevation Models are the result of a conversion of one data type (analog) to a digital form. There are basically two trends in point sampling for the construction of a DEM: specific surface, random coordinate and random surface, specific coordinate. Specific surface, random coordinate samples points (elevations) at high information areas (ridge tops, valley bottoms) with no regard to their coordinate location. Random surface, specific coordinate samples points with no regard to their information content, but is based on their coordinate location (systematic sample).

After the sample is completed, usually elevations between sample points are often desired. Two methods are used to create (predict) a complete DEM from a sample of elevation points. The first method is spatial interpolation, which in the context of this study, means if given a set of spatial data points, find a function that will represent that surface and will predict other data points in the coordinate range of the original data points. The second method, spatial extrapolation, is similar to spatial interpolation except points are predicted outside the coordinate range of known data points. Weih and Smith (1990) compared nine different interpolation methods by taking a systematic sample (random surface, specific coordinate) of 110 cells (30 meters) from a United States Geological Survey (USGS) DEM (Big Stone Gap, VA) and compared the interpolated DEM, using simple kriging and inverse distance weighting, to the original 9,900 cells in the USGS DEM. The study showed that the interpolation method used to create a complete DEM from a sample of elevation points can affect the accuracy of the DEM. Weih and Smith concluded from this comparison that different interpolation methods using the same sample data can produce entirely different DEMs in this geographical area. The results of the study are shown in Table 2. Lam (1983), Davis (1986) and Burrough (1986) are excellent sources for discussions on different spatial interpolation and extrapolation methods.

Table 2. Difference Between the Interpolated DEM and USGS DEM

Interpolation Method	Difference Mean(ft.)	Difference Standard Deviation	Minimum Difference (ft.)	Maximum Difference (ft.)
Kriging	-4.78	49.76	-221.56	193.49
w=1/D n=5	-11.58	66.19	-223.17	259.14
w=1/D n=10	-7.02	93.16	-292.58	332.24
w=1/D n=15	-6.07	114.49	-320.94	414.38
$w=1/D^2$ n=5	-8.93	58.14	-213.65	232.28
$w=1/D^2$ n=10	-7.70	67.70	-227.47	240.27
$w=1/D^2$ n=15	-8.01	73.84	-234.09	239.49
$w=1/D^3$ n=5	-7.52	61.91	-213.05	251.27
$w=1/D^3$ n=10	-7.29	64.09	-212.75	240.86
$w=1/D^3$ n=15	-7.59	64.74	-201.59	237.23

N = 9900 cells (30 meters)
w = Inverse Distance Weighting (No-Constraint search, n nearest neighbors)
D = Distance from point being interpolated to neighbor
(Interpolated DEM - USGS DEM)

Methods of Representing a Surface

The variation of the earth's surface can be modeled using mathematical patch models, line models or point models (Mark, 1978). Mathematical patch models use three-dimensional functions to represent patches (sections) of the earth's surface. These methods are not used often in representing a surface in cartography (Burrough, 1986). The line model is the most familiar method of representing the surface. A line model is created by passing horizontal surfaces parallel to a datum through a three-dimensional surface and projecting the boundary intersections perpendicular to the datum. Quadrangle map contour lines are an example of a line model. There are two common methods used by a point model to represent the earth's surface. They are an altitude matrix (regular rectangle grid) and Triangulated Irregular Network (TIN). Both methods represent the earth's surface with X, Y and Z coordinate pairs in digital form.

Most DEMs in GIS use one or both of the point methods. The most popular method is the altitude matrix. The popularity of the altitude matrix is because it conforms to computer array data structures and it is the most available form of DEM. The altitude matrix is a tessellation (cellular) spatial data model. There are four major disadvantages of an altitude matrix.

- Data redundancy in areas of uniform terrain
- Methods in which cell elevation values are determined vary
- Cell size is fixed and cannot vary based on relief complexity
- Computations using grid cells are usually based on the cell centroid point, although the cell represents an area

Peuker et al. (1978) designed the Triangulated Irregular Network system for DEMs to avoid redundancy of data as in the altitude matrix and to be more efficient in some types of calculations (slope, aspect, etc.). A TIN is a DEM that represents a three-dimensional surface with a sheet of continuous triangles (facets) of varying sizes. It is based on the principle that a flat plane can be fitted to any three non-collinear points. Christensen (1987), Dwyer (1987) and Scarlatos (1988) show different methods used in developing a TIN from sample points (elevations). The TIN allows extra information to be gathered in areas of complex relief, which is not the case with altitude matrices. The TIN is usually associated with vector GIS even though it is an irregular tessellation data model. Triangulated Irregular Networks have two major disadvantages: they have a complex data structure and generation of a TIN from an altitude matrix usually involves some type of data smoothing.

United States Geological Survey Digital Elevation Models

Since the United States Geological Survey (USGS) is the major source of DEMs, a thorough discussion of the different methods used to create the DEM and the errors and problems associated with them is called for. United States Geological Survey DEMs represent elevations of the earth's surface using an altitude matrix (regular rectangle grid). The entire United States has been covered with the 1:250,000 scale series and a portion of the United States has been covered with the 7½ minute series. The 1:250,000 DEMs are constructed with a three arc-seconds non-square cell and the 7½ minute DEMs with a 30 meter square cell. The 1:250,000 scale series DEMs are based on latitude and longitude and are non-square because the cells reflect the convergence of the meridians as the distance from the equator increases. The 7½ minute DEMs are based on the Universal Transverse Mercator (UTM) projection grid system. Because of the higher resolution and square grid cells the 7½ minute USGS DEMs have the greatest potential for use in natural resource decision models. They will be discussed in more detail than the 1:250,000 scale series.

United States Geological Survey 7½ minute DEMs are produced in 7½ x 7½ minute blocks (7½ minute quadrangle maps) from digitized contour overlays or from automated or manual scanning of quad-centered National High Altitude Aerial Photography (NHAP) (USGS, 1987a). Since 7½ minute DEMs are based on the UTM cartesian coordinate system, the coverage for the DEM is a quadrilateral. Each profile (raster) of an USGS DEM starts at the southern boundary of the quadrangle. The first profile starts at the southwestern corner of the quadrangle as shown in Figure 3. Cell elevation values are either in meters or feet referenced to Mean Sea Level (MSL). Digital Elevation Models of quadrangle maps with greater than 5 foot contours are usually in meters

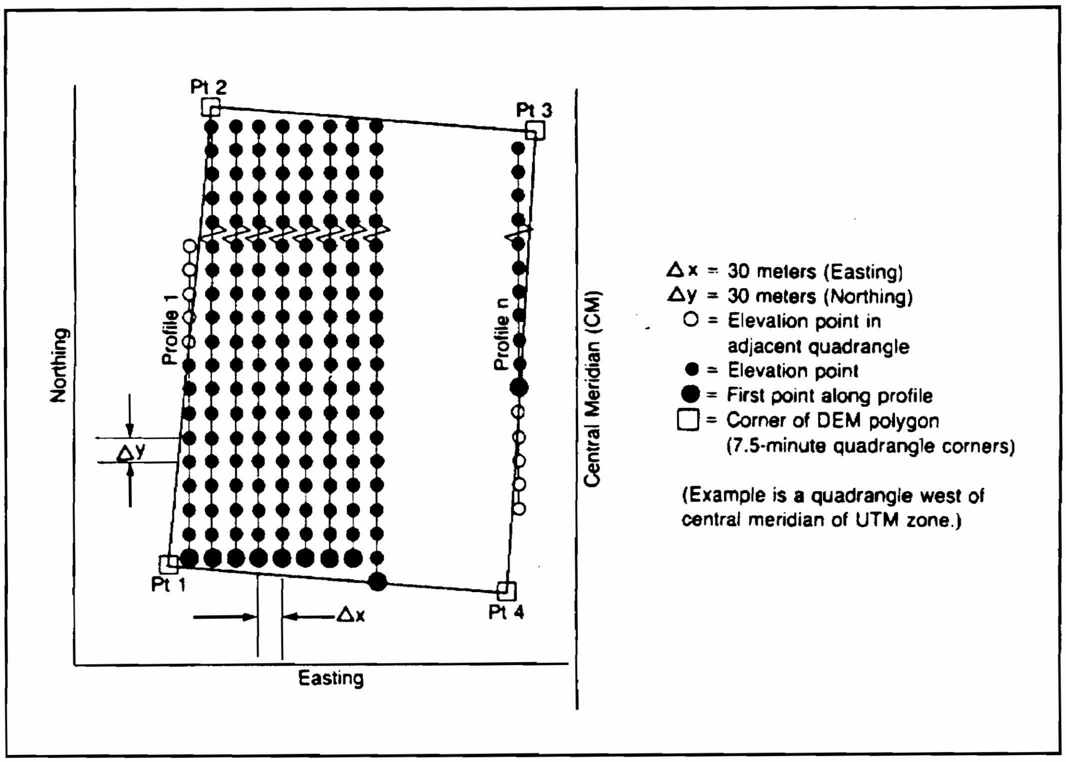


Figure 3. File structure of a USGS 7½ minute Digital Elevation Model (USGS, 1987a)

and maps with less than or 5 foot contours are in feet. In the production of 7½ minute DEMs the USGS has used four different processes (USGS, 1987a).

- Gestalt Photo Mapper II System (GPM2)
- Profiling photogrammetric stereo models
- Derivation from USGS Digital Line Graphs (DLGs) hypsography and hydrography categories
- Stereo model digitizing of contours

Gestalt Photo Mapper II

The Gestalt Photo Mapper II System (GPM2) is a highly automated photogrammetric system designed to produce DEMs from a stereopair of aerial photographs. The GPM2 measures the parallax of 2,444 points (182 microns between points) within each 9 x 8 mm area (patch) of the stereo model (USGS, 1987a). On a 1:80,000 scale aerial photograph 182 *um* is approximately 48 feet on the ground. A subset of each patch is overlapped with the next patch to ensure continuity in the DEM. Approximately one million points (elevations) are taken from two NHAP stereo models, which are used to create a 7½ minute USGS DEMs. Allam (1978) and Kelly et al. (1977) explain in detail the process used to create a DEM using the GPM2.

Profiling Photogrammetric Stereo Models

Profiling photogrammetric stereo models to create a DEM is a manual process using a stereoplotter. The operator successively scans high altitude aerial photographic stereopair profiles with the distance between the profiles, usually 90 meters, selected by the operator based on the terrain complexity (USGS, 1987a). For each profile elevation data is collected at numerous points with there respective X and Y coordinates. The digital elevation data is then gridded into a regular 30 meter UTM DEM and tested for accuracy before being entered in the National Digital Cartographic Data Base (NDCDB).

Digital Elevation Models created using USGS Digital Line Graphs

Digital Line Graphs (DLGs) describe a digital map data set in vector form. There are nine different categories of USGS DLGs available (USGS, 1987b).

- Political and administrative boundaries
- Hydrography - standing and flowing water
- Public Land Survey System
- Transportation - roads, railroads, transmission lines, etc.
- Significant manmade structures - dams, gas fields, etc.
- Hypsography - contour lines, spot elevations and watershed divides
- Surface cover - vegetative surface cover
- Non-Vegetative cover - sand, lava, etc.
- Survey control and markers

Currently there is very little data available for the latter five categories in the National Digital Cartographic Data Base (NDCDB). The 7½ minute DLG series are produced from either 7½ minute or 15 minute quadrangle maps (USGS, 1986).

Digital Elevation Models have been created using the hydrography and hypsography DLG categories. Rinehart and Coleman (1988) calls this the DLG2DEM system. Contours and spot elevations are taken from the hypsographic DLG while lake and shoreline data are taken from the hydrographic DLG. The various elevations are interpolated, using Zycor's Contour-to-Grid-Transformation Program (CTOG), into a 30 meter grid of elevations that are used to create a 7½ minute DEM.

Stereo Model Digitizing of Contours

During the production of 1:24,000 scale quadrangle maps, from stereopairs of aerial photographs, the contour data is stored in digital form. The location and elevation of the contour line is stored. A 30 meter altitude matrix is computed using bilinear interpolation to create the 7½ minute DEM (USGS, 1987a). The DEM is tested for accuracy before it is entered into the NDCDB.

Accuracy of USGS Digital Elevation Models

Accuracy of Digital Elevation Models depend on the source of the sample points (elevations), number of sample points, interval between sample points in relation to surface variability, method of determining sample point elevations, final grid spacing of the DEM and the method of interpolation employed to create the DEM if necessary. In topographic data both horizontal and vertical errors can occur that may be impossible to distinguish from each other (Vitek and Richards, 1978). An example would be, if cell C4 of the altitude matrix shown in Figure 4, which is from the study area, had a true elevation of 874 meters. We could say that cell C4 had an error of 4 meters but we could not distinguish if it was caused by a vertical error or the cell was displaced (horizontal error). Because of this problem the USGS does not distinguish between vertical and horizontal error when they determine the error characteristics of DEMs. Also the accuracy of the DEM is based on grid cell size of the altitude matrix because as cell size increases more generalization of the surface must be done. Based on sampling theory, a feature has to be greater than or equal to twice the size of the grid cell to be adequately described (Weibel and DeLotto, 1988). For 7½ minute DEMs, the feature would have to be greater than or equal to 60 meters to be effectively characterized. Sometimes in the literature the vertical accuracy of a DEM is stated to be within one meter. This is a misconception because the elevation values are recorded to within one meter but the accuracy of the DEM varies based on the above factors.

The United States Geological Survey has classified DEM errors into three types: blunders, random and systematic errors. Blunders are gross errors such as a 100 meter mountain in the middle of a lake and are usually removed by editing before the DEM is entered into the National

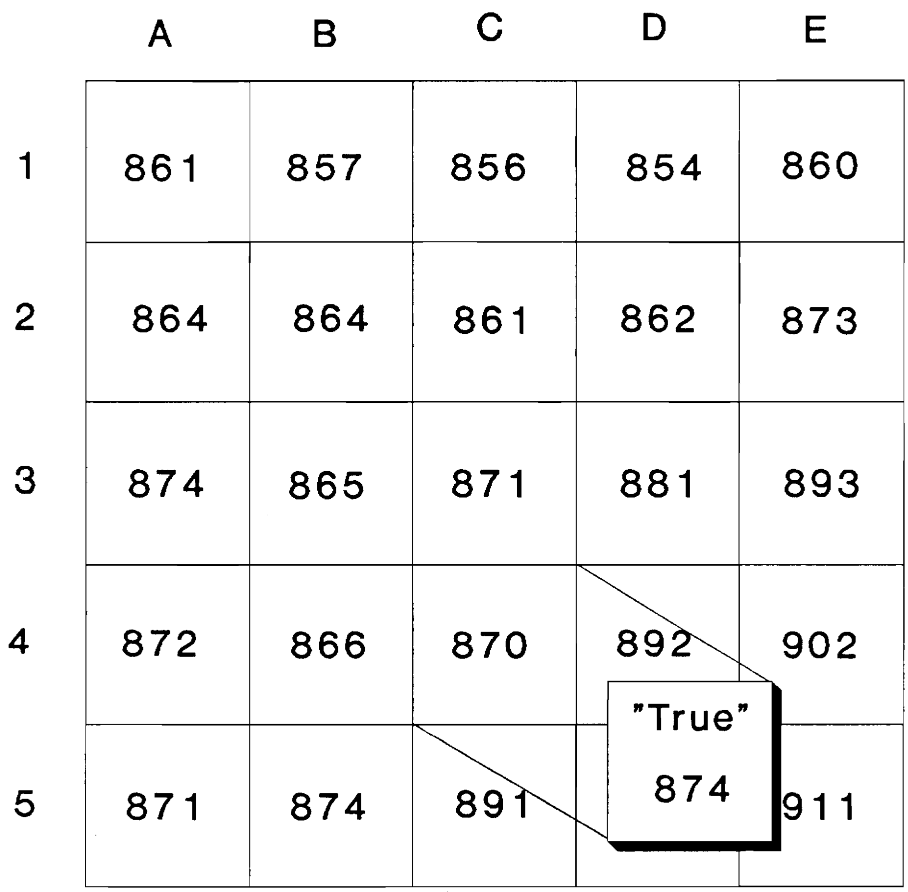


Figure 4. Vertical and Horizontal Error of a Digital Elevation Model

Cartographic Data Base. Random errors are errors that are independent of previous errors and take into account unpredictable and unknown factors in developing the DEM. Systematic errors are measurement errors and are usually caused by improperly adjusted equipment or equipment operation.

The USGS determines the accuracy of the 7½ minute series of DEMs by computing the root mean square error (RMSE) for linear interpolated elevations in the DEM and the corresponding "true" elevations from published maps. At least 20 test points (elevations) per DEM are used and the points are usually located at bench marks and contour lines (USGS, 1987a). United States Geological Survey DEMs are classified into one of three levels of quality, which is indicated in the type A data record of the DEM. Virtually all 7½ minute series USGS DEMs are in the Level 1 quality category which has the following specifications (USGS, 1987a).

- No cell has an absolute error greater than 50 meters when compared to the "true" elevation
- No array encompasses more than 49 points (elevations) in which the relative integrity is not greater than 21 meters
- A RMSE which is recorded in the type C data record of the DEM, must be less than 15 meters to be acceptable

Few papers have noted the type of errors that were encountered when using actual USGS DEMs. Carter (1988b, 1989) describes some of the errors he has encountered in USGS DEMs and tried to determine what caused them. Carter found that bodies of water are not always flat and this led him to studying the NHAP from which the DEM was created. Carter came to the conclusion that this was caused by the near-perfect specular reflectance of water. The GPM2 could not objectively correlate the images on the stereopair. Carter also discovered some linear errors along steep ridges, which he concluded could have been caused by the inability of the GPM2 to bring the patches together. The DEMs that Carter studied also had some errors that would be called blunders, in which the elevation of a single cell was 200 feet greater than the adjacent cells. Carter (1988b) summarized the errors in USGS Digital Elevation Models with the following statement.

> Errors of various types are always going to be with us, in whatever we do. As the digital production activities of the National Mapping program become refined with experience and overt actions, we can expect to see fewer and fewer errors occurring in the data sets entered in to the National Digital Cartographic Database. But it is presumptuous to assume that the Database will ever be error-free. Therefore, it behooves users to become aware of the nature of the types of errors that might exist in any digital database.

Balce (1987b) and Tempfli (1980) discuss different methods that can be used to determine the accuracy of DEMs.

Describing Surface Complexity

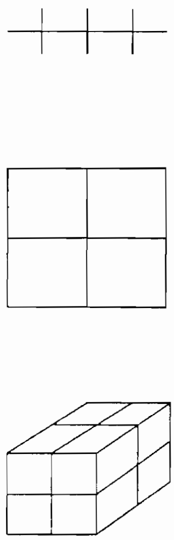
To effectively analyze or make inferences about any method that analytically determines a value for a terrain feature (slope, aspect, etc.) you have to quantify the complexity (geometric signature, grain, roughness) of the land surface. This allows the separation of study areas (polygons) into categories based on surface complexity. This is desirable because one method that determines a value for a terrain feature that is superior on simple surfaces (Coastal Plains) might be unsuitable for complex surfaces (Rocky Mountains). Since this study evaluates different methods for determining and characterizing slope values in polygons, a discussion on different methods in describing surface complexity is in order.

The characterizing of surface complexity has evolved from a long recognized need (Wolfanger, 1941; Wood and Snell, 1960). Pike and Acevedo (1988) discuss a method of measuring surface complexity using relief/distance variograms to measure the topographic grain of the surface. Topographic grain is defined as the size of a sample area beyond which the relief range ceases to increase with area size (Wood and Snell, 1960). The most frequently applied method to measure surface complexity is fractals (Elliot, 1989; Goodchild and Mark, 1987; Clarke, 1986; Yokoya et al. , 1989; Mandelbrot, 1982).

Mandelbrot (1975, 1977, 1982) proposed using fractals as a measure of surface complexity based on the work done by Richardson (1961) and the theoretical background developed by Hausdorff (1919). The fractal dimension sometimes called the Hausdorff-Besicovitch dimension explains objects that occur in nature that classical geometry (Euclidean geometry) would call formless. The fractal dimension is not an integer like the more familiar Euclidean dimension, which is one for a line (curve), two for a plane (area) and three for a volume (cube). The key concept of fractals is self-similarity (scaling), which is used to define the fractal dimension. This means a portion of an object is statistically indistinguishable from the whole when the part is enlarged to the same scale as the whole.

If an object with one dimension (line segment) is divided into N identical parts, which are 1/N in length (r), the whole line segment equals Nr^D. If the fractal dimension (D) is equal to one then the line is a simple line. As the Fractal dimension increases from one to two the line becomes more irregular (fills more space) because as the size of parts decrease (r) the length of the whole line increases. Similar logic can be applied to areas and volumes as shown in Figure 5.

The application of fractals for landscapes can be separated into two types. The first type involves trying to simulate "natural looking" landscapes, which is very popular in the computer graphics field. Excellent examples of landscape generation using fractals are shown in Mandelbrot (1982), Barnsley (1988) and Goodchild (1980). The other type involves determining the fractal dimension of natural landscapes. Mark and Aronson (1984), Shelberg et al. (1983), Lam (1990) and



1 - D N identical parts $r = 1/N^{1}$

2 - D N identical parts $r = 1/N^{2}$

3 - D N identical parts $r = 1/N^{3}$

From an object of N identical parts,
the whole would equal one.

$$Nr^{D} = 1$$

The following defines the fractal dimension (D)
from the above equation.

$$D = \frac{\log N}{\log 1/r}$$

Figure 5. Euclidean Dimension in Terms of Self-Similarity and the Extension to Fractals (Barnsley et al., 1988)

Roy (1987) stated that most natural surfaces have a fractal dimension between 2.1 and 2.5. As the fractal dimension of a surface increases from 2 to 3 the surface increases in complexity (roughness).

Automated Slope Calculation Methods using USGS Digital Elevation Models

Since this study is investigating different methods of determining and characterizing slope values of polygons, a complete review of the different methods used to determine slope of a cell utilizing Digital Elevation Models is provided in this section. Slope is defined by a plane tangent to the surface (hypsometric curve) at a given point. Slope is composed of two components: gradient which is the rate of change in altitude, and aspect which is the direction of the change. Slope and gradient are used synonymously throughout this study and defined as the rate of change in altitude at a point on the surface. Since gradient (slope value) is of interest in this study, only methods of determining gradient from an altitude matrix will be reviewed. Currently there is no common terminology for the numerous methods that have been used to calculate slope. The methods are referred to as method one through eleven in this study.

Theoretical Considerations For Calculating Slope

The theoretical considerations for slope calculation is briefly discussed in this section to provide a common framework for the different slope methods. The equation $z = f(x, y)$ describes points on a three dimensional terrain surface with z equal to the perpendicular distance from the terrain surface to point P(x, y) lying on a plane referenced by X and Y coordinates. Then the elevation of the terrain surface at point P(x, y, z) is the perpendicular distance z. If the equation for the terrain surface consisting of points is expressed in the general form $F(x, y, z) = c$ and c is a constant set equal to zero so that $F(x, y, z) = z - f(x, y)$ then the tangent plane at $P(x_0, y_0, z_0)$ can be defined by the normal vector, provided the gradient is not zero (Zill, 1985). Figure 6 shows a

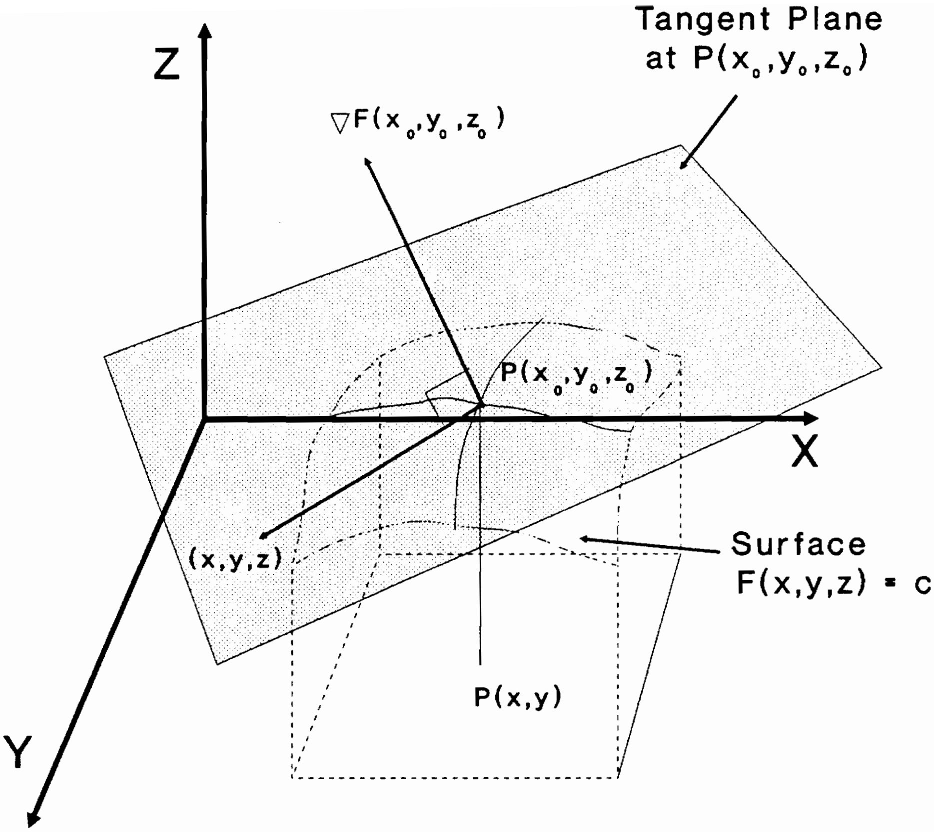


Figure 6. Tangent Plane to a Surface at $P(x_0, y_0, z_0)$

graphical representation of the normal vector to a surface. The normal vector can be expressed as shown below.

$$\vec{N} = \nabla F(x_0, y_0, z_0) = -\frac{\partial f}{\partial x}\hat{i} - \frac{\partial f}{\partial y}\hat{j} + \hat{k} \tag{2.10}$$

$\hat{i}, \hat{j}, \hat{k}$ = orthogonal vectors directed along the x, y and z axis

Slope can be defined by the magnitude of tilt from the horizontal of a plane perpendicular to the normal vector, which is equivalent to the zenith angle. The slope angle (ϕ) in radians can be derived from the components of the normal vector and expressed using the following equation.

$$\tan \phi = \sqrt{\left[(\frac{\partial f}{\partial x})^2 + (\frac{\partial f}{\partial y})^2 \right]} \tag{2.11}$$

Development of Algorithms for Calculating Slope from Digital Elevation Models

For most of the methods discussed in this study, gradient is usually derived locally for each cell using elevations from a 3 x 3 cell grid window (neighbors) of the altitude matrix. All the slope methods discussed in this study treat an elevation value of a cell as a point elevation, even though the value represents a 30 x 30 meter area. The cell location of the point is the centroid of the cell. The notation that is used in this study to describe the elevations of the cell neighbors in the slope method equations are shown in Figure 7. The west-east coordinate direction will be denoted by X, south-north direction by Y and the elevation (altitude) by Z. The delta (δ) notation is used in the following equations to represent the increment (difference) in the X, Y and Z axis. The equation for calculating slope angle (ϕ) in radians shown below, can be derived from equation 2.11.

$$\tan \phi = \sqrt{\left[(\frac{\delta Z}{\delta X})^2 + (\frac{\delta Z}{\delta Y})^2 \right]} \tag{2.12}$$

Substituting $(\frac{\delta Z}{\delta X})$ for $(\frac{\partial f}{\partial x})$ and $(\frac{\delta Z}{\delta Y})$ for $(\frac{\partial f}{\partial y})$

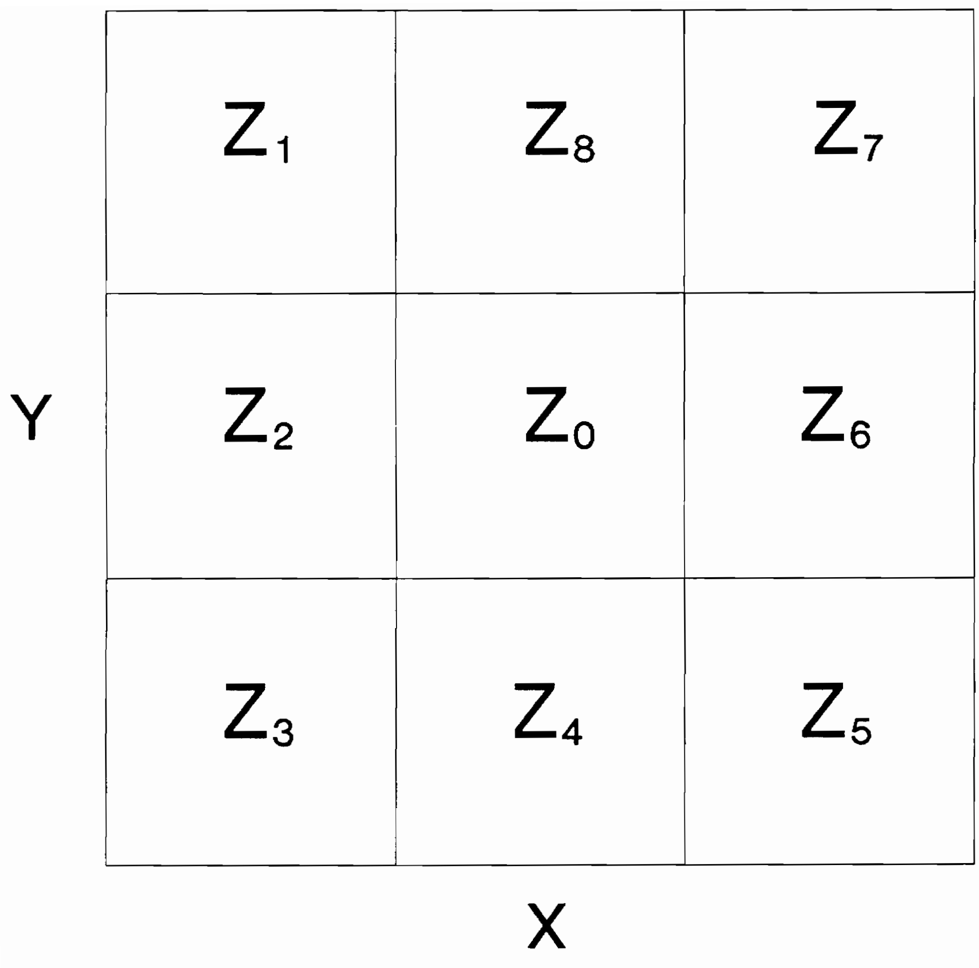


Figure 7. Notation for Elevations used in Computing Slope from an Altitude Matrix Window.

Slope Method One

This is the most common method for calculating slope in the literature mainly because it is computatively simple and easy to program. Numerous papers have presented this method for calculating slope using a Digital Elevation Model (Dozier and Strahler, 1983; Fleming and Hoffer, 1979; Horn, 1982; Duguay et al., 1989). This method is also explained in great detail by Ritter (1986). The steps involved in determining slope of cell Z_0 using this method is shown below.

$$[\delta Z/\delta X] = [Z_2 - Z_6]/2\Delta X$$

$$[\delta Z/\delta Y] = [Z_4 - Z_8]/2\Delta Y$$

ΔX is the spacing between points in the horizontal direction

ΔY is the spacing between points in the vertical direction

With substitutions into equation 2.12 the slope of the cell Z_0 can be determined.

Slope Method Two

Slope method two was used by O'Neill and Mark (1985, 1987) to study the frequency distribution of land slope using 18 7½ minute USGS DEMs. The cell to the north (Y axis) and to the east (X axis) was used to define a triangle as shown in Figure 8. This forms a horizontal right triangle plane with sides equal to cell width, which is 30 meters for a 7½ USGS DEM. There are two steps involved in determining the slope of Z_0 using this method.

$$[\delta Z/\delta X] = [Z_0 - Z_6]/\Delta X$$

$$[\delta Z/\delta Y] = [Z_0 - Z_8]/\Delta Y$$

With the appropriate substitutions into the equation 2.12 the slope of cell Z_0 can be determined.

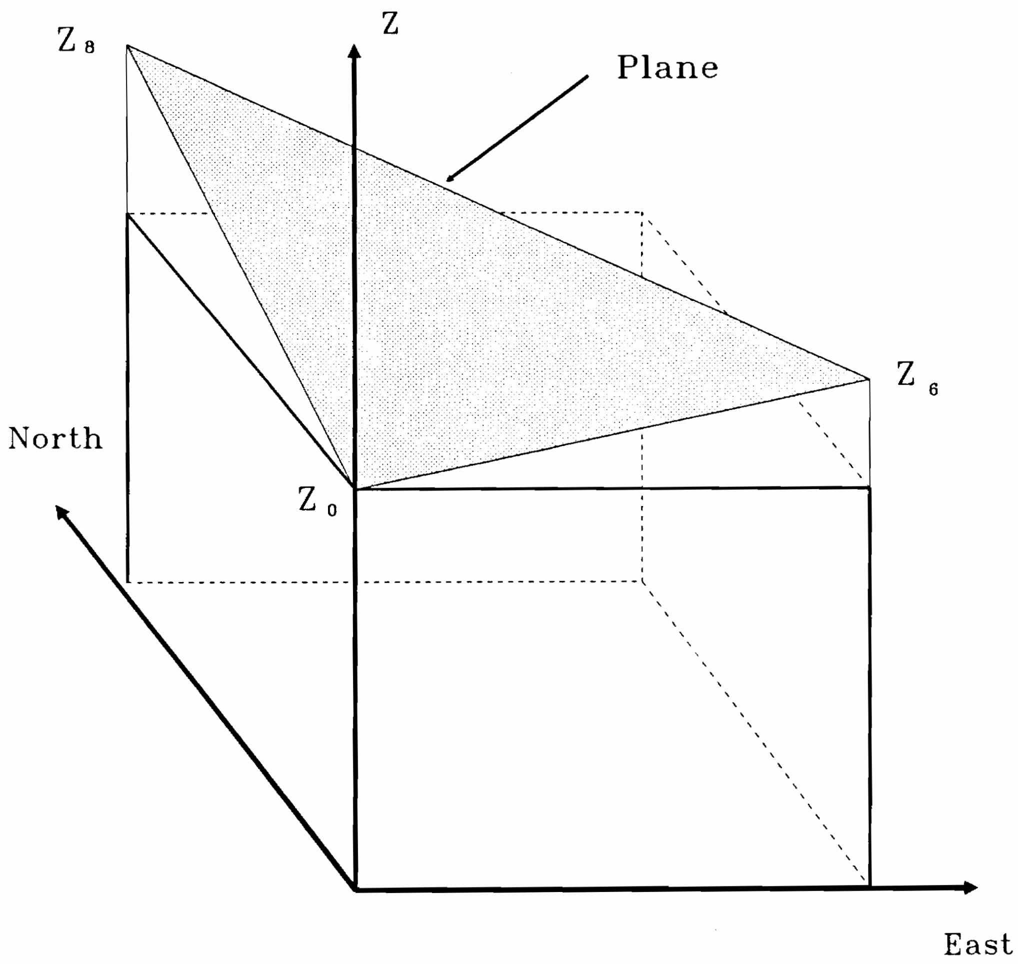


Figure 8. Horizontal Right Triangle Plane used to Calculate Slope.

Slope Method Three

This method of determining slope is used in VIEWIT, a computer program developed by the U. S. Forest Service to determine the terrain visible from a single point or a group of points (Travis et al., 1975). Struve (1977) describes in detail how one can use this method to determine slope. This method is also used in the Map Analysis Package (MAP) (Tomlin, 1980) and was also used by Sieg (1988) to correlate timber volume with topographic variables. Slope is determined for Z_0 by calculating the slope from Z_0 to each of its eight neighbors by taking the absolute value of the difference in elevation between Z_0 and one of its neighbors divided by the cell size. The maximum slope of the eight calculated slopes is then assigned to cell Z_0. IDRISI (1990) modifies this method by assigning the maximum absolute slope value of only the neighbors above, below and to either side of Z_0.

Slope Method Four

Method four, which is called the plane algorithm by Struve (1977) assigns the maximum slope of the four surrounding right triangle planes that have Z_0 as a common point. The slope for each plane is calculated similar to method two. Figure 9 shows the configuration of the four planes that are used in determining the slope value assigned to Z_0.

Slope Method Five

The eight neighbors of cell Z_0 are used to calculate the maximum slope of two three-dimensional surfaces, which are called S and S'. Surface S uses the four nearest neighbors, which are Z_2, Z_4, Z_6 and Z_8 to determine the partial derivative for the X and Y directions. The next-nearest neighbors Z_1, Z_3, Z_5 and Z_7 are used to determine the partial derivative for the X' and Y'

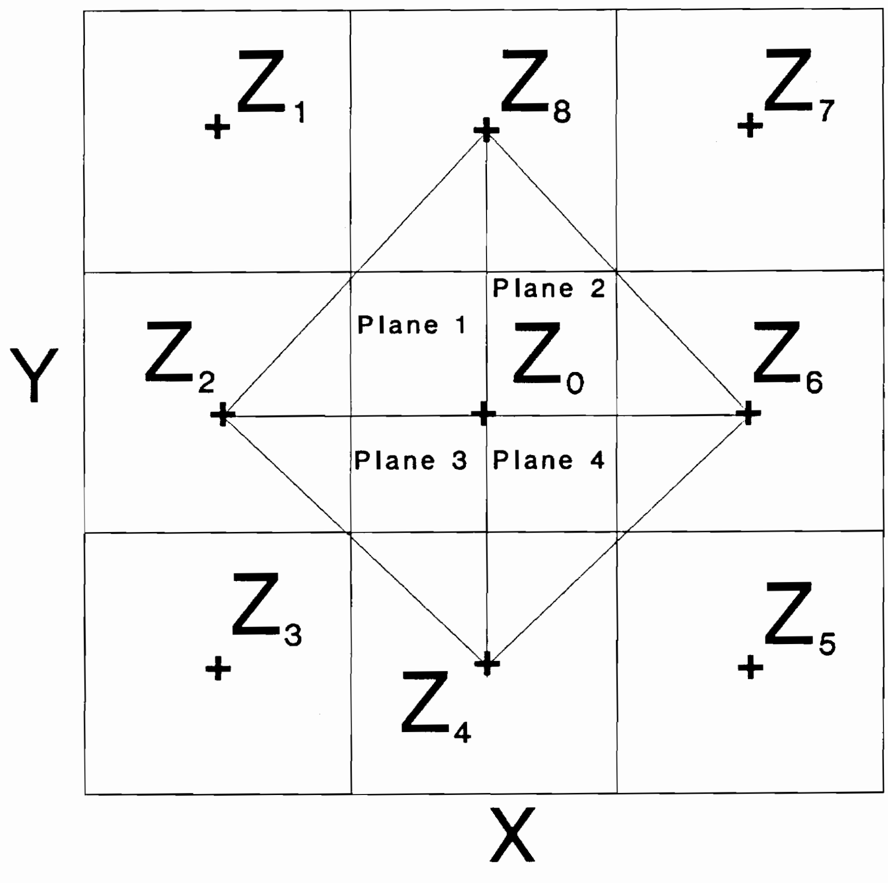


Figure 9. Configuration of the Four Right Triangles used by Method Four to Determine Slope.

directions of surface S'. Figure 10 shows the local coordinate system used by this method.

$$[\partial f/\partial x] = [\delta Z/\delta X] = [Z_2 - Z_6]/2\Delta X$$

$$[\partial f/\partial y] = [\delta Z/\delta Y] = [Z_4 - Z_8]/2\Delta Y$$

$$[\partial f/\partial x'] = [\delta Z/\delta X'] = [Z_3 - Z_7]/2\sqrt{2}\Delta X$$

$$[\partial f/\partial y'] = [\delta Z/\delta Y'] = [Z_5 - Z_1]/2\sqrt{2}\Delta Y$$

Using the above equations the maximum absolute value derived from the partial derivatives in each direction is substituted in equation 2.12 to calculate the slope. The partial derivatives do not necessarily have to come from the same surface. Struve (1977) thoroughly describes the benefits of using this method in calculating slope from an altitude matrix.

Slope Method Six

Burrough (1986), Horn (1981, 1982) and Skidmore (1989) proposed a third-order finite difference method for calculating slope. Horn (1981) stated that the method gave good results because it is based on numerical analysis. The method uses a weighting of three central differences.

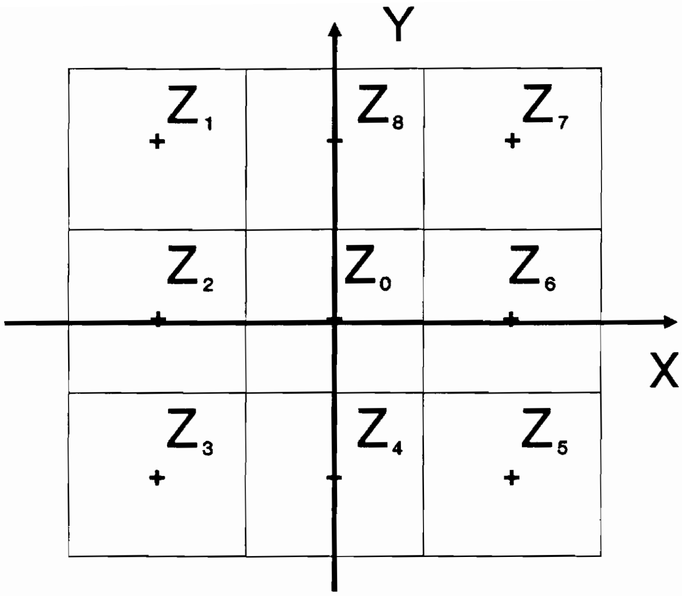
$$[\delta Z/\delta X] = [(Z_1 + 2Z_2 + Z_3) - (Z_7 + 2Z_6 + Z_5)]/8\Delta X \qquad (2.13)$$

$$[\delta Z/\delta Y] = [(Z_1 + 2Z_8 + Z_7) - (Z_3 + 2Z_4 + Z_5)]/8\Delta Y \qquad (2.14)$$

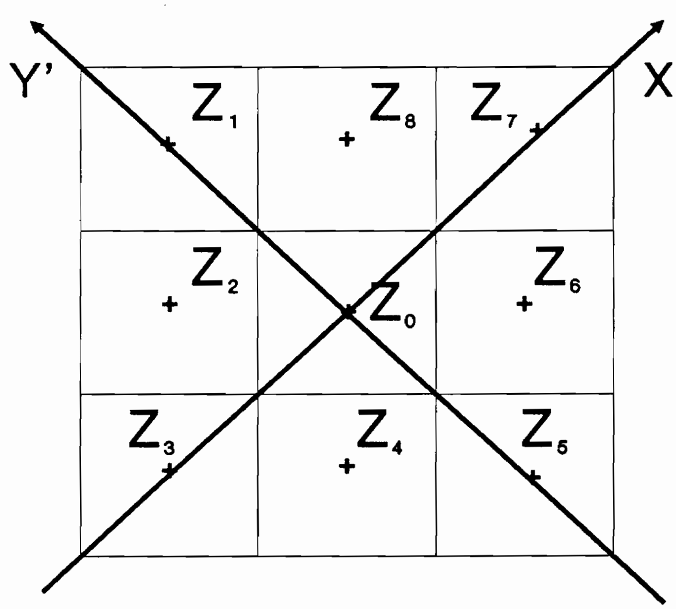
Substituting the results of the above equations into equation 2.12, the slope value is calculated for Z_0.

Slope Method Seven

Sharpnack and Akin (1969) proposed a third-order finite difference model for calculating slope of Z_0 from a 3 x 3 window which, is similar to method six. The only difference is a change in



(a) Nearest - Neighbors of Surface S



(b) Next Nearest - Neighbors of Surface S'

Figure 10. Coordinate System used by Method Five to Calculate Slope of Cell Z_0 (Struve, 1977)

the weighting of cells Z_2, Z_4, Z_6 and Z_8. Using the Sharpnack and Akin (1969) slope model, equations 2.13 and 2.14 can be rewritten as shown below.

$$[\delta Z/\delta X] = [(Z_1 + Z_2 + Z_3) - (Z_7 + Z_6 + Z_5)]/6\Delta X \tag{2.15}$$

$$[\delta Z/\delta Y] = [(Z_1 + Z_8 + Z_7) - (Z_3 + Z_4 + Z_5)]/6\Delta Y \tag{2.16}$$

The third-order finite difference model for calculating slope of Z_0 can have any reasonable weighting scheme, but only this weighting scheme and the method six weighting scheme have been proposed in the literature.

Slope Method Eight

This method is used in the program TOPO III (Grender, 1976). The program calculates the maximum and average slope for cell Z_0, by determining the slope from Z_0 to the perimeter of a circle surrounding Z_0. The radius of the circle can range from one grid cell to one half the minimum altitude matrix dimension. The radius size successively doubles (30, 60, 120, 240, etc.) in the program.

Slope Method Nine

This method uses a multiple linear regression model proposed by Travis et al. (1975) and Skidmore (1989). A surface is fitted to a 3 x 3 cell window using least squares. The least squares minimize the square difference between the fitted surface and the cell elevations. The regression model is shown below.

$$Z_i = \beta_0 + \beta_1 X_i + \beta_2 Y_i + \varepsilon_i \tag{2.17}$$

Assuming that the ε_i is approximately uncorrelated with X and Y, the partial derivatives with respect to X and Y are shown in equation 2.18 and 2.19. Substituting equations 2.18 and 2.19 into equation 2.12 the slope value for cell Z_0 can be derived.

Substituting $[(\partial E(Z)/\partial X] = \beta_1$ for $(\delta Z/\delta X)$ (2.18)

Substituting $[\partial E(Z)/\partial Y] = \beta_2$ for $(\delta Z/\delta Y)$ (2.19)

This method uses all nine elevation values to fit the surface and determines the slope of cell Z_0.

Slope Method Ten

Evans (1979, 1980), Young (1978) and Skidmore (1989) proposed fitting a least squares full quadratic multiple regression to the nine elevation values of a 3 x 3 window to determine the slope value of Z_0. The regression model is shown below.

$$Z_i = \beta_0 + \beta_1 X_i + \beta_2 Y_i + \beta_3 X_i^2 + \beta_4 Y_i^2 + \beta_5 X_i Y_i + \varepsilon_i \qquad (2.20)$$

Assuming that ε_i is approximately uncorrelated with X and Y, the partial derivatives with respect to X and Y are shown in equation 2.21 and 2.22. Substituting equations 2.21 and 2.22 into equation 2.12 the slope value for cell Z_0 can be derived.

Substituting $[\partial E(Z)/\partial X] = \beta_1 + \beta_3 2X + \beta_5 Y$ for $(\delta Z/\delta X)$ (2.21)

Substituting $[\partial E(Z)/\partial Y] = \beta_2 + \beta_4 2Y + \beta_5 X$ for $(\delta Z/\delta Y)$ (2.22)

Evans (1980) showed that if the data are arranged in a square grid, the slope value of Z_0 with a local window coordinate of 0, 0 can be determined using the equations shown below. These equations are more computatively efficient when determining the slope value of Z_0 then using equations 2.21 and 2.22.

$$[\delta Z/\delta X] = [(Z_1 + Z_2 + Z_3) - (Z_7 + Z_6 + Z_5)]/6\Delta X \qquad (2.23)$$

$$[\delta Z/\delta Y] = [(Z_1 + Z_8 + Z_7) - (Z_3 + Z_4 + Z_5)]/6\Delta Y \qquad (2.24)$$

Equations 2.23 and 2.24 are identical to equations 2.15 and 2.16 of method seven respectively, which is the method proposed by Sharpnack and Akin (1969).

Summary

Since the purpose of this study is to evaluate different methods of determining and characterizing slope values that are incorporated into a GIS, the definition and history of GIS were reviewed along with the concepts of spatial data models. Fractals are discussed in the context that they can be used to measure the surface complexity, which is required to effectively analyze or make inferences about polygon slope. Slopes are determined digitally using DEMs and some slope algorithm, so both of these topics were discussed thoroughly.

After examining the literature, no studies were located that were concerned with evaluating methods to characterize slope conditions in polygons or the effects of different tessellation slope algorithms on the characterization of slope for a polygon. Also, no studies were located that comprehensively evaluated the differences between slope methods based on a cell or an aggregation of cells for different surface complexities.

Chapter 3 - MATERIALS AND METHODOLOGY

The study was divided into four phases. Phase one involved collecting and synthesizing the polygon and elevation data to create a DEM for each polygon. This phase also involved categorizing of the polygons into similar size and surface complexity groups. The calculation of cell slope values from real elevation data using eight different slope methods was done in phase two. Also, the eight slope methods were compared cell by cell for all the polygons. The effects different slope methods had on polygon slope statistical descriptors were examined in phase three for the different polygon categories. Phase four compared the methods used to characterize the slope condition within a polygon for different size and surface complexity categories and also investigated a new method of determining slope of a polygon.

Data Collection

Study Area

The area chosen for this study was in Wise and Lee counties in southwestern Virginia. All the study stands (polygons) were located in Big Stone Gap 7½ USGS quadrangle on the Clinch Ranger District of the Jefferson National Forest, which is located in the Appalachian Mountains. The area consisted of ridges with steep slopes and flat valleys. The elevation of the study area ranged from 424 meters (1,391 feet) to 1,079 meters (3,540 feet). Figure 11 shows a perspective trace map of the Big Stone Gap quadrangle with an overlay of the stands (red) in the Jefferson National Forest.

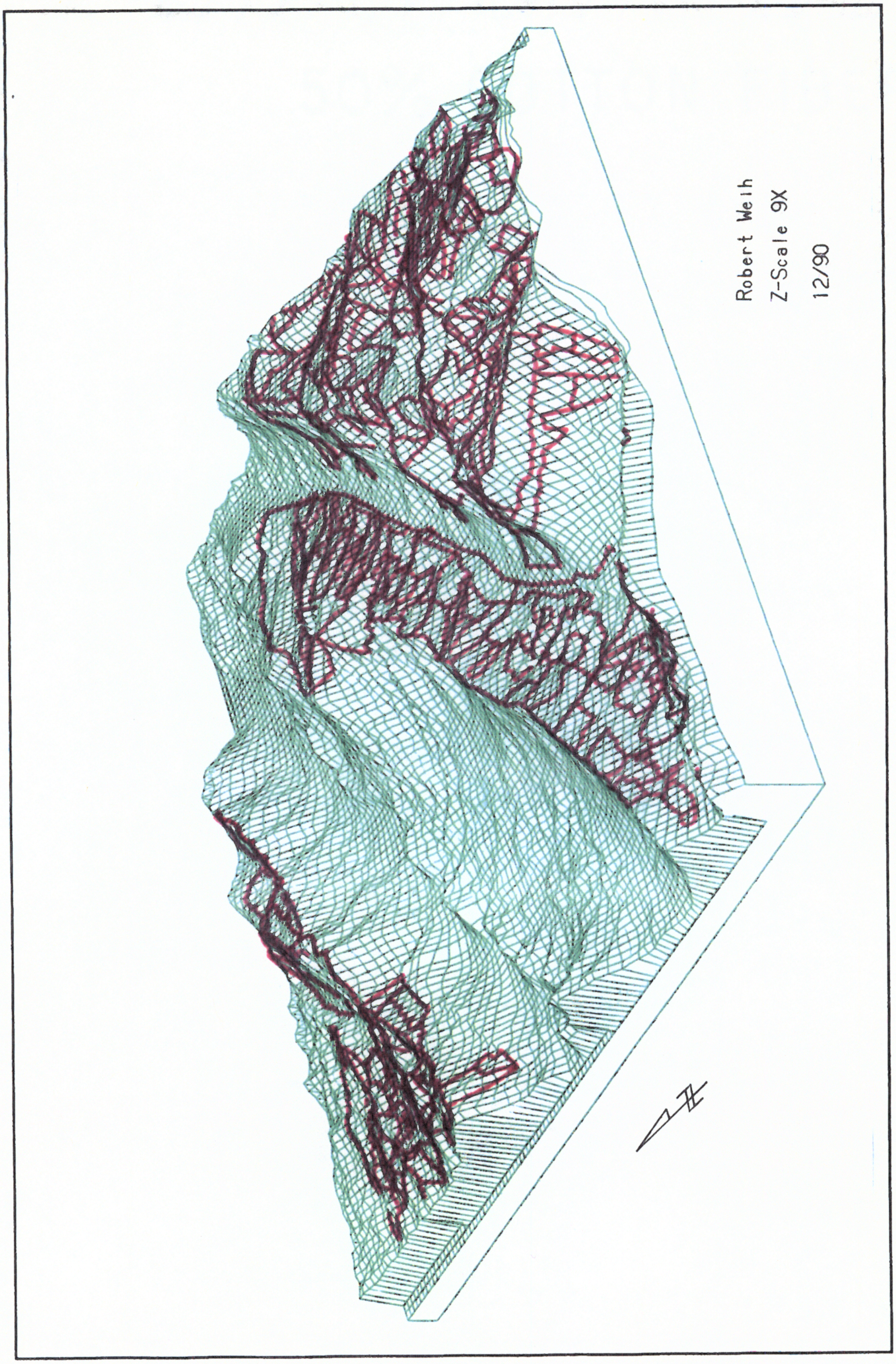


Figure 11. Perspective Trace Map of Big Stone Gap Quadrangle

Polygons Selected

All the polygons selected for the study were digitized by the Tennessee Valley Authority (TVA) from U.S. Forest Service stand maps in vector format. See Dull et al. (1989) for the procedures used to create the forest stand database. The polygons were actual Forest Service management unit stand boundaries on the Jefferson National Forest. The polygons selected for this study met the following criteria.

- Polygons included in the study do not have a common boundary with the USGS 7½ quadrangle.
- Polygon elevation values must be available at least 60 meters from the polygon perimeter.

Figure 12 shows the 245 polygons in the Big Stone Gap quadrangle that meet the first criteria, which was determined using ARC/Info. Two hundred and forty polygons with a variety of shapes and surface complexities were used in the study. Areas ranged from .6 hectare (1.5 acres) to 371.4 hectares (917.8 acres) with a mean of 28.8 hectares (71.2 acres), based on the rasterized polygon area. Polygon 99 was excluded because ARC/Info did not correctly convert the polygon into the Map Overlay Statistical System (MOSS) format. Polygons 224, 237, 244 and 245 were eliminated from the study because of the last criteria listed above.

Digital Elevation Model

The elevations used in this study to calculate slope values were from the USGS Big Stone Gap DEM. United States Geological Survey created the DEM in March of 1976 using the Gestalt Photo Mapper II System. No statistical information pertaining to the horizontal and vertical accuracy of this DEM was available. It was assumed the DEM was a reasonably accurate representation of the Big Stone Gap quadrant surface. The accuracy of the DEM in representing the surface would not affect the comparative aspects of this study but places the study in the context of situations that are encountered in an operational sense. Cell size for the DEM was 30 meters in which cell location was based on the Universal Transverse Mercator (UTM) projection grid system.

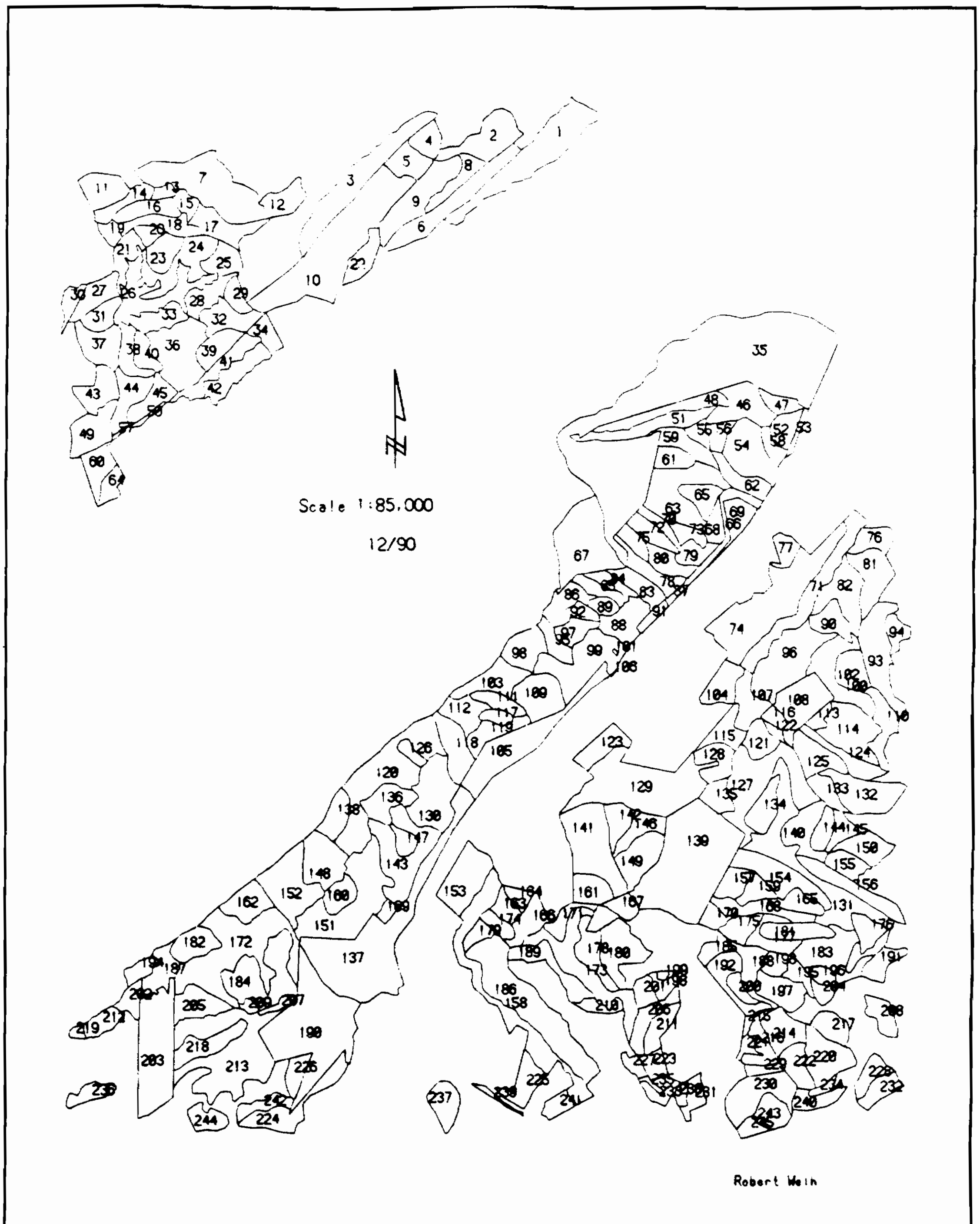


Figure 12. The 245 Original Polygons in Big Stone Gap Quadrangle

Each cell in the study represents 900 square meters (.22 acres). Elevation values were recorded to the nearest whole meter. Even though the cell elevation values of the DEM represented an average elevation of each 900 square meter cell, the values were treated as point elevation values with the location at the center of each cell. This is common practice for numerical calculations using raster data.

Data Synthesizing

The stand (polygon) data obtained from the TVA was in the ARC/Info interchange format. They were converted to an ARC/Info coverage in which all polygons with a boundary common with the 7½ minute quadrangle were removed. The remaining polygons were exported from the ARC/Info into a MOSS format data file. A vector-to-raster program written by the author was used to convert the 245 polygons into a raster format with the same file structure and coordinate system as the polygon DEMs. This transformation from vector to raster generalizes the original map data into 30 meter cells. This had no effect on the outcome of the study except that the areas for the rasterized polygons, which are used to determine area, were greater than the area of the polygons in vector format using the vector-to-raster procedure discussed below. The vector-to-raster program used Bresham's algorithm and a modified YX scan algorithm discussed by Newman and Sproull (1979). If the cell was in the polygon, or on the border, a one was recorded, otherwise a zero was recorded for the cell in the raster polygon file. The bounding rectangle for each of the 245 polygons plus 90 meters on each side was used to clip the appropriate elevations out of the USGS DEM. This created 245 DEMs that were subunits of the original USGS DEM. These DEMs had the same file structure as the rasterized polygons. Figure 13 shows the flow chart of the steps used to create the rasterized polygon files and the polygon DEMs used in the study.

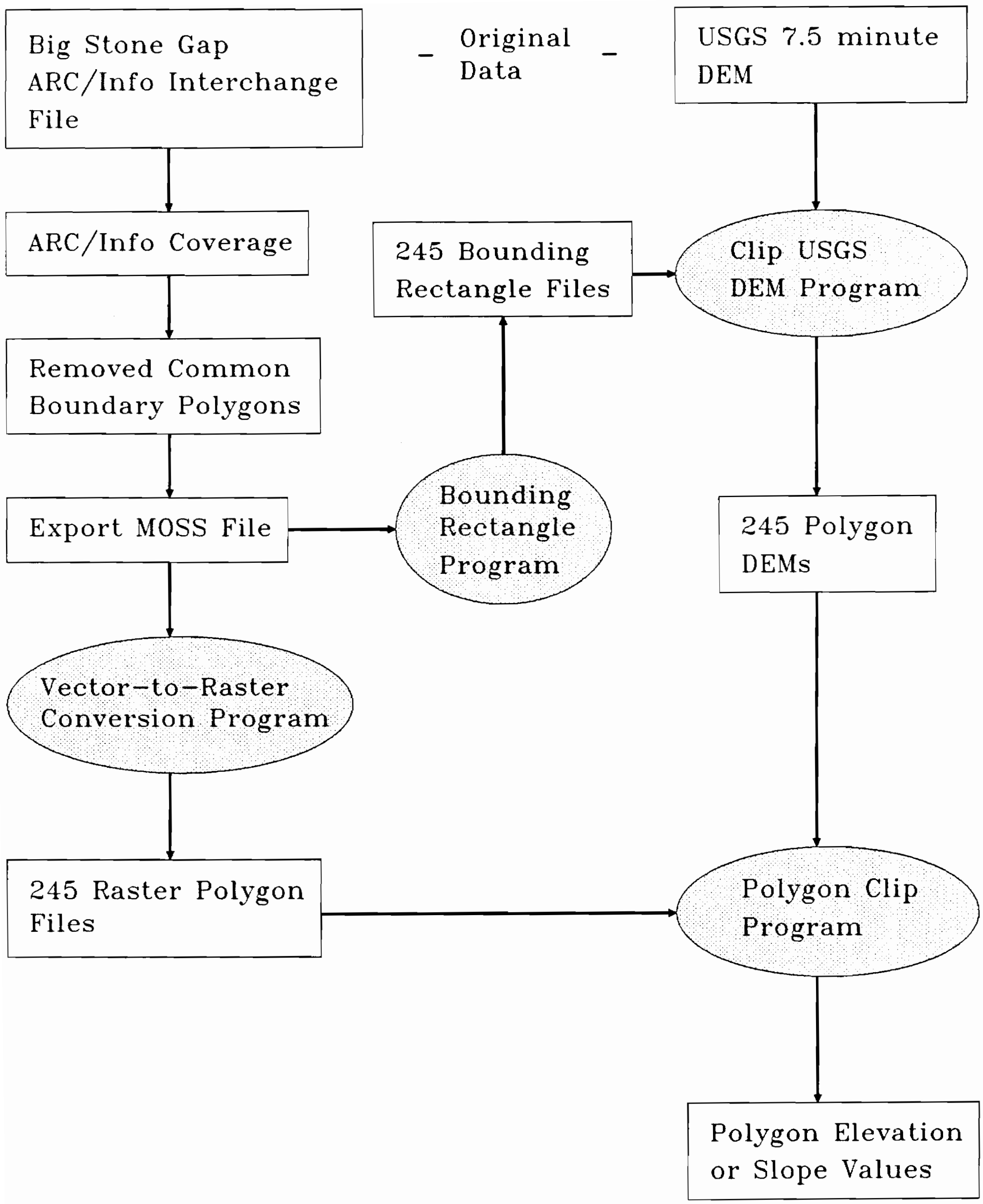


Figure 13. Polygon Digital Elevation Data Synthesizing Flow Chart

Polygon Classification

Polygons in the study area were categorized using two methods, polygon area and surface complexity. The polygons were categorized into different size categories because the polygon size could affect the descriptive statistics that were used in the study. A preliminary investigation indicated that polygon cell slope values were less variable for smaller stands. The polygon area for each of the polygons was determined and the polygons were separated into five categories. These five categories represented natural groups in the size of the polygons. This method of grouping was used since there was no standard method of categorizing polygons based on size. The categories for polygon area are shown in Table 3 with the associated range of cells for the study polygons in each category.

Table 3. Polygon Area Categories

Category	Range(acres, cells)
1	0.0-19.99 hectares (0.0-49.419 acres, 0-222 cells)
2	20.0-39.99 hectares (49.420-98.839 acres, 223-444 cells)
3	40.0-119.99 hectares (98.84-296.52 acres, 445-1,333 cells)
4	120.0-199.99 hectares (296.53-494.209 acres, 1,334-2,222 cells)
5	Greater than or equal to 200 hectares (≥ 494.21 acres, ≥ 2,223 cells)

The polygon area was based on the rasterized polygon area. To effectively analyze and characterize slope conditions within polygons, the complexity of the polygon surface had to be quantified. This could be used to stratify the polygons into categories of similar complexity, which provided a basis for comparing polygon slopes to determine if the slope descriptors were influenced by surface complexity. The surface complexity of each polygon was characterized by the estimated fractal dimension of the polygon surface. A fractal dimension of 2.0 meant the surface was completely smooth, while a dimension of 3.0 meant the surface was infinitely complex. The estimated fractal dimension of each polygon was based on the slope of the surface variogram sampled. This technique was similar to the technique used by Roy (1987), Mark and Aronson (1984), and Goodchild and Mark (1987), but used all points (cells) in the polygon. This method produced about $c^{\#cells}_{2}$ elevation differences. This study had different factors than previous studies, that used estimated fractal dimension to determine surface complexity, because the polygons had varying sizes and shapes. Previous studies concentrated on larger areas with a rectangular shape (quadrangle map, etc.). Only cells within the polygon were used in determining the fractal dimension of the polygon. If the number of sample points for a particular mean square elevation difference between points was less than one half percent of the total points (cells), or only one point, the mean square elevation difference was not used in determining the variogram slope and associated fractal dimension. The coefficient of determination (r^2) for each polygon was determined to indicate linear fit. If the coefficient of determination was near one, the fractal dimension of the polygon surface was estimated with a high degree of confidence. A log variance by log distance plot was done for each polygon in the study to give an indication of linear trend. The slope of the surface variogram was determined using least squares linear regression. The variogram of the fractional Brownian function is described below.

$$E[(Z_i - Z_j)^2] = d^{2H}$$

$E[(Z_i - Z_j)^2]$ = expected value (mean) of the squared elevation difference between two points

d = distance between two points

Z_i = elevation at cell i

Z_j = elevation at cell j, which is distance d from Z_i

H = a value in the range $0<H<1$

The variogram slope (b) was used in the following equation to calculate the fractal dimension (D) of the polygon surface.

$D = 3 - H \quad (H = b/2)$

Theoretically, the value of H would vary between zero and one.

The polygons were separated into the six equal interval fractal dimension categories shown in Table 4.

Table 4. Fractal Dimension Categories

Category	Fractal Dimension
1	less then 2.0
2	2.0 - 2.199
3	2.2 - 2.399
4	2.4 - 2.599
5	2.6 - 2.799
6	2.8 - 3.0

The fractal dimension categories included fractal dimensions less than 2.0, which were theoretically impossible fractal dimensions. The reason for that category was that some polygons fell into this range. The implications, of this and fractal dimensions greater than expected (>2.5), are discussed in the next chapter. Categorizing the polygons based on area and fractal dimension allowed investigation of how these factors affected the methods used to characterize polygon slope and determined if any methods were sensitive to these polygon characteristics.

Slope Method Analyses

Slope methods 1, 2, 3, 4, 5, 6, 7 and 9 (as described in detail in the Literature Review) were investigated. Slope method 10 was not investigated because it was the same as slope method 7. Since slope method 8 has only been discussed in one article, and not referenced or found in any other article, it was not examined in this study. The slope value (in percent) for each cell in every polygon in the study was calculated using the above methods. A program was written in C by the author to calculate the slope values of every cell in the 240 polygons for slope methods 1, 2, 3, 4, 5, 6 and 7. Slope method 9 cell slope values were calculated using a program written in Fortran by the author that incorporated the IMSL STAT Library (1989). This provided the basic data used in this study.

Comparing Slope Methods based on Cell Slope Values

A cell by cell slope value comparison for all the polygons was evaluated across all size and surface complexity categories for each slope method. Even though the ultimate concern of this study was a polygon slope value, an understanding of the effects of slope calculation methods on determining cell slope values was necessary since polygon slope was characterized by aggregating cell slope values in some fashion. This phase of the study did not attempt to determine which method was "best," but determined the magnitude of differences between the methods. The "best" slope method could not be determined because real surface elevation data were used in this study, and the "true" slope values were unknown for comparison purposes. The 95% confidence intervals of the pair wise differences between slope methods were calculated. Also, the mean, variance, minimum and maximum differences between the slope methods were calculated and are discussed in the next chapter.

Cell by cell comparisons were examined in previous studies by Evans (1979), Young (1978), Struve (1977) and Skidmore (1989), but this investigation is unique because actual surface elevation data were used in the calculation of cell slope values. Most of the previous studies used elevation data created by mathematical models, which did not contain all the irregularities of the earth's surface that affect the calculation of slope. Further, this study examined eight different slope methods for a total of 28 pair wise comparisons, whereas previous studies usually compared two or three slope methods. The majority of the previous studies were aimed at determining the "best" slope method, not examining the differences between slope methods, as in this study.

Evaluating Slope Methods Based on Polygon Slope Statistics

Proceeding one step further, the effect different slope methods had on each polygon slope descriptor for different area and surface complexities was examined. The effects of slope methods on polygon slope descriptors were important since the ultimate concern of this study was characterizing polygon slope. For each of the 240 polygons the following descriptive statistics were computed using the cell slope values.

- Number of slope values (cells)
- Mean slope value
- Median slope value
- Trim Mean slope value (middle 90% average)
- Slope Mode value
- Standard deviation of slope values
- Slope values range (minimum, maximum)
- First Quartile (25 percentile)
- Third Quartile (75 percentile)

The above basic statistics were used since they provided a broad range of descriptive measures of polygon slope that could be utilized in different natural resource modeling situations. The mean, a central tendency descriptive measure, was the most commonly used measure of polygon slope in previous studies. Another central tendency measure was the median, which could provide a better measure of central tendency when the cell slope values of the polygon were skewed. The trim mean calculated the central tendency of the middle 90% of cell slope values of the polygon and eliminated the values at the extremes. This was beneficial if the elevation data used to calculate cell slope values had errors that fell in the 5% tails of the distribution. Mode measured the cell slope value that occurred most often, which was helpful if the model required the most frequently occurring slope value or slope class value in a polygon. If variability of cell slope values within a polygon was important for incorporation into a natural resource model, standard deviation of the cell slope values was a good measure. When a natural resource model required polygons with a slope greater or less than some slope value, the minimum or maximum descriptive measures could be used. Some natural resource models required that a certain percentage of slope values be less or greater than a specific slope value; the quartile measures were appropriate for this type of model. Besides to these descriptor statistics, box plots and histograms were created for the slope values in each polygon to aid in understanding the effect of slope methods on polygon slope descriptors. All the descriptors were calculated using MINITAB (1989) except slope mode. Slope mode was calculated for each polygon by separating the polygon cell slope values into 0.02% slope value classes and using this data to determine the polygon slope mode. A program written by the author using Fortran incorporating the IMSL STAT Library (1989) was used to calculate these values.

Polygon Slope Characterization

The next step was to examine different methods for characterizing polygon slope conditions across the different area and surface complexity categories. This step allowed the examination of the behavior of polygon slope descriptors across a range of polygon sizes and surface complexities to investigate their applicability to differing natural resource uses in Geographic Information Systems. In natural resource models that use slope as a variable, certain polygon slope descriptors were more valuable than others. Characteristics of the slope method and polygon slope descriptor(s) with their applicability to the objectives of the natural resource model were considered in determining the appropriate slope method, polygon descriptor(s) combination. For example, instead of using the average polygon slope, which is commonly used in determining erosion potential in a GIS for a forest stand, the first and third quartile could be used to state an erosion potential range. The descriptors that were examined were described in the previous section. This gave 9 slope methods by 9 descriptors across 5 area and 6 fractal categories, or 2,430 possible comparisons to examine. Grouping by size, surface complexity or slope methods was performed when it was determined to be appropriate. For example, if polygon size did not have any affect on slope methods or polygon slope descriptors, polygons could be grouped together and this would decrease the number of possible comparisons to 486.

Slope is a point phenomenon, and this study investigated methods of characterizing a slope value for an area (polygon), which has administrative importance in GISs used for natural resource management, but mathematically slope of a polygon does not exist. The differences between the polygon slope descriptors in characterizing polygon slope were discussed based on how appropriate the polygon slope descriptor was in meeting the model objectives for particular management goals. This was a subjective comparison of trends based on the application, but very important. There is no universal polygon descriptor(s) and slope method that is always appropriate. The most appropriate method and descriptor(s) varies since slope is an important component of many different models that are used in numerous applications.

Besides examining methods to characterize polygon slope from an aggregation of cell slope values, polygon slope was characterized by fitting a plane through the elevation values of a polygon. This was a new approach for determining polygon slope, that used a well established technique called trend surface analysis. This approach was called slope method 11 (Y-method) throughout this paper. The benefit of this approach is that one polygon slope value is determined utilizing all the elevations of the polygon instead of aggregating cell slope values from numerous small windows of elevations. This method would eliminate any inherent problems caused by using a particular slope method. The disadvantage of this method was that it might smooth the data more than the other slope methods. For example, if the polygon was divided by a ridge, this method would calculate a polygon slope value near zero, when in fact the slope was steep on both sides of the ridge top. In natural resource management, polygon boundaries usually occur at breaks in the terrain (ridge tops, stream bottoms) due to administrative boundaries or ecological changes. The trend surface analysis takes the form of a polygonal regression model to fit a surface to sample points as shown below.

$$Z_i = \beta_{00} + \beta_{10}X_i + \beta_{01}Y_i + \ldots + \beta_{pq}X_i^p Y_i^q + \varepsilon_i$$

$\beta's$ = are coefficients of the polynomials

X_i, Y_i = geographic coordinates in the X and Y directions respectively

p = degree of polynomial in the X direction (1 to p)

q = degree of polynomial in the Y direction (1 to q)

Z_i = elevation value

See Davis (1986), Taylor (1977) and Goodman (1983) for a more comprehensive discussion of trend surface analysis. Since the objective was to characterize the slope value of a polygon, only the first-degree (linear) trend was examined. The first-degree trend surface takes the following form.

$$Z_i = \beta_0 + \beta_1 X_i + \beta_2 Y_i + \varepsilon_i \quad (3.10)$$

Assuming the ε_i is approximately uncorrelated with X and Y, the partial derivatives of equation 3.10 with respect to X and Y are shown in equations 3.11 and 3.12. Substituting equations 3.11 and 3.12 into equation 2.12, a slope value for a polygon can be determined.

$$\text{Substituting } [\partial E(Z)/\partial X] = \beta_1 \text{ for } (\delta Z/\delta X) \quad (3.11)$$

$$\text{Substituting } [\partial E(Z)/\partial Y] = \beta_2 \text{ for } (\delta Z/\delta Y) \quad (3.12)$$

This approach was similar to slope method 9 discussed in the Literature Review, except instead of determining the slope value for a single cell using nine elevations, all the elevations of the polygon are used to determine the slope value for a polygon. The coefficient of determination was calculated to give indicate how well the plane fit the elevation values. Doveton and Parsely (1970) stated that the distribution of data points used in trend surface analysis should meet the following criteria.

- Reasonable sample size
- Even distribution of sample points
- The mapped area should be roughly square

Doveton and Parsely (1970) found that when the spatial distribution of sample points were elongated, the trend appeared to parallel the direction of elongation. Since some of the study polygons were elongated, criteria three was not met and the Cook's distance and residual plots were examined to determine if this lack of compliance affected the determination of the polygon slope using this method. This method was compared to the other methods of characterizing slope of a polygon for the different area and surface complexity categories.

Chapter 4 - RESULTS AND DISCUSSION

This chapter is divided into six sections that discuss the results for the four different phases of the study. The first section discusses the outcome of categorizing the polygons into area and surface complexity categories. The Cell Slope Differences section presents a comparison of the different cell slope methods. Slope method 11 is discussed in section three. In the next section, a hypothetical example of how different methods of determining cell slope values affect a decision model is presented. Effects of polygon area and surface complexity on polygon slope descriptors are reviewed in the fifth section. The final section discusses characteristics of the polygon slope descriptors and methods of characterizing the slope of a polygon.

Polygon Categorization

Area Categorization

The 240 polygons were divided into five size categories as previously described. The areas were based on the rasterized polygons. The number of polygons in each category are shown in Table 5. The polygons were not distributed evenly among the different area categories. Sample sizes were small for categories 4 and 5, thus impairing statistical inferences in these two cases. Even though only one polygon (Polygon 35) fit the definition for area category five, it was retained as a separate class. This polygon, at 371.43 hectares, was larger than the other polygons and it would allow for subjective, if not statistical, examination of the possible effect of large polygons on the study results. Note that these are real polygons, and conditions like these would be encountered in operational situations.

Table 5. Area Categories

Category	Number of Polygons
1	118
2	77
3	40
4	4
5	1

Fractal Categorization

As discussed in the previous chapter, the 240 polygons were divided into six fractal categories. Table 6 shows the number of polygons in each category, and Figure 14 shows the location of the stands for each category.

Table 6. Fractal Dimension Categories

Category	Number of Polygons
1	18
2	70
3	59
4	49
5	29
6	15

Fractal category one (less than 2.0) is a theoretically impossible fractal dimension for a surface. However, using the method selected to estimate the fractal dimension of a surface, 18 polygons (fractal dimension 1.848 - 1.997) fell into this category. The estimated slope for the variograms of the 18 polygons have coefficients of determination (r^2) from .99308 to .99779. A log mean square elevation difference by log distance plot was performed for each of these polygons, and it indicated

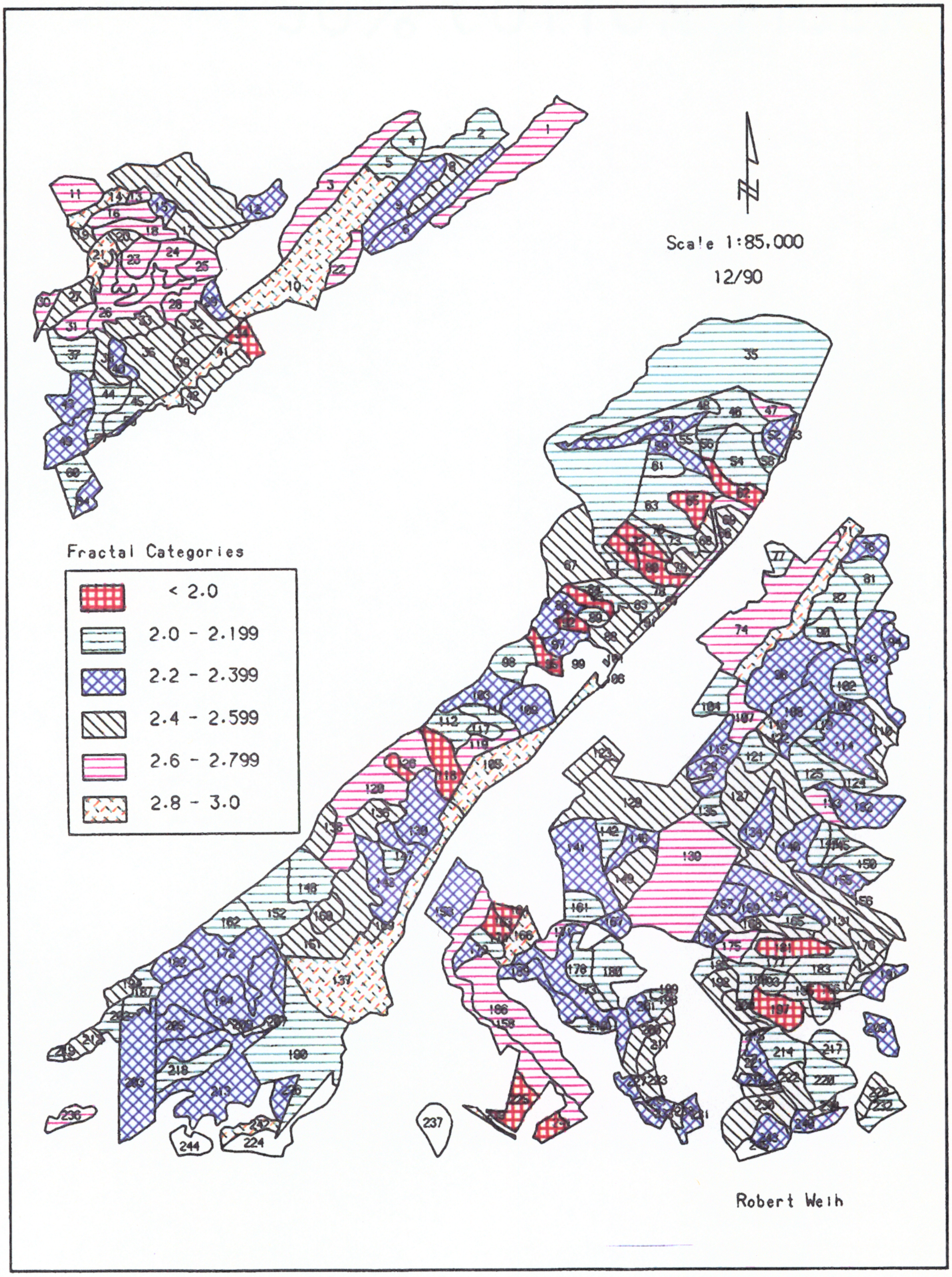


Figure 14. Spatial Locations of Fractal Categories for the 240 Stands in the Study

a strong relationship between these values, as expected with such a high coefficient of determination. The 99% confidence interval (CI) of the variogram slope used to compute the fractal dimension showed that eight of the 18 polygons with fractal dimensions less than 2.0 had confidence intervals that included an estimated fractal dimension greater than or equal to 2.0. Of the 18 polygons with an estimated fractal dimension less than 2.0, 13 were in area category one (0.0 - 19.99 hectares) and five were in area category two (20.0 - 39.99 hectares). The range of sizes for the 18 polygons with fractal dimensions less than 2.0 was from 8.46 to 30.60 hectares. All but one of the 18 polygons were smaller than the mean polygon area for the study (28.8 hectares).

Mark and Aronson (1984) found theoretically impossible fractal dimensions (less than 2.0) over short distances for four USGS 7½ minute quadrangle DEMs in Oregon and one in Pennsylvania using the same method to estimate the fractal dimension as used in this study. They concluded that a possible explanation for these theoretically impossible fractal dimensions could have been that the Pennsylvania 7½ minute DEMs were produced by profiling and interpolation, which could have influenced the small-distance aspect of the variograms. This was not the case in this study since the USGS Big Stone Gap 7½ quadrangle DEM was created using the Gestalt Photo Mapper II. However, Mark and Aronson (1984) also found that impossible fractal dimensions occurred only for small-distance aspects (small areas) of the variograms.

Previous studies that estimated the fractal dimension of surfaces were based on large areas (quadrangle maps, etc.) of rectangular shape. This study was determining the fractal dimension of polygons, which are actual natural resource management units of varying sizes and shapes. No studies could be located that dealt with determining the fractal dimension of areas of various sizes and shapes. This called for further investigation into the causes of the theoretically impossible fractal dimensions for the 18 polygons, even though the estimated fractal dimension was used only to separate the polygons into surface complexity categories in this study.

After producing numerous variogram plots, examining the individual polygon cell elevations and creating perspective trace plots of the surfaces, the following explanations for the impossible fractal dimension estimates were hypothesized.

1) Small distance (d) mean square differences are more sensitive to errors in DEM elevations than large distance (d) mean square differences.

2) The smallest change in distance (d) in a 7½ minute DEM is 30 meters.

3) A model is being used to estimate the fractal dimension and it is estimating the fractal dimension at the lower extreme (2.0).

4) The elevations are recorded in integers (nearest meter) so there are many occurrences of $(Z_i - Z_j)^2 = 0$. This rarely occurs in reality, except for bodies of water. This causes the small distance (d) mean square differences to be underestimated, and consequently, decreases the fractal dimension. The reason that small distance mean square differences are underestimated is that there are higher occurrences of $(Z_i - Z_j)^2 = 0$ because the eight neighbor cells are similar due to spatial autocorrelation.

5) When determining the fractal dimension of a smooth surface (fractal dimension ≈ 2.0) a larger area is necessary to determine the fractal dimension. This is because as the number of log mean square difference points decrease (smaller area, smaller sample), the influence of the first two distances (log distance 3.40 and 3.75) on the estimated slope of the regression fit increases.

The fourth and fifth surmised explanations for impossible fractal dimensions were investigated further because these two hypotheses could be examined using the available data.

Impossible Estimated Fractal Dimension is a Consequence of the Elevation Data. Hypothesis four was examined by simulating real elevation values that were within the rounded integer elevation value range, using random numbers from a uniform distribution. Table 7 shows 18 polygons selected from the study area with their fractal dimensions and associated coefficients of determination. Polygons with estimated fractal dimensions greater than 2.0 were included along with

Table 7. Fractal Dimension and r^2 of Polygons using Simulated Real Number Elevations

Polygon	Integer	Simulation 1	Simulation 2	Simulation 3	Simulation 4
62	**1.984** .98747	1.984 .98754	1.985 .98736	1.985 .98727	1.985 .98748
63	2.107 .99652	2.107 .99652	2.107 .99652	2.107 .99652	2.107 .99652
65	**1.974** .99611	1.975 .99600	1.975 .99600	1.975 .99599	1.975 .99606
66	2.763 .38570	2.762 .38902	2.763 .38615	2.763 .38700	2.763 .38663
67	2.428 .98652	2.428 .98647	2.4274 .98650	2.428 .98649	2.428 .98652
69	2.523 .81011	2.525 .80949	2.524 .80938	2.523 .81010	2.523 .80908
72	**1.977** .99657	1.977 .99658	1.977 .99665	1.978 .99657	1.978 .99656
73	2.031 .98811	2.032 .98811	2.031 .98798	2.031 .98816	2.032 .98820
75	**1.893** .99490	1.895 .99481	1.894 .99482	1.893 .99489	1.894 .99492
79	2.556 .80729	2.558 .80656	2.558 .80653	2.556 .80743	2.556 .80574
80	**1.987** .99221	1.9787 .99218	1.988 .99215	1.987 .99217	1.987 .99221
81	2.028 .98682	2.028 .98680	2.029 .9867	2.028 .98682	2.028 .98687
85	**1.968** .99262	1.969 .99255	1.968 .99256	1.969 .99260	1.968 .99269
89	2.029 .99236	2.029 .99241	2.030 .99240	2.030 .99227	2.029 .99248
91	2.484 .72957	2.482 .73377	2.488 .72974	2.484 .73166	2.484 .73122
92	**1.947** .99477	1.948 .99475	1.947 .99477	1.948 .99474	1.948 .99476
93	2.309 .98760	2.309 .98758	2.309 .98763	2.309 .98765	2.309 .98766
95	**1.953** .99453	1.954 .99450	1.953 .99452	1.954 .99448	1.953 .99454

polygons with a fractal dimension less than 2.0 to examine the effects of using non-integer elevation values on them also. The first column is the fractal dimension based on the integer values and the other four columns are the fractal dimension of the same polygon, but using simulated real number elevation values. All polygons with fractal dimensions of less than 2.0, using integer cell elevation values, had estimated fractal dimensions greater than or equal to the integer elevation value fractal dimensions using the simulated real number cell elevation values. This was the case for all 18 polygons in fractal category one (fractal dimension less than 2.0) for 200 simulations. However, the differences between using integer elevation values and real elevation values had little influence on determining the fractal dimension of a surface since the increase in fractal dimension was from 0.000 to 0.003.

Influence of Sample Points on Fractal Dimension. The fifth hypothesis for theoretically impossible fractal dimension estimates was examined using two different approaches. The first approach calculated the fractal dimension for all elevations (cells) in a bounding rectangle plus 30 meters for each polygon. This increased area (number of cells) was used to estimate the fractal dimension of the polygon surface. Table 8 shows the fractal dimension, r^2, and the area of the same 18 selected polygons shown in Table 7. In Table 8, the fractal dimension was estimated 1) using only the integer elevation values in the polygon, and 2) with the elevation values in the bounding rectangle plus 30 meters of the polygon for comparison. All the polygons with a fractal dimension less than 2.0 based on the elevation values within the polygon, had a fractal dimension greater than 2.0 using bounding rectangle elevation values. The coefficient of determination improved for all of the 18 polygons as shown in Table 8. This shift, from having a theoretically impossible fractal dimension to having a fractal dimension greater than 2.0 with increased sample size (area) and improved coefficient of determination was caused by three factors. The increased sample size dampens the effects of extreme sample points (log distance 3.40, 3.75, etc.) on the estimated fractal dimension.

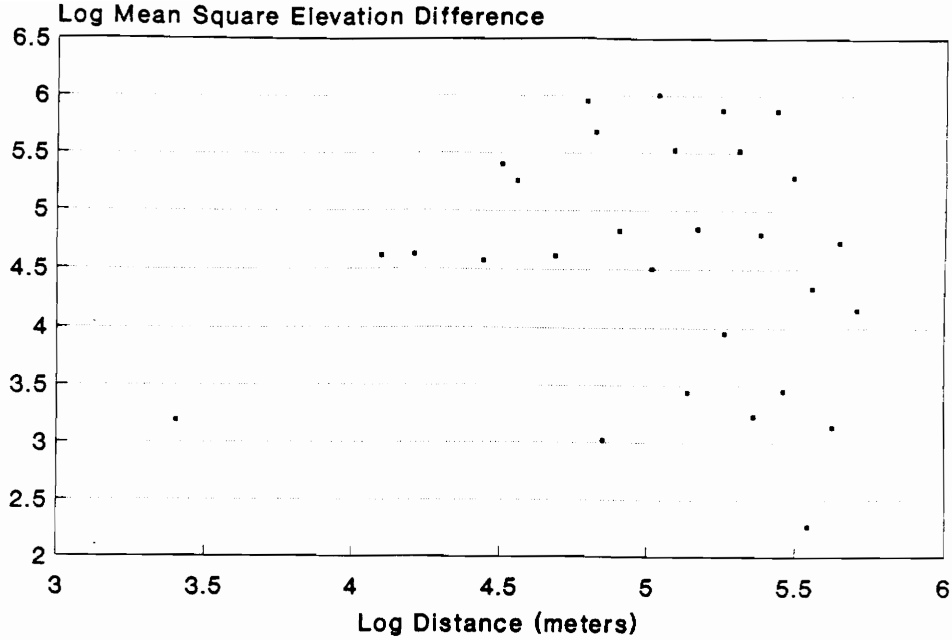
Table 8. Calculating Fractal Dimension using the Polygons' Bounding Rectangle

Polygon	Elevations within the Polygon			Elevations within the bounding rectangle		
	Fractal Dimension	Coefficient of Determination	Area in Hectares	Fractal Dimension	Coefficient of Determination	Area in Hectares
62	**1.984**	.98747	20.79	2.129	.99505	78.12
63	2.107	.99652	56.97	2.095	.99705	146.52
65	**1.974**	.99611	18.36	2.071	.99938	51.75
66	2.763	.38570	23.22	2.402	.96274	175.50
67	2.428	.98652	68.67	2.418	.99417	162.00
69	2.523	.81011	18.81	2.486	.96492	89.91
72	**1.977**	.99657	16.47	2.117	.99803	63.00
73	2.031	.98811	11.97	2.131	.99933	39.33
75	**1.893**	.99490	11.88	2.131	.99881	39.33
79	2.556	.80729	14.58	2.246	.98669	38.88
80	**1.987**	.99221	18.72	2.103	.99901	57.96
81	2.028	.98682	32.94	2.351	.99505	88.92
85	**1.968**	.99262	13.05	2.174	.99380	51.03
89	2.029	.99236	9.72	2.117	.99958	25.65
91	2.484	.72957	7.47	2.210	.99821	35.91
92	**1.947**	.99477	8.91	2.039	.99950	27.36
93	2.309	.98760	49.23	2.038	.99469	128.25
95	**1.953**	.99453	15.21	2.061	.99911	50.40

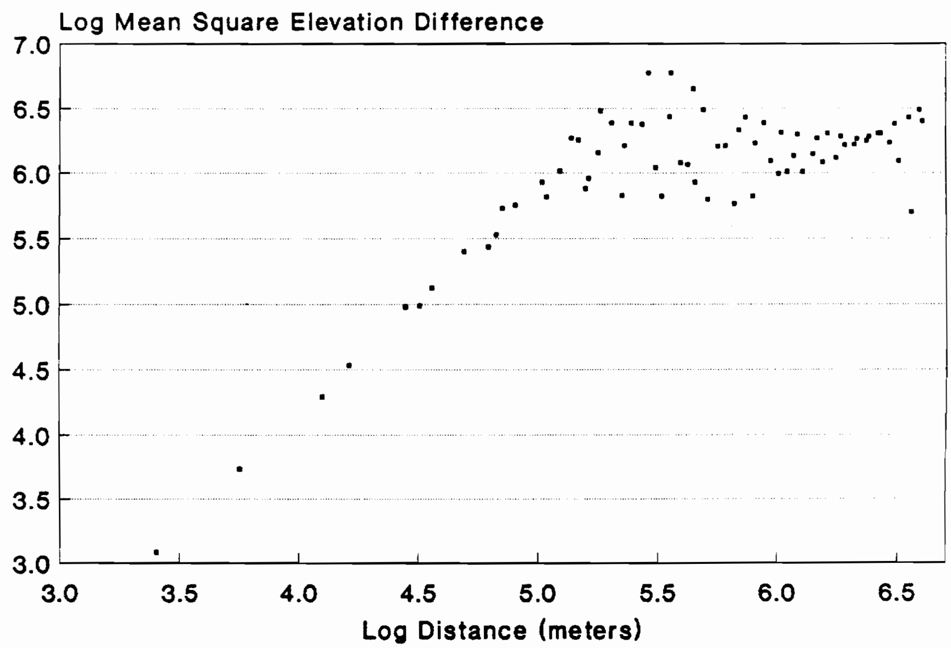
The cells that were used to estimate the fractal dimension were different for the polygon, so this affected the fractal dimension estimate. The shape of the matrix of elevation values changed from the polygon shape to a rectangle and this affected the fractal dimension, especially for polygons elongated in the diagonal direction. An example of this is polygon 66, shown in Figure 14, which was linear in the diagonal direction. The estimated fractal dimension of polygon 66 changed from 2.763 ($r^2=0.38570$) based on the elevation values in the polygon to 2.402 ($r^2=0.96274$) calculated from the elevation values in the bounding rectangle. The second approach used the elevations within the polygon and evaluated the influence of the first two distances (log distance 3.40 and 3.75) on determining the variogram slope (b) that was used to estimate the fractal dimension ($D = 3 - b/2$). The Cook's distance (D_i) for all the sample points for the 18 polygons in fractal category one were examined to determine if any of the sample points (distances) were influential. The criteria used to determine if a sample point was influential was if the Cook's distance was large enough to move the estimated $\hat{B}$ to the edge of a 50% confidence region or beyond (Weisberg (1980); Cook and Weisberg (1982)). For 15 of the 18 polygons in fractal category one, the first sample point (log distance 3.40) was influential based on Cook's distance. The second sample point (log distance 3.75) was not influential in any of the polygons. For example, the first sample point (log distance 3.40) was influential for polygons 62 and 65, which had an estimated fractal dimension of 1.984 and 1.974 respectively. Deleting the first sample point and using the remaining sample points to estimate the fractal dimension, resulted in polygons 62 and 65 having fractal dimensions of 1.969 and 1.964 respectively. Even though the first sample point was influential based on Cook's distance, the elimination of this sample point had little effect on estimating the fractal dimension of the polygon. It actually decreased the fractal dimension. This was the case for all 18 polygons in fractal category one.

Fractal Dimension for a Real Surface Greater than Expected. Forty-four polygons had a fractal dimension greater than 2.6 (fractal categories 5 and 6), which was greater than expected for a real surface. After examining the log-mean square elevation difference by log distance plots of these 44 polygons, two causes were discovered for the high fractal dimensions. First, the fractal dimension could not be estimated with any degree of certainty, because the variogram did not have a linear trend as shown in Figure 15a. The polygon surface could be fractal to a certain distance, which is discussed next, but because of the spatial resolution of the data the fractal dimension could not be determined with any degree of certainty. Second, the surface was fractal to only a certain distance as shown in Figure 15b. This polygon had a fractal surface up to a distance of 220 meters. All the polygons in fractal category five, and most of the polygons in fractal category six were fractal to a certain distance. Four of the polygons' fractal dimensions could not be estimated with any degree of certainty, based on a coefficient of determination (r^2) less than 0.3 and the lack of linear trend for the log mean square elevation difference by log distance plots. Also, a coefficient of determination by fractal dimension plot was made (Figure 16) to show the relationship between r^2 and fractal dimension. In theory, this relationship should not exist, but it reinforced the reasons stated above for the higher than expected fractal dimension, and showed possible problems with the method used to estimate the fractal dimension in this study.

In summary, the method used to estimate the fractal dimension of a polygon was sensitive to elongated polygons, especially in the diagonal direction, and to small sample areas when the estimated fractal dimension was near 2.00. This was based on the 240 polygons used in this study in which the elevation values came from the Big Stone Gap 7½ minute USGS DEM created using the Gestalt Photo Mapper II. The model could behave differently for elevation data created using other methods and from different geographic areas. Even though for some, the fractal dimension could not be estimated with any degree of certainty, other polygons had impossible fractal



(a) Fractal dimension could not be estimated with any degree of certainty (polygon 87, fractal dimension = 2.9953)



(b) Surface is fractal to a certain distance (polygon 16, fractal dimension = 2.6629)

Figure 15. Reasons for Higher than Expected Fractal Dimension for Real Surfaces

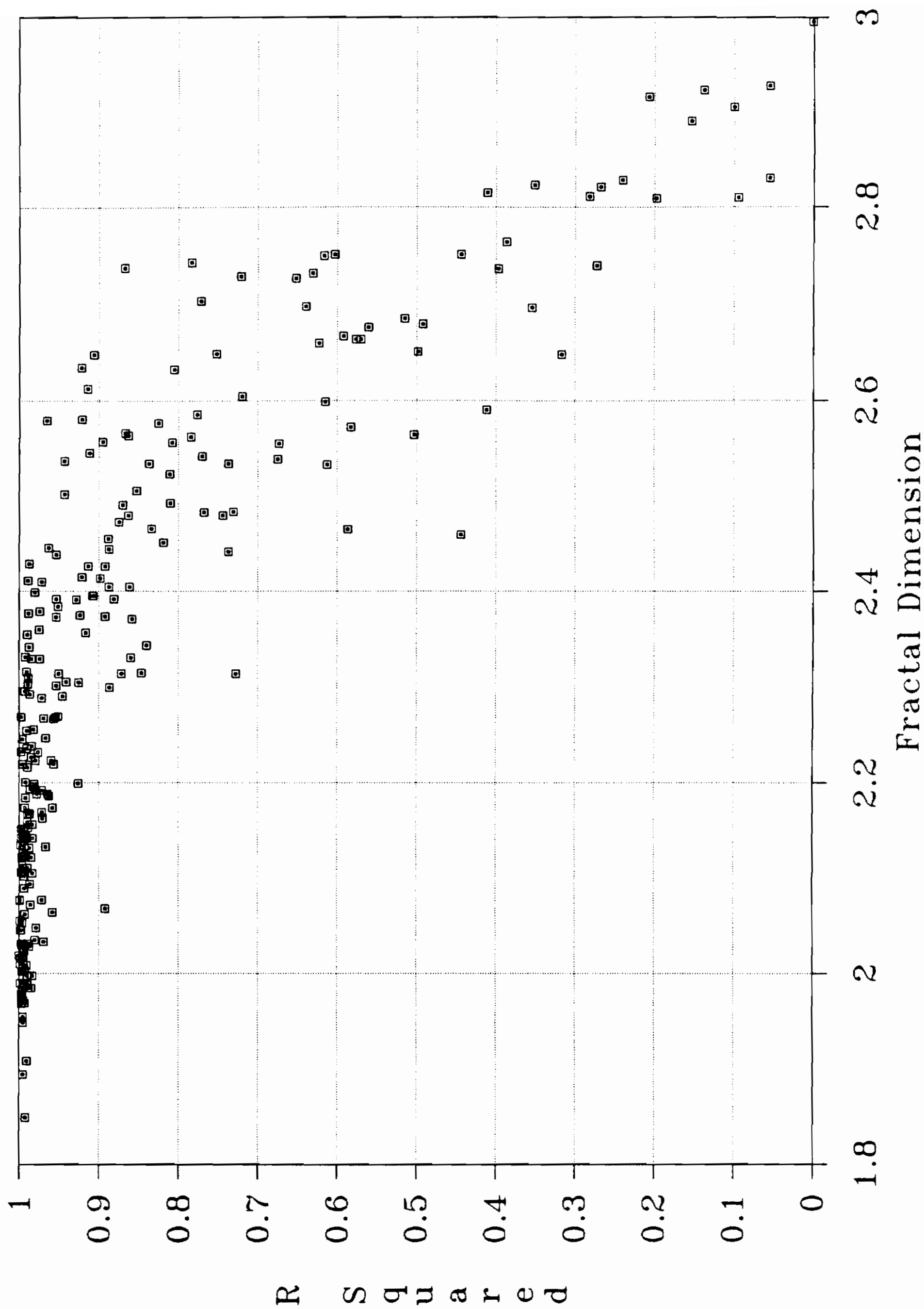


Figure 16. Relationship Between r^2 and Fractal Dimension for the 240 Polygons

dimensions and still others were fractal to a certain distance the fractal dimension was used to categorize the 240 polygons into surface complexity categories. The intent of this categorization was to examine effects of surface complexity on methods for characterizing slope, and thus the problems with estimating fractal dimension were not critical in this study. However, these problems should be noted by those intent on using fractal dimension in quantitative applications.

Cell Slope Differences

A cell by cell comparison was performed for all polygons, to evaluate the differences between individual cell slope values for the 8 cell slope methods. Seventy-seven thousand eight hundred fifty-five 30 meter square cells were used in the comparison. This produced the 28 pair wise comparisons shown in Table 9. This table shows the mean difference, the minimum and maximum difference, and the variance, all in units of slope percent. These statistics were calculated using SAS (SAS, 1985).

Slope Method Comparison Histograms

Histograms of the 28 pair wise slope method comparisons were plotted to aid in understanding the differences between slope methods and the slope methods themselves. The histograms of slope method comparisons 1-6, 1-7, 1-9, 2-5, 2-6, 2-7, 2-9, 6-7 and 6-9 all have the characteristic symmetrical bell-shaped distribution as slope method 1-2 illustrates in Figure 17a. Slope method comparisons 1-3, 2-3, 3-4, 3-6, 3-7, 3-9, 4-5, 4-6, 4-7 and 4-9 have a skewed (non-symmetric) bell shaped distribution as illustrated in Figure 17b of slope method 3-5. Comparisons 1-4, 1-5, 2-4, 5-7 and 5-9 have truncated (at zero) bell-shaped distributions as shown in Figure 17c of slope method 5-6. The histogram of the difference between slope method 7 and 9 is unique in that the differences are uniform at discrete slope differences as shown in Figure 17d. The

Table 9. Pairwise Comparisons of Slope Method Differences on a Cell by Cell Basis in Units of Slope Percent

Mean (Min,Max) Variance	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
Slope Method 1	-1.16 (-177.87, 95.28) 62.80	-15.53 (-136.03, 9.82) 98.44	-7.24 (-177.87, 0.00) 31.28	-5.79 (-78.07, 0.00) 20.25	.72 (-37.29, 34.14) 3.84	.92 (-49.73, 45.51) 6.79	.92 (-49.74, 45.53) 6.79
Slope Method 2		-14.37 (-193.19, 35.90) 143.68	-6.08 (-196.62, 0.00) 70.79	-4.63 (-120.44, 83.20) 89.23	1.87 (-71.63, 91.73) 65.23	2.07 (-67.42, 95.00) 67.66	2.07 (-67.40, 94.96) 67.69
Slope Method 3			8.29 (-65.3, 86.67) 77.01	9.74 (-22.76, 14.67) 92.55	16.25 (-7.07, 181.45) 92.40	16.44 (-9.43, 158.08) 91.52	16.45 (-9.40, 169.00) 91.82
Slope Method 4				1.44 (-74.48, 106.51) 56.06	7.95 (-33.70, 127.00) 35.10	8.15 (-46.14, 134.02) 37.93	8.15 (-46.15, 134.00) 37.93
Slope Method 5					6.51 (0.00, 51.38) 17.86	6.71 (0.00, 58.40) 18.87	6.71 (0.00, 58.38) 18.87
Slope Method 6						.20 (-12.44, 11.37) .428	.20 (-12.45, 11.39) .429
Slope Method 7							.00007 (-.05, .05) .00083

N = 77,855 Difference = Row - Column

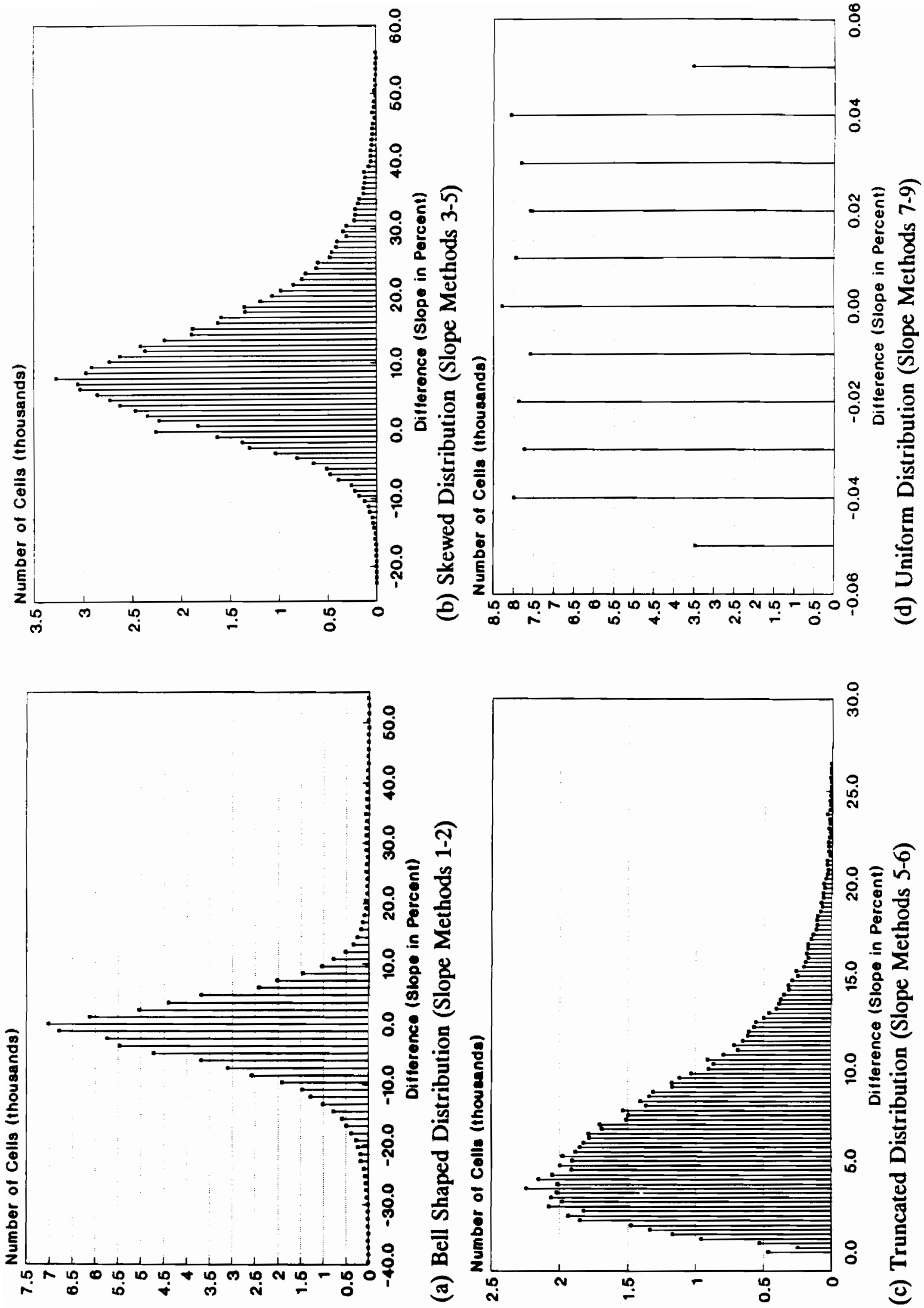


Figure 17. Histograms of Slope Method Comparisons

histograms show that the differences between the slope methods were not the standard bell-shaped normal distributions, but varied. Inferences about the differences between slope methods, especially numerical comparisons, must take this into account.

Similar Slope Methods

All the slope methods were statistically different since the 95% confidence interval of the mean difference did not include zero. This was expected with such a large sample size. However, in a practical sense six of the comparisons were not different (with a mean difference of less than one percent). The difference between slope method 7 and slope method 9 was 0.00007 percent, which for practical application makes these two slope methods essentially the same. The difference between slope method 6, slope method 7 and slope method 9 was 0.20 percent, which was negligible for practical applications. The difference between slope method 1, slope method 6, slope method 7 and slope method 9 was 0.72, 0.92 and 0.92 percent, respectively, which for most practical applications makes these methods the same. However, large single cell slope value differences were obtained between slope method 1 and slope methods 6, 7 and 9. The differences were greater than 4% slope as shown in Table 10 for cell 6 and up to a maximum difference of 49.74% as shown in Table 9. The individual cell slope values for slope method 7 and slope method 9 can be exactly the same as shown by cells 14, 15 and 19 in Table 10, but the single cell slope value differences between slope method 6 and slope methods 7 or 9 can be greater than 1% slope as shown in Table 10. The variance of the differences between these six comparisons was less than 7.0. Of the four methods, 1, 6, 7 and 9, which for most practical applications were the same, slope method 1 was the most efficient computatively and simplest to understand. Slope method 1 was the most common slope method used for calculating cell slope according to the literature.

Table 10. Cell Slope Values in Percent for Polygon 57 for each Slope Method

Cell	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
1	44.88	56.67	66.67	56.67	58.63	45.60	45.86	45.90
2	54.42	69.36	90.00	69.36	63.54	53.74	53.52	53.50
3	30.73	44.85	60.00	44.85	31.82	27.70	26.71	26.70
4	48.59	67.08	86.67	67.08	48.59	46.40	45.76	45.80
5	61.87	56.67	83.33	67.08	61.87	58.53	57.42	57.40
6	16.67	30.73	36.67	30.73	18.60	12.98	11.79	11.80
7	35.32	37.27	66.67	40.28	35.77	34.82	34.66	34.70
8	48.07	52.70	80.00	52.70	54.16	48.45	48.59	48.60
9	58.05	59.35	86.67	59.35	65.45	56.18	55.56	55.60
10	18.63	34.32	53.33	34.32	23.89	19.62	20.01	20.00
11	32.19	38.01	66.67	38.01	32.83	32.50	32.61	32.60
12	39.33	49.55	83.33	49.55	46.37	39.64	39.77	39.80
13	53.67	58.31	90.00	60.09	64.03	50.86	49.93	49.90
14	14.24	12.02	43.33	22.36	20.65	17.33	18.40	18.40
15	26.93	39.02	66.67	39.02	36.02	26.65	26.60	26.60
16	41.23	53.75	63.33	54.97	51.11	38.23	37.25	37.30
17	12.13	13.33	26.67	14.91	17.44	10.82	11.18	11.20
18	10.54	27.49	33.33	27.49	18.30	12.43	13.36	13.40
19	13.44	31.45	40.00	31.45	15.63	14.01	14.20	14.20
20	15.09	14.91	16.67	17.95	18.37	13.24	12.67	12.70
21	19.00	21.34	20.00	21.34	24.09	19.44	19.64	19.60
22	21.21	18.86	30.00	23.57	25.98	21.42	21.57	21.60
23	16.67	13.74	26.67	21.34	22.14	17.89	18.39	18.40
Mean	31.87	39.87	57.25	41.06	37.19	31.24	31.11	31.12

Slope Method 3 Comparisons

The mean cell slope difference between slope method 3 and all the other methods was always positive because slope method 3 assigned a slope value to a cell, based on the maximum percent slope to its neighbors. A graphical comparison of slope method 3 compared to slope methods 2, 6 and 9 is shown in Figure 18. This figure pictorially shows how individual cell slope values vary within a polygon. In Figure 18 the number of cells in yellow (40 - 55% slope) in the polygon are much greater for slope method 3 than the other three slope methods. Also, two of the cells in Figure 18 (slope method 3) are greater than 75% slope, which was not the case for the other methods. The mean cell slope value difference could be as large as 16.45% slope as occurred between slope method 3 and 9, shown in Table 9. The variance of the differences between slope method 3 and slope method 2 was the largest for all the comparisons. The maximum difference between a single individual cell slope value using slope method 3 and the other slope methods was 193.19%.

Slope Method Differences in which the Minimum or Maximum Cell Slope Difference was always Zero

The cell slope values of slope method 1 were always less than or equal to the values of slope method 4 and slope method 5 for all cells (Table 9), in which the maximum cell slope difference was 0.00% for both methods. Slope method 4 calculated slope using the maximum slope of the four surrounding triangle planes and slope method 5 calculates slope using the maximum absolute value derived from the partial derivatives in each direction, so the cell slope values would always be greater than slope method 1. Also, slope method 2 was always less than slope method 4 for all cells, as shown in Table 9. Slope method 4 assigned a slope value to a cell as previously discussed and slope method 2 assigned a slope value to a cell based on one right triangle plane. Slope method 5 was always greater than slope methods 6, 7 and 9 for all cells since the minimum difference between

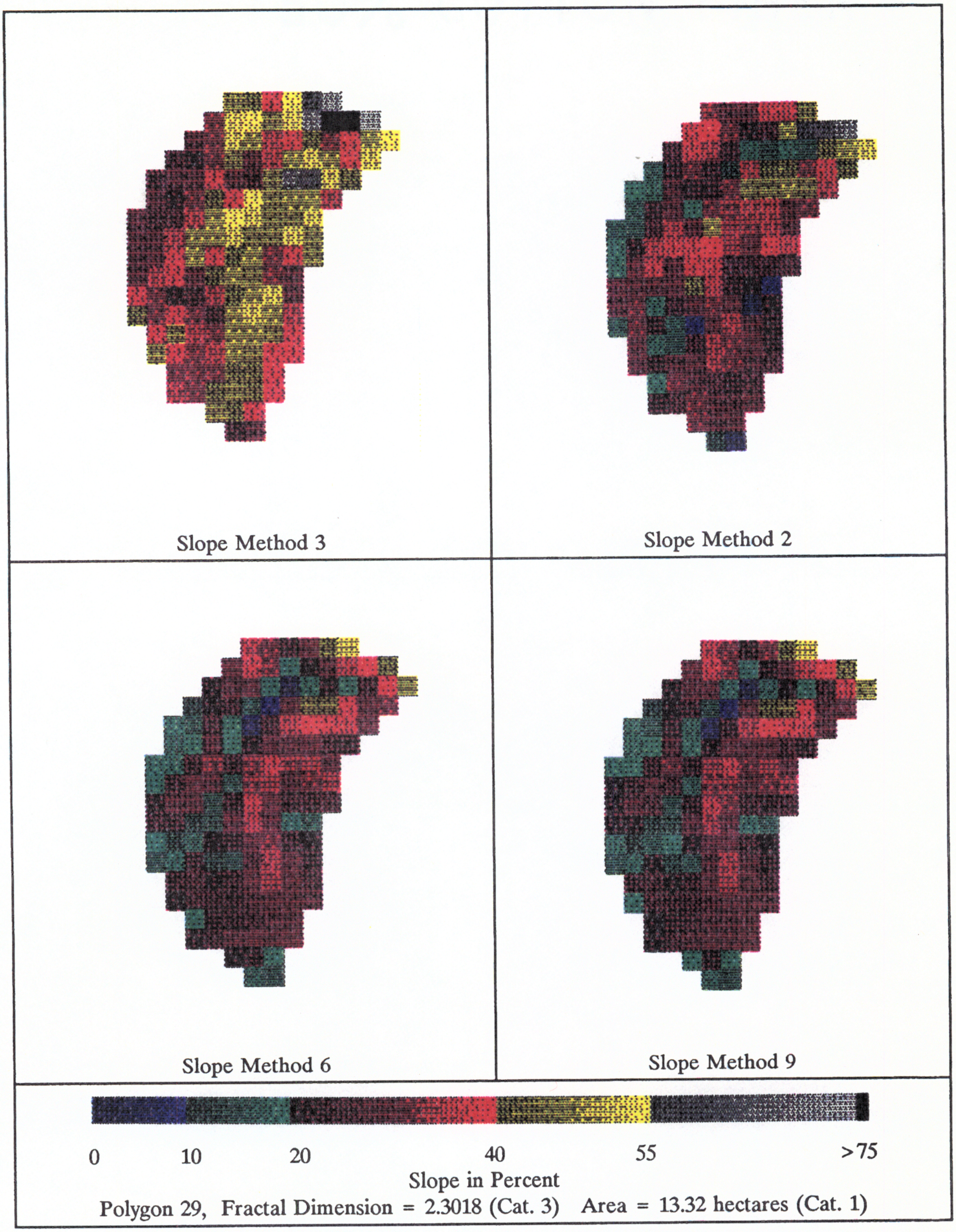


Figure 18. Graphical Comparison of Individual Cell Slope Values for Polygon 29

these methods was 0.00% because slope method 5 used the maximum absolute value derived from the partial derivatives in each direction.

Factors that Affect Slope Calculation as a Consequence of Elevation Data

Each method used in this study for calculating cell slope values was affected by the USGS DEM elevation data used, and some methods seemed more sensitive to the elevation errors and spatial resolution of the data than others. Since 7½ USGS DEM elevation values were recorded in integer values (meters), and the cell size was 30 meters, the smallest cell slope value, not including 0.00%, for the different methods ranges from 0.55% to 3.33%. Also, as discussed in the previous section, there were more neighbor cells at the same elevation (0.00% slope) than would be expected on a real surface, except bodies of water.

Some slope methods were more sensitive to irregularities (cell elevation blunders) in the elevation data than other methods. Slope method 3 was the most sensitive to large elevation errors while slope method 9 was least sensitive. For example, a 200 meter single cell elevation error (blunders) could cause a 666.6% slope error using method 3, but only a 111.1% slope error using method 9. The slope method sensitivity to elevation errors was based on the algorithm used to determine the cell slope values. Slope methods 6, 7 and 9 were the least sensitive to single cell errors because they used all eight neighbors (smoothing effect) to determine the slope of a single cell. Slope methods 1, 2, 3, 4 and 5 were more sensitive since they used fewer elevation values to determine the slope of a single cell. Slope methods 2, 3 and 4 were sensitive to linear (row, column) errors in elevation data (altitude matrix) because they calculated the slope of a cell by using neighbors in only one direction from the cell of concern. The sensitivity of the slope method to data errors must be considered when determining which slope method to use because rarely will elevation data be error-free.

In summary, the slope methods were all statistically different, but in practical applications slope methods 1, 6, 7 and 9 were the same. Slope methods 2, 3, 4 and 5 were different from each other. The cell slope values for method 3 were always greater than the other slope methods. The method used to determine the slope value of cells and the characteristics of the elevation data used would affect any model that had slope as a variable.

Computer Computational Time Required for the Slope Methods

To compare the amount of time required to do the computations using a computer for the different slope methods, a test was performed to determine the time required to compute the slope values of 8,443 cells. The computational times for the different slope methods were important when considering strategies of incorporating slope methods and polygon descriptors in a GIS. The test was done on an IBM AT compatible running at 10Mhz with a 80287 (10Mhz) math coprocessor. The Norton (Advanced Edition 4.5) computer index was 10.4 for the computer. Slope methods 1, 2, 3, 4, 5, 6 and 7 were written in Turbo C 2.0 while slope method 9 was written in Microsoft Fortran 5.0 using the IMSL STAT Library (1989). The programs were written for accuracy first and speed second. Table 11 shows the number of seconds to calculate the 8,443 cell slope values. The time

Table 11. Comparisons of Slope Methods Computational Times

Slope Method	1	2	3	4	5	6	7	9
Seconds	28	25	88	127	60	55	49	7,173

was only for the calculation of cell slope values using an elevation matrix that was stored in RAM. The time did not include I/O times. Slope method 2 was the fastest, while slope method 9 was the slowest. Slope method 9 (7,173 seconds) was considerably longer than the other methods. Since the routine for slope method 9 was written in Fortran using the IMSL STAT Library (1989) there was little control on optimization of the program. This could explain the dramatic increase in processing time. Also slope method 9 was more computatively intensive than the other slope algorithms.

Slope Method 11

Slope method 11 (Y-method), which was previously discussed, fits a plane (polynomial regression) to the elevation values for each polygon. This is called the first degree (plane) trend of the surface. This method has been used to determine trends and predict surface values at specific locations for many different types of continuous large area surfaces. The method has not been applied, as it was in this study, for determining the slope of a polygon. Appendix A lists the slope of all 240 polygons using this method. The program to calculate these slope values was written in Fortran using the IMSL STAT Library (1989). To indicate how well the plane fits the elevation values, the coefficient of determination (r^2) was calculated for each of the 240 polygons. The coefficient of determination ranged from 0.0459 for polygon 14 to 0.9918 for polygon 75. One hundred and sixty-five polygons had a coefficient of determination greater than 0.8000 and 213 of the 240 polygons had a coefficient of determination greater than 0.5000. The 27 polygons with a r^2 less than 0.5000 are shown in Table 12 with their associated fractal dimensions and areas. Polygon 14 had the smallest r^2 of 0.0459 with a fractal dimension of 2.9148 and an area of 16.83 hectares. Of the 27 polygons with a r^2 less than 0.5000, polygon 127 had the largest r^2 of 0.4353. Fractal dimensions for the 27 polygons ranged from 2.3006 to 2.9148 with 24 polygons having a fractal dimension greater than 2.5000. This was expected, as the fractal dimension increased (surface complexity increased), the r^2 decreased because the surface of the polygon conformed less to a plane.

Method 11 estimated the slope of a polygon accurately if the polygon surface conformed to a one-directional plane. The coefficient of determination was a good indicator of how well the

Table 12. Polygons with an r^2 less than 0.5000 for Slope Method 11

Polygons (fractal dimension, area in hectares)	Coefficient of Determination
14 (2.9148, 16.83), 26 (2.7369, 54.90)	< 0.1000
11 (2.6665, 26.37), 71 (2.8143, 54.54), 105 (2.4933, 0.63) 115 (2.9042, 8.01)	0.1001 - 0.2000
17 (2.5798, 29.25), 23 (2.9670, 19.08), 30 (2.6970, 19.08) 67 (2.4276, 68.67)	0.2001 - 0.3000
18 (2.7026, 21.78), 21 (2.8084, 20.07), 36 (2.5342, 55.71) 106 (2.6776, 24.39), 157 (2.7187, 78.84)	0.3001 - 0.4000
13 (2.7501, 6.30), 25 (2.6475, 18.81), 31 (2.7308, 16.83) 68 (2.5765, 12.33), 79 (2.5559, 14.58), 126 (2.4447, 75.69) 127 (2.3006, 24.30), 165 (2.8219, 20.97), 170 (2.6632, 13.95) 174 (2.6956, 16.74), 205 (2.5057, 21.33)	0.4001 - 0.5000

polygon slope was estimated. In natural resource management, especially forestry, stands are delineated on the ground or by using remote sensing imagery based on semi-homogeneous vegetation characteristics (species, age, etc.), natural (streams, ridge tops, etc.) and man-made (roads, political, etc.) boundaries. Vegetation characteristics usually change as the geomorphic character of the surface changes. An example would be vegetation species that are usually different on a steep slope than a valley bottom because of changes in the micro climate and soils. These factors complemented this slope method because stands (polygons) were delineated into surfaces that conformed to a one-directional plane (valley bottoms, side of a ridge, etc.) when vegetation characteristics and natural boundaries were used. This explains why over half of the 240 polygons had a coefficient of determination greater than 0.8000 using slope method 11. This method underestimated the slope of polygons when a ridge or steep valley bottom bisected the polygon (different slope aspects). Figure 19 pictorially shows how slope method 11 will estimate the slope of a polygon for these two cases. Polygons 14 and 26 demonstrate these cases. The calculated slope of polygon 14 using slope method 11 was 2.83% as shown in Appendix A, but the mean slope of polygon 14 using methods 2, 3, 6 and 7 was estimated at 20.42%, 30.86%, 16.50% and 16.15% respectively. Polygon 14 had a small ridge running lengthwise down the center of the polygon.

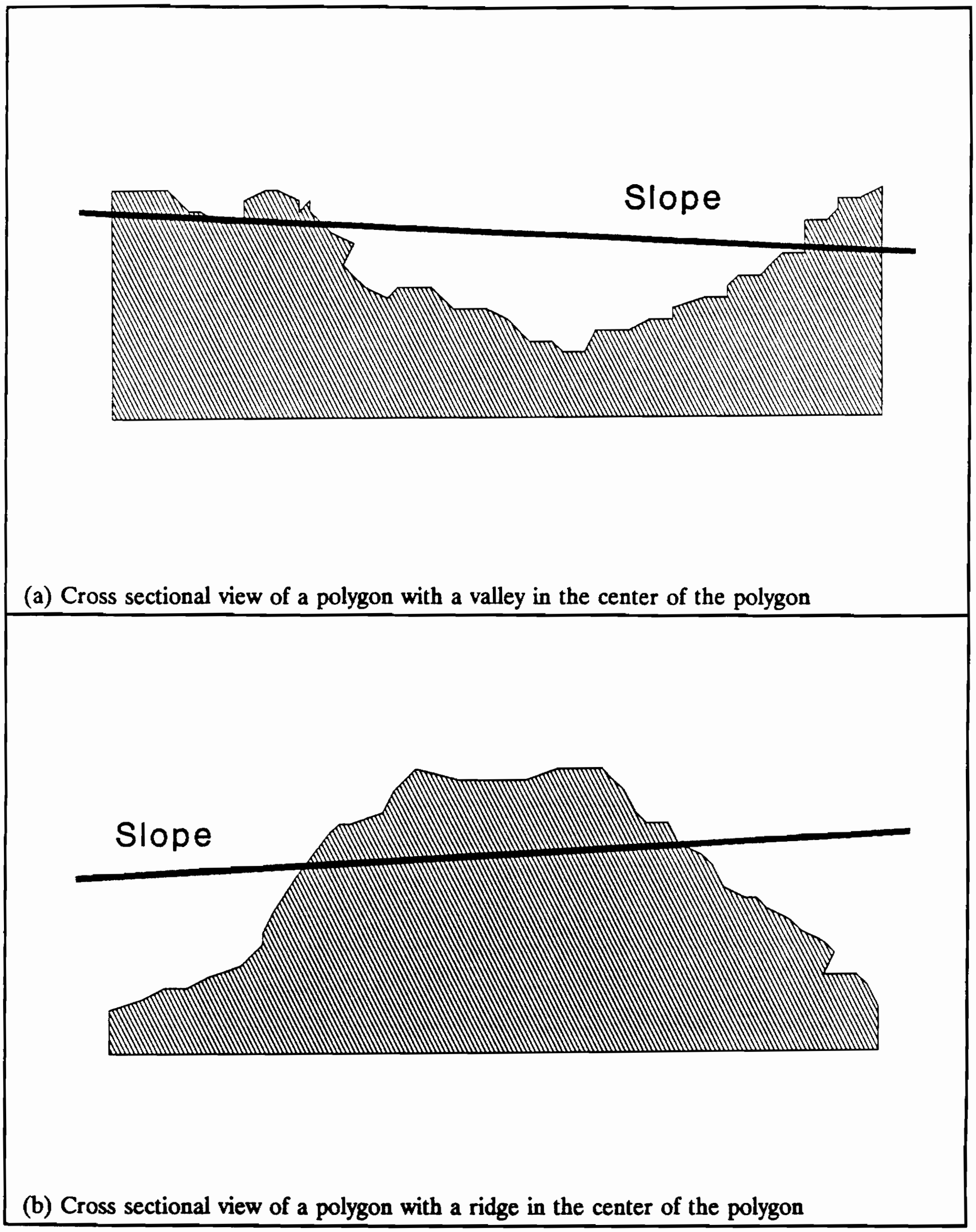


Figure 19. Conditions in which Slope Method 11 is a Poor Estimator of Polygon Slope

The sensitivity of slope method 11 to elevation errors depended on the location of the error within the polygon (polygon boundary, center of polygon, etc.), the shape of the polygon (round, oblong, etc.) and the size of the polygon (number of sample points). Cook and Weisberg (1982) discuss in detail the effects of outliers (elevation errors) on regression models. Unless there was a "large" elevation error, this slope method was less sensitive to elevation errors, for most cases, than the other 8 cell slope methods because a single cell has little influence on determining the slope of a polygon.

Effects of Slope Method on a Decision Model - Hypothetical Example

To demonstrate how the slope method can affect the results of a decision model, a hypothetical example using a real decision model was created. The model described was used by the Jefferson National Forest (USFS, 1985) to determine lands suitable for timber production based on three parameters: site index, stand slope and access as shown in Table 13.

Table 13. Suitability Guidelines for Forest Service Stands (USDA, 1985)

Stand Status	Site Index	Slope(*percent*)	Access
SUITABLE	≥ 50	35 <	Roaded/Unroaded
	60	> 35	Roaded
	≥ 70	> 35	Roaded/Unroaded
UNSUITABLE	40 ≤	---	---
	50	≥ 35	Roaded/Unroaded
	60	≥ 35	Unroaded

This is called a Level I suitability classification (USFS, 1985). Level II suitability classification further evaluates Level I suitable stands by considering various other factors, such as stand characteristics and management objectives. Another factor is the appropriate logging method that can be used to harvest the stand, based on the slope of the stand. Table 14 shows the operability guidelines for determining the appropriate harvesting equipment to use in harvesting the forest stand. These criteria for classifying forest stands (polygons) into suitable and unsuitable stands for timber production, and separating the suitable forest stands into harvest equipment operability classes were used in this example.

Table 14. Harvest Equipment Operability Guidelines (USFS, 1985)

Slope(*percent*)	Recommended Equipment
0.0 - 35.0%	Ground based skidding
35.0 - 50.0%	Advanced ground based skidding
50.0% +	Cable yarding system

The 240 polygons (forest stands) were assigned randomly site indexes between 50 and 80. This allowed some stands to be classified unsuitable because of slope, if the site index was less than 60. This eliminated the possibility of a forest stand being classified unsuitable because of site index. All stands were considered accessible by roads. The example was designed so only stand slope would affect how a particular stand would be classified. The mean stand slope was used to characterize the slope of a stand (polygon). The mean stand slope for all the slope methods and all the stands are shown in Appendix A. This does not imply that the mean slope of a stand should always be used to characterize the slope of a stand, but one stand slope characteristic had to be chosen for this example, and the mean is commonly used. Slope method 11 (Y-method) was also compared in the example.

Based on the above criteria, the 240 polygons were divided into unsuitable, suitable (ground skidding), suitable (advanced ground skidding) and suitable (cable yarding) as shown in Table 15. If the stand (polygon) had a site index less than 60 and a mean polygon slope equal to greater than 35% the stand was classified unsuitable. The number of stands that were unsuitable for timber production ranged from 12 (175.3 hectares) using slope method 11 to 59 (1,735.2 hectares) using

Table 15. Classification of Stands into Suitable and Unsuitable Categories

Slope Method		Suitable, Ground skidding	Unsuitable	Suitable, Advanced ground skidding	Suitable, Cable yarding
1	Polygons	183	20	32	5
	Hectares*	4,437.5	388.9	817.7	260.3
2	Polygons	173	24	37	6
	Hectares*	4,230.9	518.9	882.9	271.8
3	Polygons	49	59	91	41
	Hectares*	921.0	1,735.2	2,116.4	1,131.9
4	Polygons	120	38	70	12
	Hectares*	2,649.5	1,199.6	1,676.1	379.2
5	Polygons	135	34	57	14
	Hectares*	3,276.6	764.7	1,415.0	448.1
6	Polygons	188	18	29	5
	Hectares*	4,578.9	382.9	682.4	260.3
7	Polygons	191	18	26	5
	Hectares*	4,632.5	382.9	628.7	260.3
9	Polygons	191	18	26	5
	Hectares*	4,632.5	382.9	628.7	260.3
11	Polygons	212	12	13	3
	Hectares*	5,338.2	175.3	277.9	113.0

* Based on raster polygon area

slope method 3. This was almost a ten times difference in area of unsuitable forest production land based on the method used to calculate the cell slope values of a stand (polygon). Slope method 11 had the largest number of stands, 212 (5,338.2 hectares), suitable for ground skidding while slope method 3 had the least, 49 (921.0 hectares). The number of stands in each category in Table 15 and their associated areas were the same for slope method 7 and 9. Slope method 6 had essentially the same number of polygons and area as slope methods 7 and 9.

The spatial locations of the 240 stands in each of the four categories for slope methods 1, 2, 3, 4, 5, 6, 7 and 11 are shown in Figures 20, 21, 22, 23, 24, 25, 26 and 27 respectively. Since the stands in each of the categories for slope methods 7 and 9 were the same, a map of slope method 9 was not included. The maps were produced using the ARCPLOT module of ARC/Info. All of the figures (maps) were at the same scale and used the same color patterns for each category. Some stands were in all three suitable categories based solely on the algorithm used to calculate the slope. For example, polygon 67 was classified suitable for cable yarding using slope method 3, advanced ground based skidding using slope methods 1, 2, 4, 5, 6, 7 and 9 and ground based skidding using slope method 11. Polygon 35 was classified unsuitable using slope methods 3 and 4, but when using slope methods 1, 2, 5, 6, 7, 9 and 11 the stand was classified suitable for ground based skidding.

As shown by this simple decision model, the method used to calculate slope of a cell can have a definite effect on the outcome of the model. The magnitude of the differences in model results depends on how sensitive the model is to changes in slope. Also, how the slope is characterized for a polygon will affect the results of a model. This is discussed in the final section of this chapter.

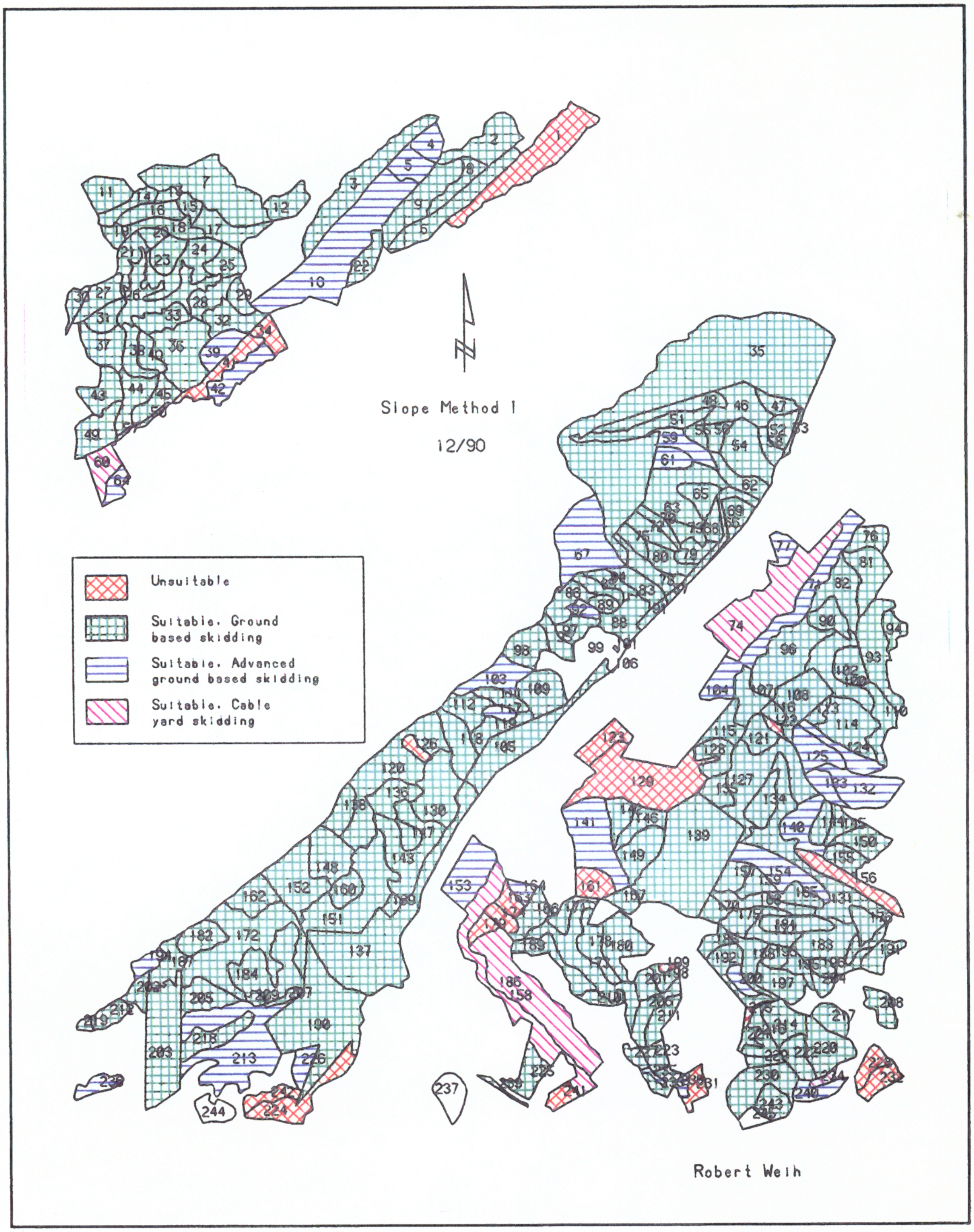


Figure 20. Suitable and Unsuitable Forest Stands using Slope Method 1

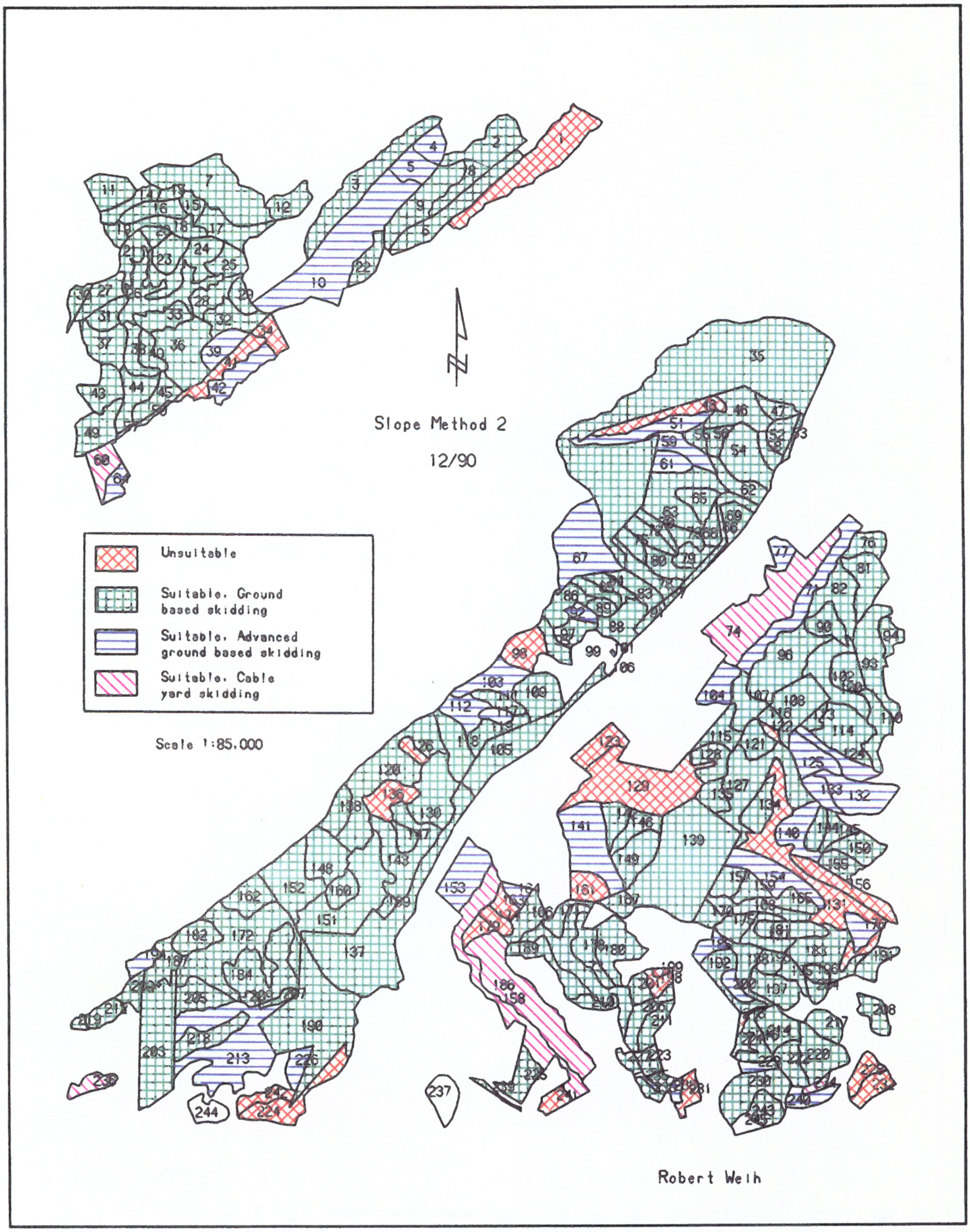


Figure 21. Suitable and Unsuitable Forest Stands using Slope Method 2

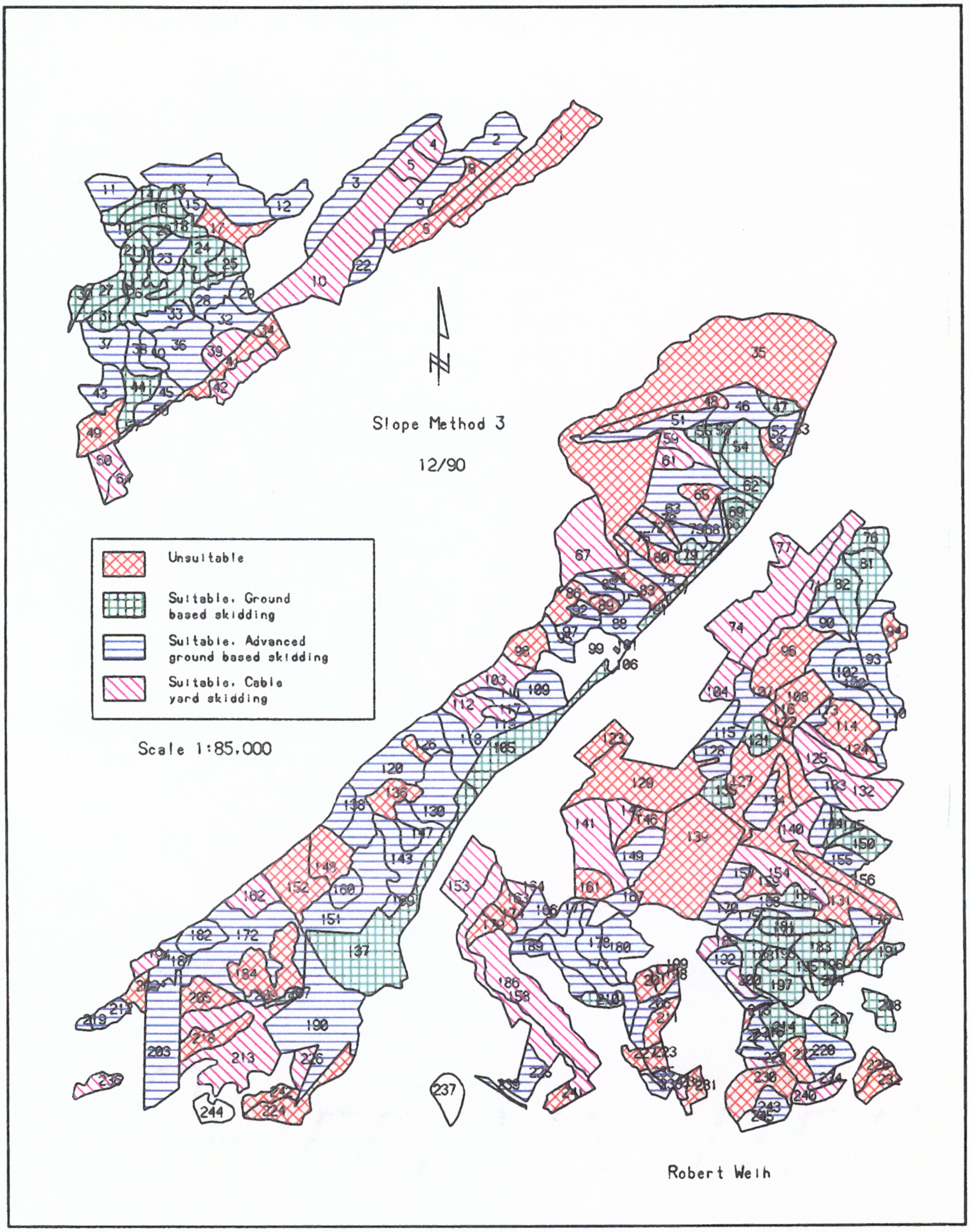


Figure 22. Suitable and Unsuitable Forest Stands using Slope Method 3

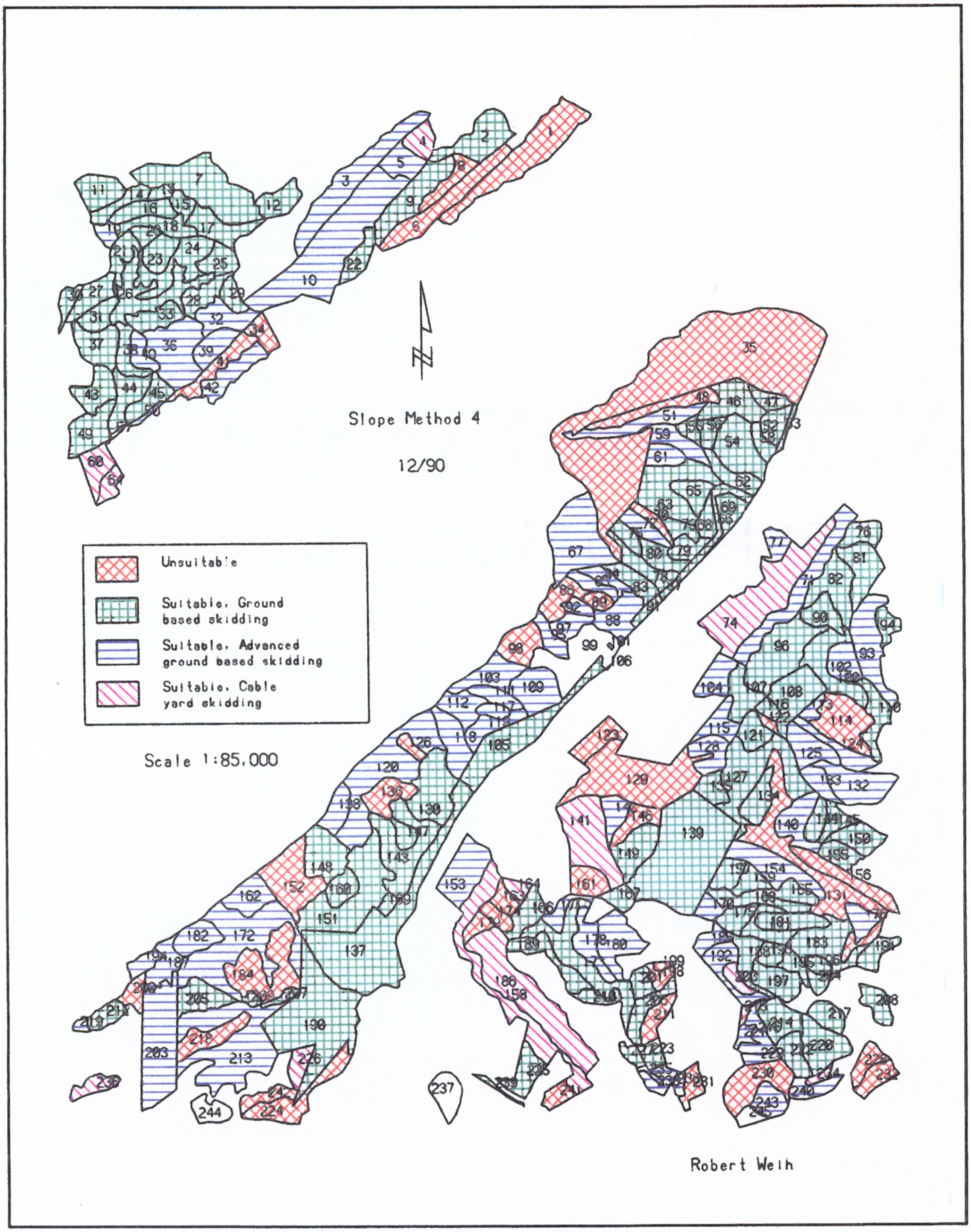


Figure 23. Suitable and Unsuitable Forest Stands using Slope Method 4

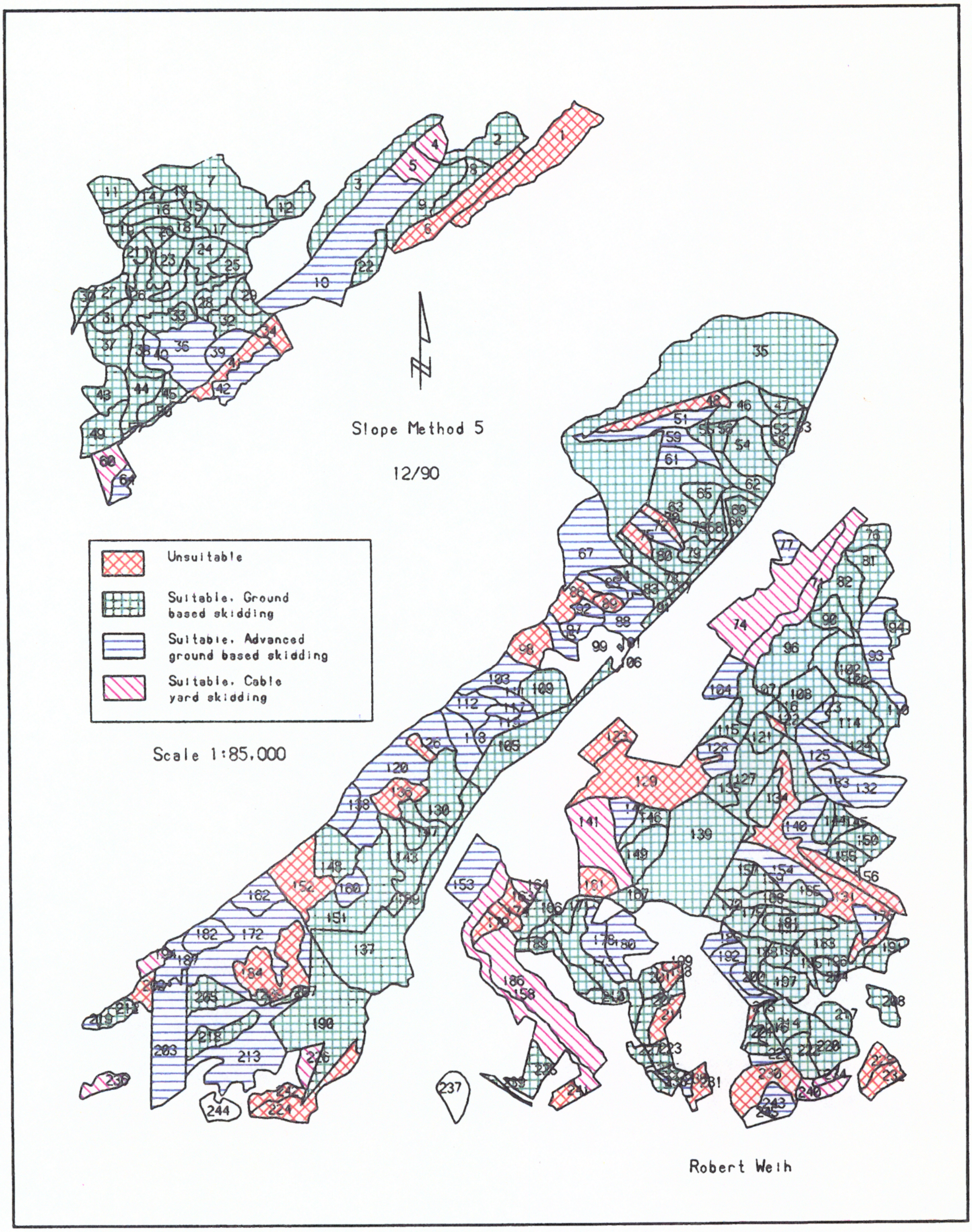


Figure 24. Suitable and Unsuitable Forest Stands using Slope Method 5

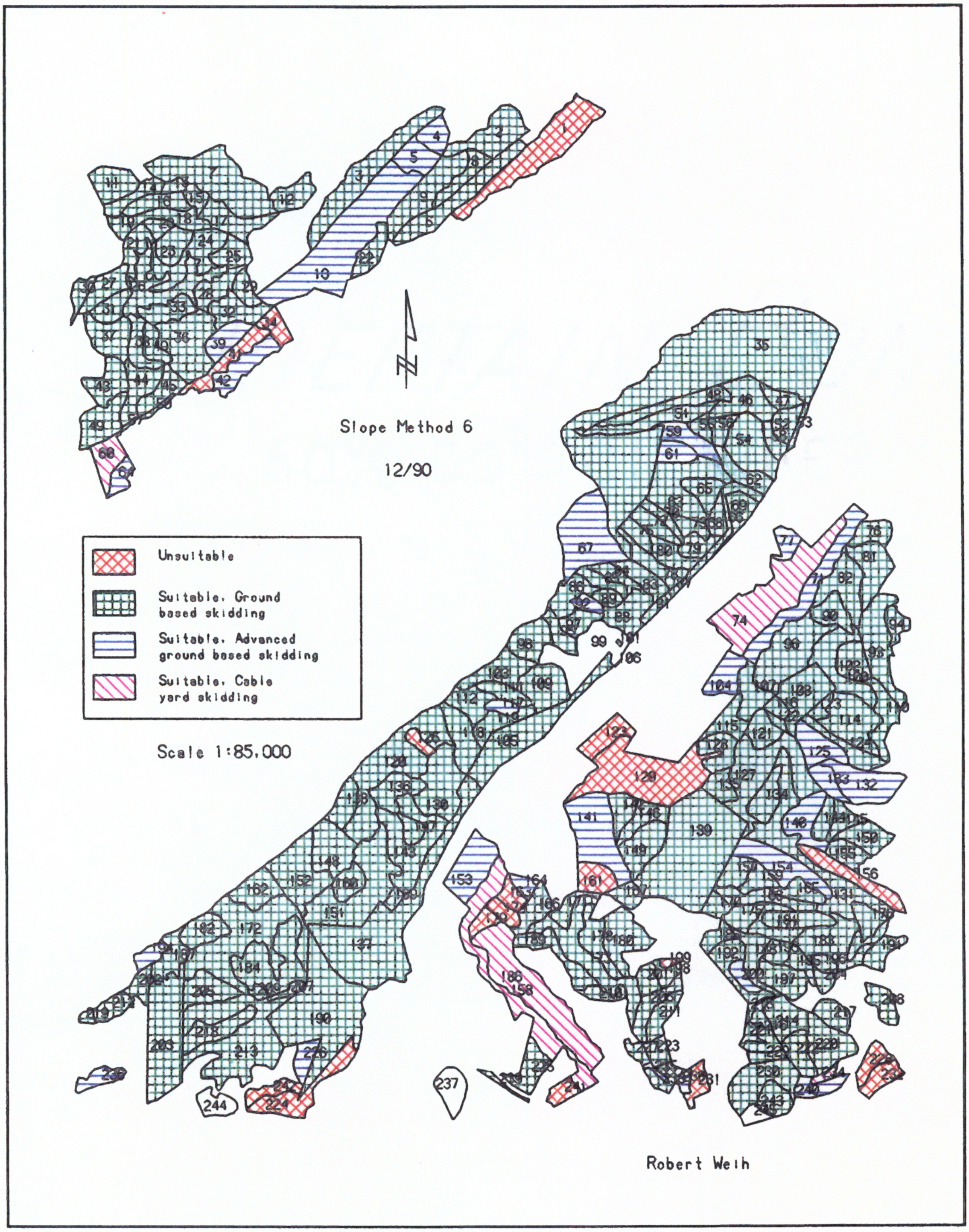


Figure 25. Suitable and Unsuitable Forest Stands using Slope Method 6

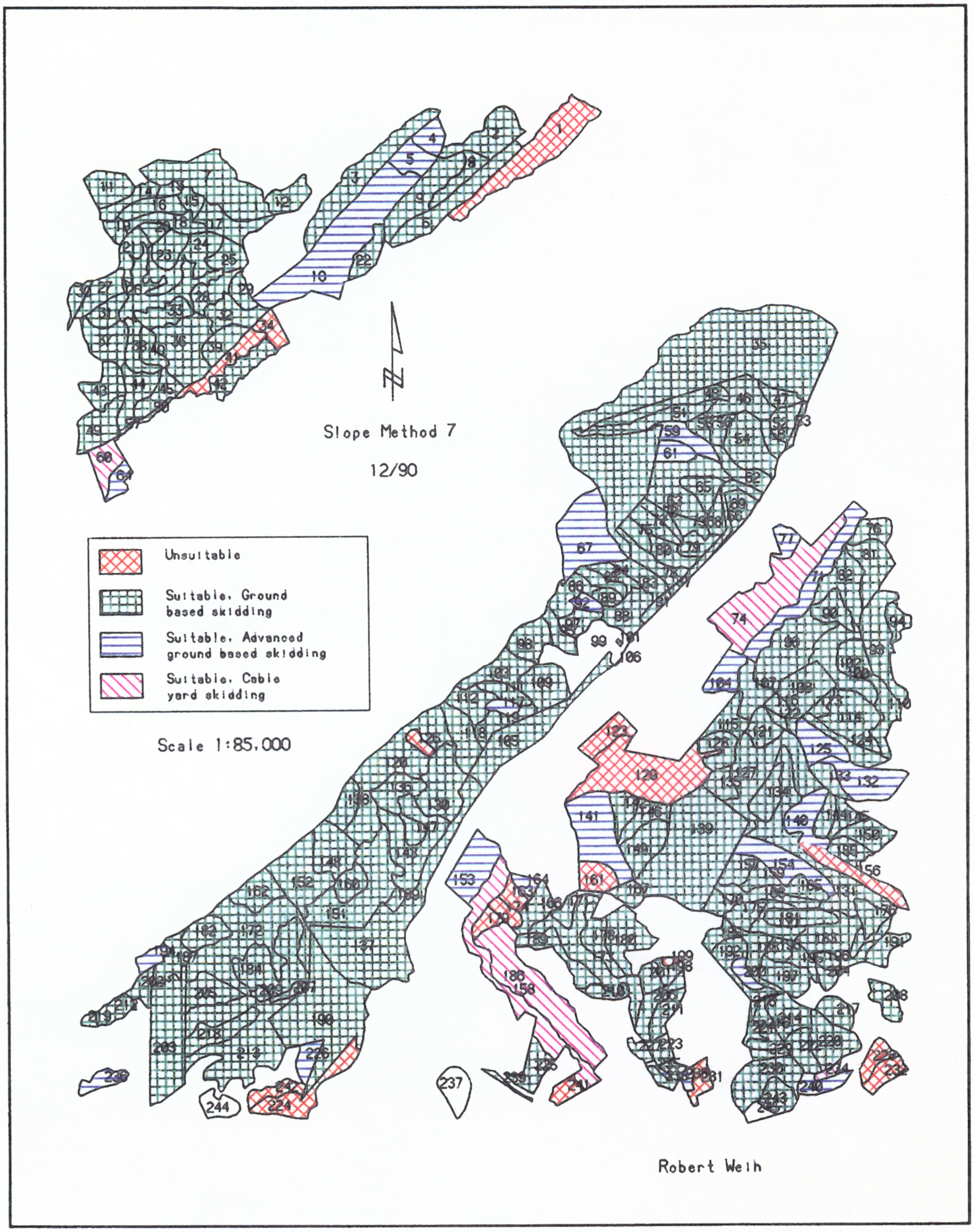


Figure 26. Suitable and Unsuitable Forest Stands using Slope Method 7

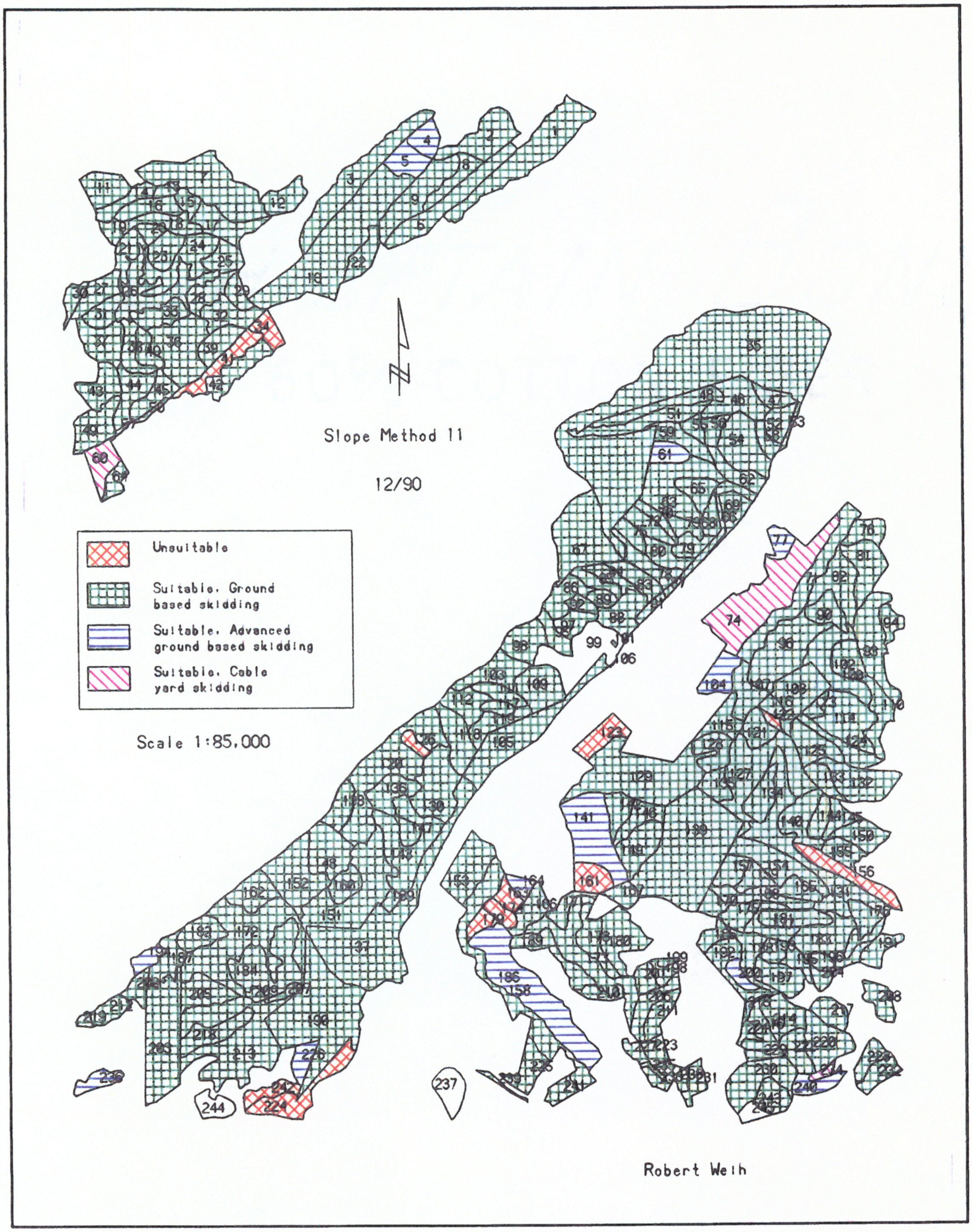


Figure 27. Suitable and Unsuitable Forest Stands using Slope Method 11

Effects of Polygon Area and Surface Complexity on Polygon Slope Descriptors

To effectively analyze polygon slope descriptors or make inferences about these descriptors, it is imperative that an understanding of factors that could affect these descriptors be examined, specifically area and surface complexity. Applying programs written by the author in the C language and the MINITAB (1989) statistical package, eight polygon slope descriptors were calculated for each of 240 polygons. They were mean slope value, median slope value, first quartile (25%) slope value, third quartile (75%) slope value, minimum cell slope value, maximum cell slope value, standard deviation of polygon cell slope values and trim mean slope value for each area and fractal class. The above polygon slope descriptor values for each slope method across all the fractal and area classes are listed in Appendices A through H in slope percent. A ninth descriptor, mode, was also calculated as previously discussed and the results are shown in Appendix I. For any polygon in which there was not a definite higher slope frequency mode class, the polygon mode could not be determined, so the Appendix I cell is blank. Also shown in each appendix is the mean and standard deviation of the polygon slope descriptor for each slope method, area and fractal class to aid in interpretation. The effects of polygon area and surface complexity on each polygon along with the characteristics of each descriptor are discussed individually with a summary at the end of this section. These area and surface complexity effects on polygon slope descriptors are based on observations of the data listed in the appendices and various plots of the data sets.

Mean Polygon Slope Descriptor

The mean slope values for each slope method, area and fractal class are listed in Appendix A. Also included in Appendix A, for comparison, is the slope value of a polygon for each area and fractal class using slope method 11. The mean is a measure of central tendency of a set of measurements. This polygon slope descriptor is sensitive to extreme slope values (elevation errors) because all the polygon cell slope values are used with equal weight for its calculation. A summary of Appendix A mean and standard deviation of the polygon mean slope descriptor values are shown in Table 16 and Table 17 respectively to aid in the following discussion. Based on the reasons previously discussed in this chapter, the mean polygon slope value for slope method 3 was greater than the other methods. This occurred for all area and fractal classes. Also, the standard deviation of the mean polygon slopes in each area and fractal class was greater for slope method 3 than the other methods. Slope methods 1, 2, 6, 7, 9 and 11 were very similar for area class and fractal class 1:1 and 1:2 (area category:fractal category). For example, in 1:2 the mean of the polygon slope means were 33.78%, 34.09%, 33.29%, 33.09%, 33.09% and 30.54% (Table 16) using slope methods 1, 2, 6, 7, 9 and 11 respectively for the 13 polygons in this category. But for the 1:5, slope method 11 was very different. The mean of polygon slope means for slope method 11 was 15.23% compared to 26.57%, 28.69%, 25.63%, 25.37% and 25.37% for slope methods 1, 2, 6, 7 and 9 respectively. The mean of the polygon slope descriptor means for slope methods 4 and 5 were similar for all area and fractal categories.

After examining all the polygons in the different fractal and area classes, there was no apparent effect of these characteristics on determining the mean slope descriptor, except for the effects of surface complexity on slope method 11. As surface complexity increased the differences between slope method 11 and slope methods 1, 2, 6, 7 and 9 increased. This is illustrated in Figure 28, which is a plot of the polygon slope difference (Slope Method 11 - Slope Method 7) by fractal dimension. A trend line is also shown in Figure 28 to aid in interpretation. If there were no effects of fractal dimension on slope method 11, the differences would be similar across all fractal dimensions, which was not the case in this illustration. This trend is small. Slope method 11 was underestimating the slope because of the difficulty in fitting a plane to the elevations, which was discussed in the Slope Method 11 section of this chapter. The differences between slope methods

Table 16. Summary of Appendix A, Mean of the Mean Polygon Descriptor in Slope Percent

(Area: Fractal) Category	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11[1]
1:1	33.78	34.09	49.37	39.93	40.29	33.24	33.09	33.09	30.54
1:2	28.09	29.35	42.50	35.16	33.65	27.43	27.25	27.25	23.37
1:3	28.65	30.52	44.75	37.02	34.06	27.80	27.57	27.57	20.98
1:4	28.26	30.16	43.77	35.75	33.44	27.57	27.39	27.39	20.40
1:5	26.57	28.64	40.80	34.45	31.11	25.63	25.37	25.37	15.23
1:6	31.11	33.54	49.75	39.14	36.33	30.12	29.83	29.83	24.73
2:1	22.90	24.39	34.05	29.26	27.25	22.33	22.19	22.19	18.42
2:2	29.26	30.73	44.57	36.35	34.98	28.59	28.40	28.40	23.46
2:3	29.63	31.30	44.96	37.03	35.44	28.96	28.77	28.77	20.70
2:4	29.65	31.50	45.09	37.29	34.75	28.66	28.37	28.37	19.51
2:5	22.96	24.62	36.05	30.32	27.23	22.04	21.79	21.79	11.77
2:6	29.67	31.12	47.06	37.95	35.08	28.85	28.64	28.63	19.86
3:2	24.70	26.07	37.38	30.86	29.50	24.11	23.96	23.96	19.71
3:3	30.86	32.58	46.19	38.14	36.81	30.20	30.20	30.20	20.12
3:4	32.53	34.13	48.53	40.09	38.42	31.73	31.50	31.50	12.76
3:5	37.91	39.14	56.41	44.59	45.19	37.33	37.17	37.17	22.83
3:6	31.79	31.83	48.71	38.73	37.69	30.97	30.74	30.74	13.97
4:2[2]	26.29	27.89	39.14	32.83	31.07	25.66	25.50	25.50	15.09
4:5[2]	25.21	27.24	38.98	32.66	29.76	24.51	24.32	24.32	10.00
4:6	30.38	32.20	47.81	38.14	35.92	28.79	29.19	29.19	20.20
5:2[2]	28.40	30.00	42.60	35.39	34.32	27.80	27.64	27.64	12.43

[1] Slope of the Polygon, not a polygon mean descriptor
[2] Only one polygon in this area:fractal category

Table 17. Summary of Appendix A, Standard Deviation of the Mean Polygon Descriptor in Slope Percent

(Area: Fractal) Category	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11[1]
1:1	8.66	8.17	12.34	8.98	9.93	8.62	8.60	8.61	7.94
1:2	8.09	7.90	11.18	8.37	9.75	8.14	8.14	8.14	8.94
1:3	7.98	7.31	11.96	8.92	10.15	8.14	8.19	8.19	10.40
1:4	8.31	8.05	9.98	8.20	9.46	8.10	8.03	8.03	11.29
1:5	10.20	9.89	11.83	9.85	12.42	10.27	10.27	10.27	13.89
1:6	16.01	15.60	22.81	16.42	19.96	16.28	16.36	16.36	18.38
2:1	7.02	6.60	8.39	6.72	8.26	7.00	6.98	6.98	7.04
2:2	9.31	8.75	12.40	9.20	11.32	9.40	9.41	9.41	10.93
2:3	5.60	5.39	6.77	5.68	6.74	5.64	5.64	5.64	8.05
2:4	7.43	7.18	10.25	7.38	8.61	7.41	7.40	7.40	10.21
2:5	4.39	4.12	5.22	4.14	5.57	4.47	4.49	4.49	7.30
2:6	15.36	14.70	19.09	14.25	18.63	15.41	15.39	15.39	18.63
3:2	6.03	5.41	7.84	4.97	7.46	6.14	6.15	6.15	6.64
3:3	6.74	6.54	8.10	6.92	8.36	6.82	6.84	6.84	8.17
3:4	7.94	7.44	10.67	8.02	9.63	8.08	8.12	8.12	10.14
3:5	21.77	21.29	27.93	22.23	25.75	21.78	21.76	21.76	18.55
3:6	15.07	13.93	20.84	15.49	17.71	15.08	15.06	15.06	1.83
4:6	15.22	14.61	20.45	15.27	18.38	14.52	15.48	15.48	16.47

[1] Slope of the Polygon, not a polygon mean descriptor

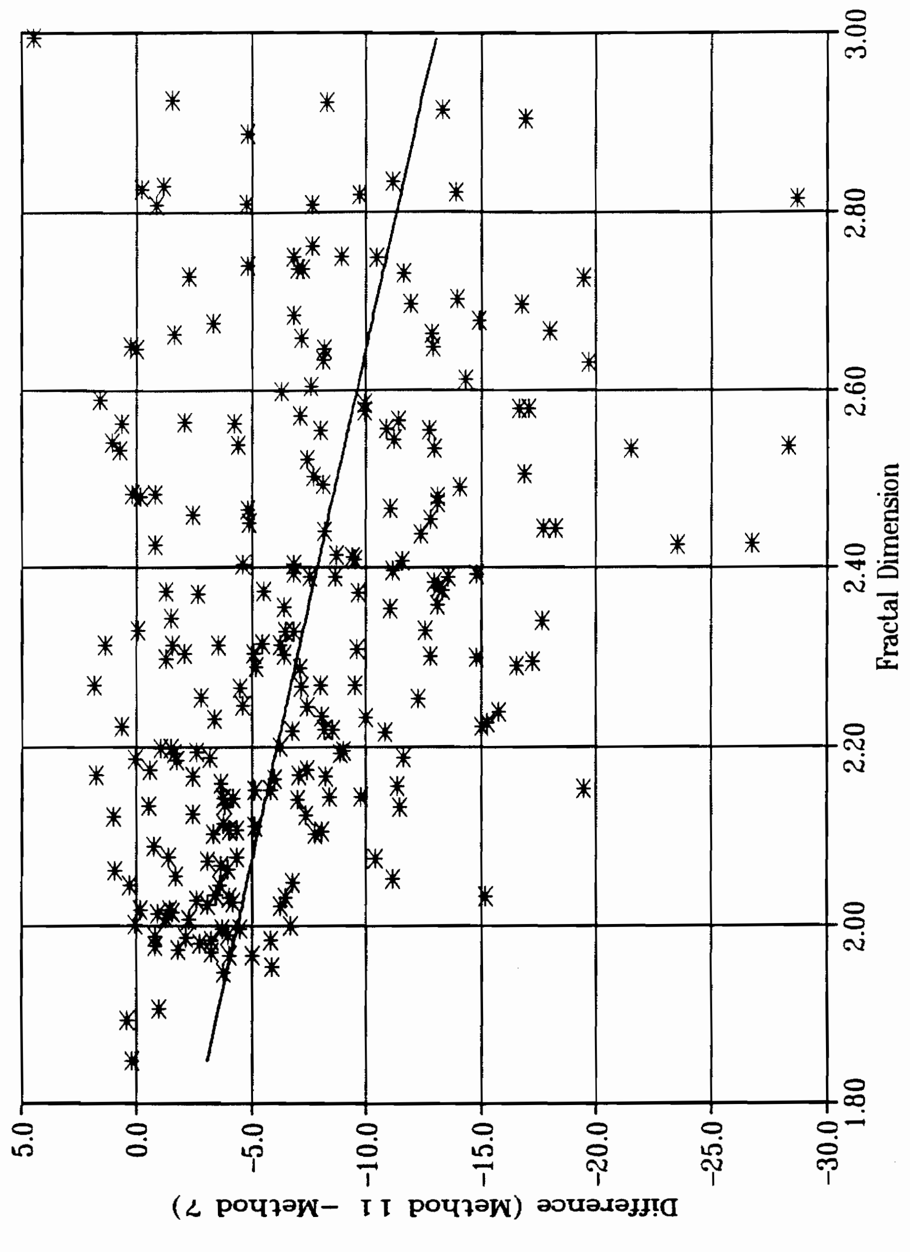


Figure 28. Effects of Fractal Dimension on Slope Method 11 (Linear Trend r^2 = 0.104)

using this descriptor were the same as the differences between the slope methods using all the cells, as previously discussed in the Cell Slope Differences section of this chapter.

Median Polygon Slope Descriptor

Appendix B lists all the median slope values for each area and fractal class. Also, for comparison, slope method 11 is listed. The median is a measure of central tendency of a data set. The median polygon slope descriptor is less sensitive than the mean polygon slope descriptor to single cell slope errors (elevation errors) in the data set because the median is the middle cell slope value when all the polygon cell slope values are arranged in order of magnitude. The mean of the polygon slope medians for slope method 3 was greater than the mean of the polygon slope medians for the other eight slope methods as shown in Appendix B. The mean of the slope medians for slope methods 4 and 5 were similar for all fractal and area classes. The polygon slope medians for slope methods 1, 2, 6, 7 and 9 were similar for each fractal and area class. Fractal and area class had no apparent affect on calculating polygon slope medians for the different slope methods.

First Quartile (25%) Polygon Slope Descriptor

The first quartile (25%) values are listed in Appendix C for each polygon in each area and fractal class. The first quartile is the cell slope value of a polygon that exceeds exactly 25% of the cell slope values. It is a measure of polygon cell slope variability. This slope descriptor is less sensitive to single cell elevation errors since this descriptor is based on the order of values in magnitude and does not consider the magnitude of the differences between individual cell slope values. For fractal classes 1 and 2, the mean first quartile slope value was essentially the same for slope methods 1, 2, 6, 7 and 9, but for fractal classes 3, 4, 5 and 6 the slope method mean first quartile polygon slope value increased. For example, the mean first quartile difference was from 0.47% slope between slope methods 1 and 2 for 1:1 (area category:fractal category) to 2.43% slope for 1:6. This small trend only occurred in area class one. Slope method 3 had the largest mean first quartile polygon slope value for all the area and fractal classes. This polygon slope descriptor seemed affected little by polygon area or surface complexity.

Third Quartile (75%) Polygon Slope Descriptor

Appendix D lists the third quartile slope descriptor values for each area and fractal category of the 240 polygons in the study. The third quartile (75%) is a slope value that exceeds exactly 75% of the cell slope values. It measures the variability of the polygon cell slope values in the polygon. This slope descriptor was less sensitive to single cell elevation errors for the same reason as discussed previously. Slope method 3 had the largest third quartile slope values for all the area and fractal classes. The largest mean third quartile slope value difference for all area and fractal categories was only 0.03% slope between slope methods 7 and 9. There was no indication that area class and fractal class affected the calculation of the third quartile slope descriptor for the different slope methods.

Minimum and Maximum Polygon Slope Descriptors - Range

The minimum and maximum polygon slope values for each area and fractal class are listed in Appendix E and F respectively. These two descriptors measure the variability (dispersion) of the polygon cell slope values. Both of these polygon slope descriptors are very sensitive to errors in the elevation data. For example, polygon 174 using slope method 3 had a maximum slope of 226.67% as shown in Appendix F. Either the cell slope value was an error (elevation data error) or in that particular area of the polygon the surface was very "steep". Upon examining the elevation data and topographic map of polygon 174, the cause of such a large cell slope value was in this case elevation error. The sensitivity of this descriptor is compounded if the slope method is sensitive to single cell elevation errors, such as slope method 3. There was little effect from polygon size and surface complexity on these slope descriptors. For the previous slope descriptors discussed, slope methods 1, 2, 6, 7 and 9 mean values for the slope descriptors were very similar for each area and fractal category. This was not the case for the maximum polygon slope descriptor. For example, for 1:2 (area category:fractal category) the mean maximum polygon slope was 59.24% for slope method 1 and 76.77% for slope method 2. The mean maximum polygon slope value was always larger for slope method 2 than slope methods 1, 6, 7 and 9 for each area and fractal category.

Standard Deviation Polygon Slope Descriptor

The standard deviation slope descriptor values for the 240 polygons in the study are listed in Appendix G. This descriptor measures the variability of cell slope values within the polygon. The sensitivity of this descriptor to single cell slope errors (elevation error) varies based on the polygon size (number of cells). The larger the polygon, the less effect the cell error will have on the calculation of the standard deviation. Slope method 3 had the largest mean standard deviation slope value for each area and fractal class. There seemed to be a small increase in the mean for the standard deviation slope descriptor for all slope methods when area and fractal categories increased. For example, the mean standard deviation slope descriptor value for 1:1 (area category:fractal category) for slope methods 1, 2, 3 and 4 were 8.40%, 9.96%, 11.05% and 8.17% respectively, while for the same slope methods, for 1:6, the values were 11.37%, 12.46%, 14.35% and 10.61%. Using the same previous slope methods, the standard deviation polygon slope values were 13.21%, 13.66%, 16.56% and 12.56% respectively for 3:4. This trend suggests that the variability of polygon cell slope values increased as polygon size and surface complexity increased. Figure 29 is a plot of standard deviation polygon slope values by fractal dimension. Figure 30 is a plot of standard deviation polygon slope values by polygon area. Polygon 35 was not included in this plot to increase the legibility of the plot. Both plots show the small increase in the standard deviation polygon slope descriptor values with increasing area and fractal dimension. The trend line for slope method 1 is

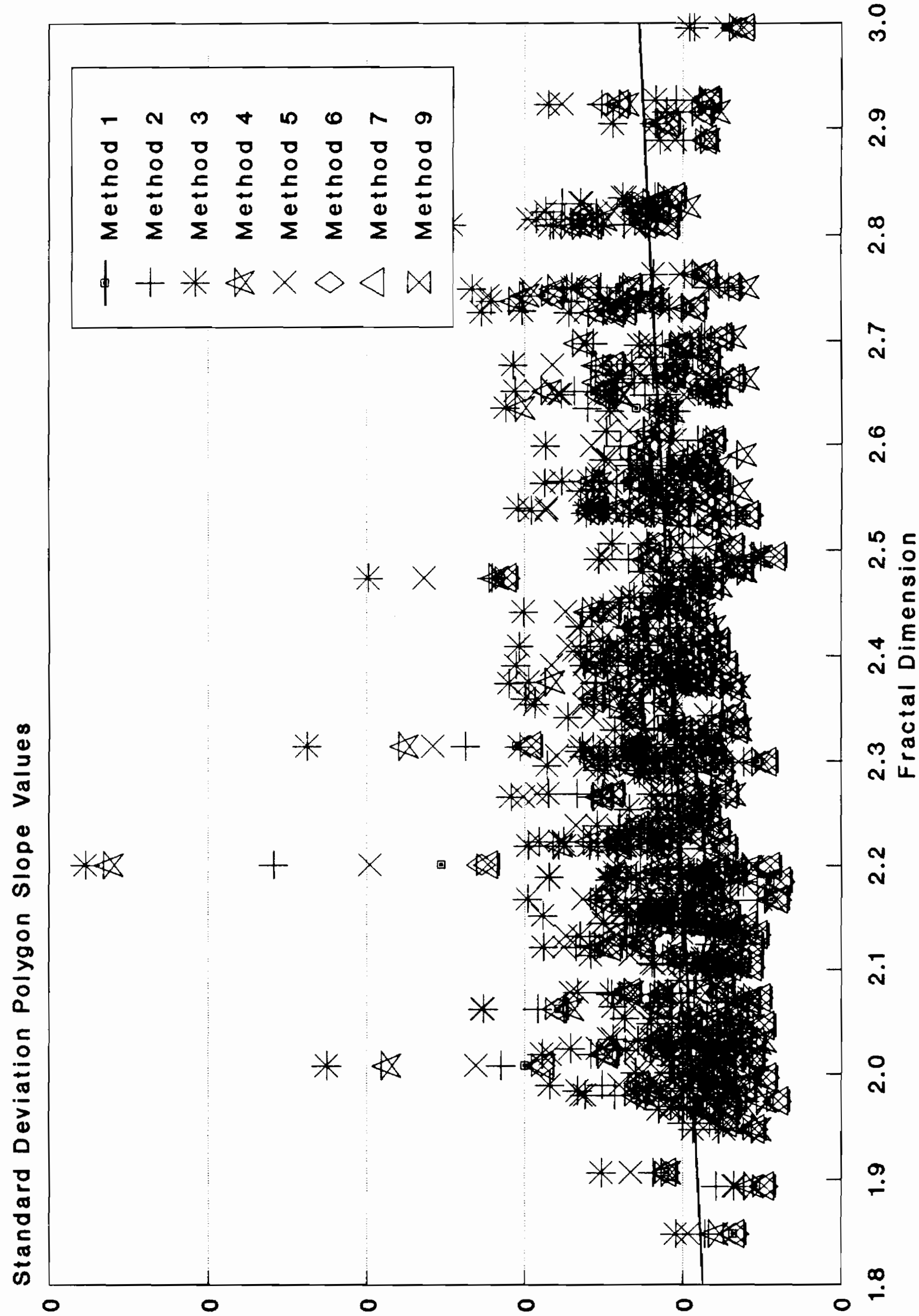


Figure 29. Plot of Standard Deviation Polygon Slope Values in Slope Percent by Fractal Dimension for the 8 Cell Slope Methods

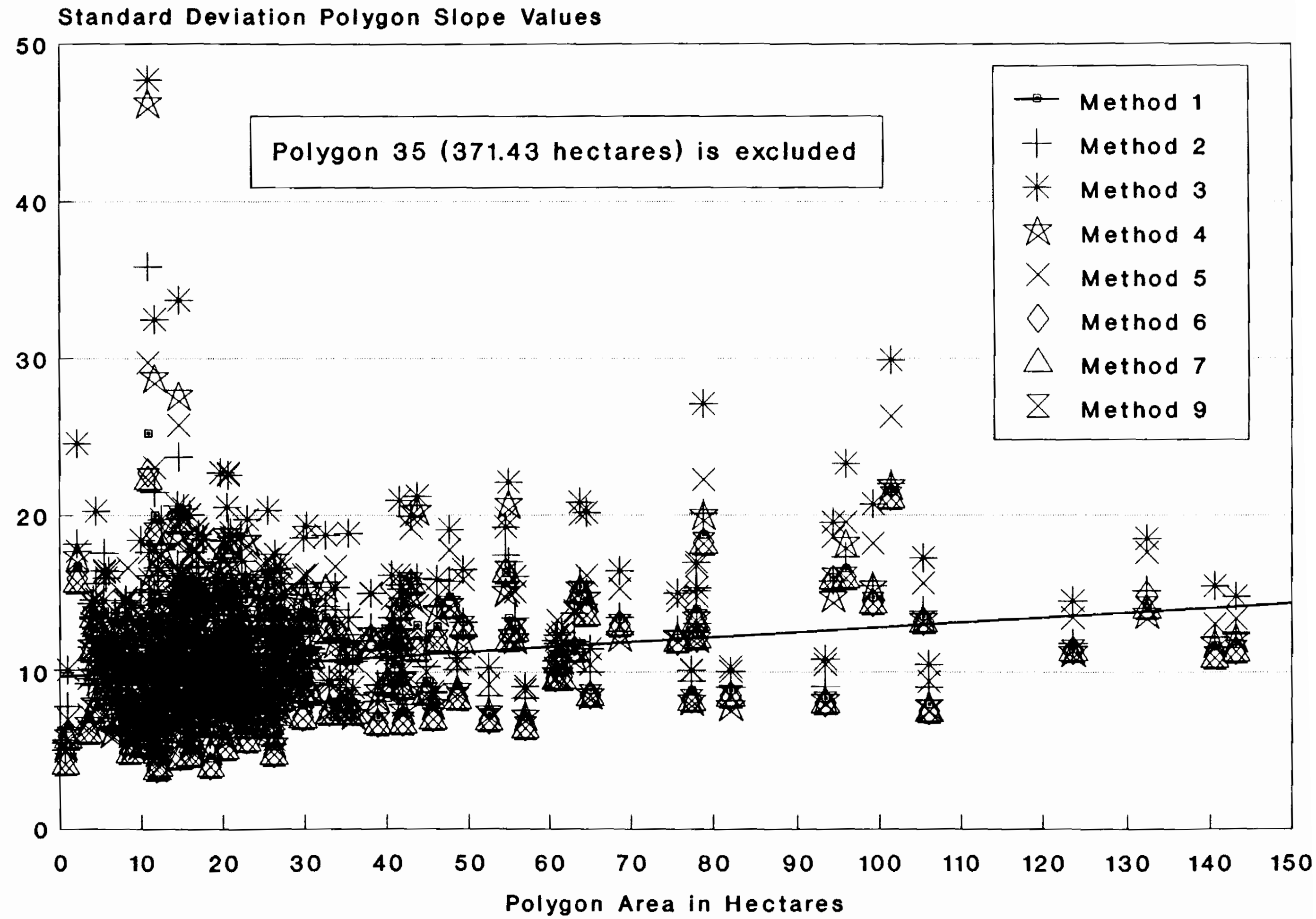


Figure 30. Plot of Standard Deviation Polygon Slope Values in Slope Percent by Area for the 8 Cell Slope Methods

shown in both figures to aid in interpretation. However, the information was insufficient to conclude that the standard deviation slope descriptor increases with area and fractal dimension without question.

Trim Mean Polygon Slope Descriptor

The trim mean is the mean of the middle 90% cell slope values when the cell slope values are arranged in order of magnitude (MINITAB, 1989). The trim mean values for each polygon, slope method, area and fractal category are shown in Appendix H. This descriptor measures the central tendency of the polygon cell slope values. Trimming the lower and upper 5% of the polygon cell slope values eliminated the extreme values, which made this descriptor less sensitive to cell slope errors (elevation errors). But, as a consequence, this descriptor smoothed the data by eliminating the extreme values that could have information value for determining the slope of a polygon. Slope method 3 had the largest trim mean polygon slope value for each area and fractal category. There was no indication that the trim mean was affected by the size and surface complexity of the polygon, based on plots of slope method difference against surface complexity and polygon size.

Mode Polygon Slope Descriptor

Appendix I lists the mode polygon slope values for each area and fractal category that could be determined. The mode polygon slope descriptor measures the most frequently occurring cell slope class value in the polygon. This descriptor is a measure of the central tendency of a data set. Since the cell slope values were continuous, the mode slope descriptor value was the most frequently occurring slope class as discussed previously in the Materials and Methodology chapter. For many of the polygons, the mode polygon slope could not be determined as shown in Appendix I. Based on this limited data, there was no indication that this descriptor was affected by size and surface complexity of the polygon.

Summary of the Effects of Size and Surface Complexity on Polygon Slope Descriptors

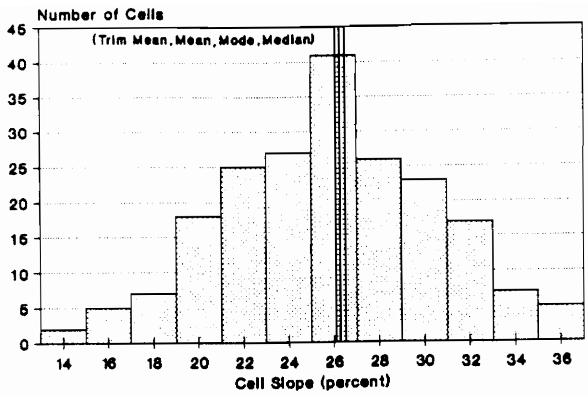
The only polygon descriptor affected by polygon size or surface complexity seemed to be the standard deviation slope descriptor. This slope descriptor showed a small increasing trend with increasing area and fractal category. The evidence was not conclusive to prove this without question. Slope method 11 seemed affected by the surface complexity of the polygon. As the fractal category increased, this method increasingly underestimated polygon slope based on comparisons to the mean and median polygon slope values for slope methods 1, 6, 7 and 9, but the evidence was not conclusive.

Characterizing the Slope of a Polygon

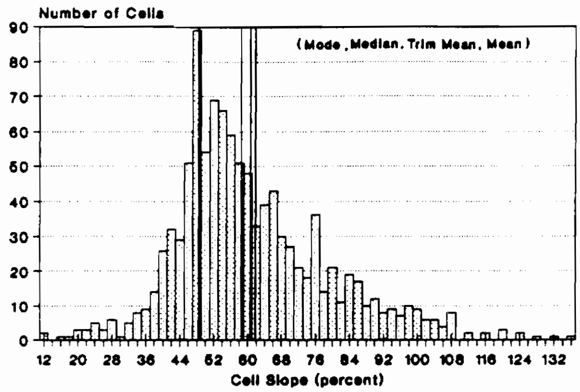
There are two sets of polygon slope descriptors; one measures the central tendency of the polygon cell slope values and the other measures the variability (dispersion) of polygon cell slope values. How these descriptors were affected by size and surface complexity was discussed previously. First, this section will concentrate on the relationship between the descriptors and how the distribution of the data affects each type of descriptor and, second will give examples of how to select and incorporate these polygon slope descriptors into a natural resource model.

Polygon Slope Descriptor Characteristics

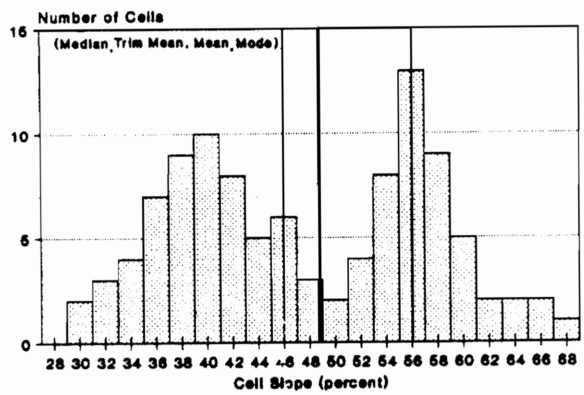
The first set of descriptors, mean, median, trim mean and mode, measure the central tendency of the polygon cell slope values. Each of these descriptors calculates the central tendency differently and they can all be virtually the same for a near symmetrical bell-shaped distribution as shown in Figure 31a, where polygon 65 using slope method 1 had polygon slope values 25.95%, 26.03%, 25.91% and 26.00%, respectively, using the mean, median, trim mean and mode slope descriptors. But these same slope descriptors behave differently for a non-symmetric (skewed)



(a) Polygon 65 (Slope Method 1), Near Symmetrical Bell-Shaped Distribution



(b) Polygon 186 (Slope Method 4), Skewed Distribution

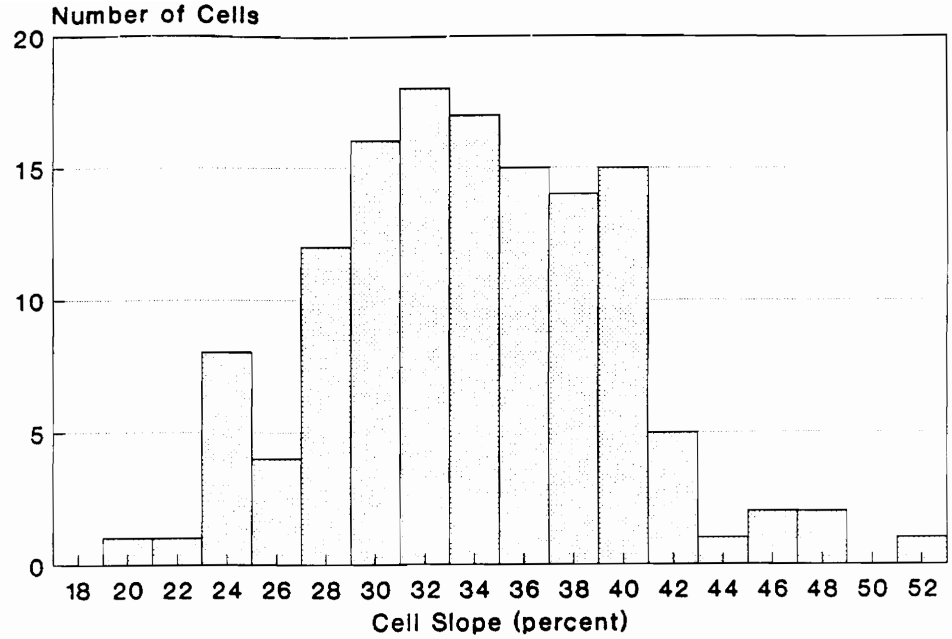


(c) Polygon 126 (Slope Method 5), Bimodal Distribution

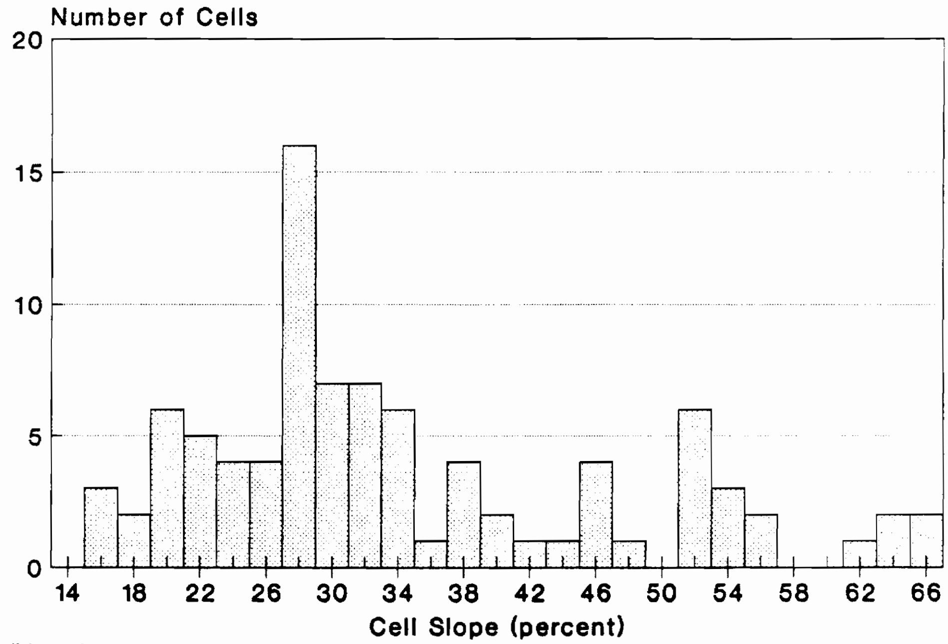
Figure 31. Central Tendency Polygon Slope Descriptors for Different Distribution Shapes

distribution as shown in Figure 31b, where polygon 186 using slope method 4 had the polygon slope values of 61.89%, 57.35%, 61.09% and 49.60%, respectively, for mean, median, trim mean and mode slope descriptors. For a bimodal distribution, as shown in Figure 31c, polygon 126 using slope method 5 had polygon slope values 47.13%, 45.96%, 47.07% and 56.00%, respectively, for the mean, median, trim mean and mode slope descriptors. The mean and trim mean polygon slope descriptors are essentially the same for each distribution shape, while median and mode polygon slope descriptors are different from each other for the skewed and bimodal cell slope value distributions. The mode polygon slope descriptor value was one of the modes in a multimodal distribution. The median polygon slope descriptor was the most robust central tendency descriptor for these three polygon cell slope value distributions.

The second set of descriptors, minimum, maximum, standard deviation, first quartile and third quartile, measure the variability (dispersion) of the polygon cell slope values. Two distributions can have the same central tendency descriptor (mean, trim mean, etc.), but there can be a vast difference in the variability around this descriptor as shown by the distributions in Figure 32. Both of these polygons, 75 and 113 had similar polygon mean slope values of 34.84% and 34.52% respectively (using slope method 4) but the variability of the cell slope values were quite different. The minimum and maximum polygon descriptors together can measure the range of cell slope values within a polygon. For example, the range for polygon 75 was 31.36% and for polygon 113 the range was 50.41% using slope method 4. The problem with using these two descriptors was that they were very sensitive to extreme cell slope values. For example, polygon 140 using slope method 4 had a maximum cell slope value of 149.07% while 329 of the 332 cells had cell slope values less than 74%. The calculated range using the minimum and maximum for this polygon would be 131.12%, while a more appropriate measure of variability would be 56.1% using only the 329 cells. Also, polygons can have the same range yet differ substantially in variability about the central tendency descriptor.



(a) Polygon 75 (Slope Method 4), Polygon Mean Slope = 34.84%



(b) Polygon 113 (Slope Method 4), Polygon Mean Slope = 34.52%

Figure 32. Difference in Cell Slope Variability for Polygons with Similar Central Tendency Descriptors

The first and third quartile slope descriptors can be used to calculate the interquartile range of the polygon cell slope values. The interquartile range is less sensitive than the range to extreme cell slope values. For example, the interquartile range for polygon 140 using slope method 4 was 16.56%, while the range was 131.12%. The interquartile range is useful in comparing the variability of two polygons, but little information can be obtained for describing the variability of cell slope values in a single polygon. Based on Tchebysheff's Theorem, shown below, the standard deviation polygon

> **Tchebysheff's Theorem:**
>
> Let Y be a continuous (discrete) random variable with density function $f(y)$ or probability function p(y). Then for any $k>0$,
>
> $$P(|Y-\mu| < k\sigma) \geq 1-(1/k^2) \quad \text{or} \quad P(|Y-\mu| \geq k\sigma) \leq 1/k^2$$
>
> where $E(Y) = \mu$ and $V(Y) = \sigma^2 < \infty$

(Mendenhall, et al., 1986)

slope descriptor can be used to give an indication of polygon cell slope variability in the polygon without regard for the distribution of cell slope values. Mathematical manipulation of Tchebysheff's Theorem can state that at least $(1 - 1/k^2)$ of the cell slope values will lie within k standard deviations. This approach is very conservative since the distribution of cell slope values are not known.

Incorporating Polygon Slope in a Model

In most situations that incorporate the slope of a polygon in some type of model, the mean polygon slope descriptor has been used. Examples of this are the land use policy analysis study for San Francisco Bay (Gardels et al., 1990), a spatial decision support system for the Jefferson National Forest (Reisinger and Kenney, 1990) and hydrologic modeling for planning (Shanholtz et al., 1990). The remainder of this section demonstrates that the mean slope descriptor is not the most appropriate descriptor in some models, and forwards the idea that the slope method and polygon slope descriptor(s) used in the model should depend on the application and objectives of the model. These ideas will be presented in this section in the form of two hypothetical examples.

Identifying Forest Stands that can be Harvested with Wheeled Skidders. Wheeled skidders (rubber tire skidders) are the most common and economical method used for removing logs from the forest in North America (Studie et al., 1984). In areas having steep topography, it is desirable to know which stands can be harvested using this method, since the slope of the stand limits the locations where wheeled skidders can be utilized. The operability slope limit of wheeled skidders is based on equipment configuration and type, but for management planning the slope limit is usually 25% - 35% (Wackerman et al., 1966).

In this hypothetical example, the equipment slope limit for economical operation is 35% on the average. The forest planner wants to use a Geographic Information System (GIS) to identify all stands (polygons) with 75% or greater of their area having a slope of less than 35%. The equipment can winch logs over steeper slopes, and physically operate on steeper slopes, but not economically.

Before tackling this problem two major decisions had to be made, what slope method would be used to calculate the cell slope values for the polygon and which descriptor(s) would be used to describe the slope of the polygon. For this problem, the maximum cell slope was of interest, to be conservative. Slope method 11 was not appropriate for this model because it calculated the average slope of the polygon. There are three slope methods that involved calculating the maximum cell slope values using its neighbors; they were slope methods 3, 4 and 5. Due to the likelihood of elevation data errors in the DEM, slope method 3 was not used because of its extreme sensitivity to elevation errors. The choice between slope methods 4 and 5 was diminutive, being very subjective, but slope method 5 was chosen since it was not as sensitive as slope method 4 to linear (row, column) elevation errors. A second decision regarding this problem was what polygon slope descriptor(s) was needed based on the objectives of the model. There were two groups of polygon slope descriptor(s) that would meet this objective, the third quartile descriptor and the mean descriptor with the standard deviation descriptor. The third quartile polygon slope descriptor is a slope value that exceeds 75% of the polygon cell slope values. The mean polygon slope descriptor, used with the standard deviation descriptor and applying Tchebysheff's Theorem can estimate the probability that 75% of the cell slope values are less than 35%. An example of this procedure is shown below for polygon 193 using slope method 5.

$P(\lvert Y-\mu \rvert \geq k\sigma) \leq 1/k^2 \quad (k > 0)$	Tchebysheff's Theorem
$\mu = 18.00\%$	Appendix A
$\sigma = 4.68\%$	Appendix G

For the example, $y = 35.00$ exceeds the mean $\mu = 18.00$ by $k = 17.00/4.68$ standard deviations. Then applying Tchebysheff's Theorem:

$$P(\lvert Y-18.00 \rvert \geq 17.00) \leq 1/(3.63)^2 = .076$$

The 0.076 is the combined area of the tails of the distribution as shown in Figure 33. The probability for the individual tails could not be determined since the distribution was not known. Using both the mean and standard deviation polygon slope descriptors showed that polygon (stand) 193 could be harvested using a wheeled skidder because $P(Y \geq 35.0)$ is small (less than $\alpha = 0.25$), since the forest planner was interested in identifying the stands that had at least 75% of their area with less than 35% slope.

To demonstrate the differences between using the mean polygon slope descriptor, third quartile slope descriptor and the mean descriptor with the standard deviation descriptor, the 240 polygons in this study were tested to see if they could be harvested using a wheeled skidder. Slope

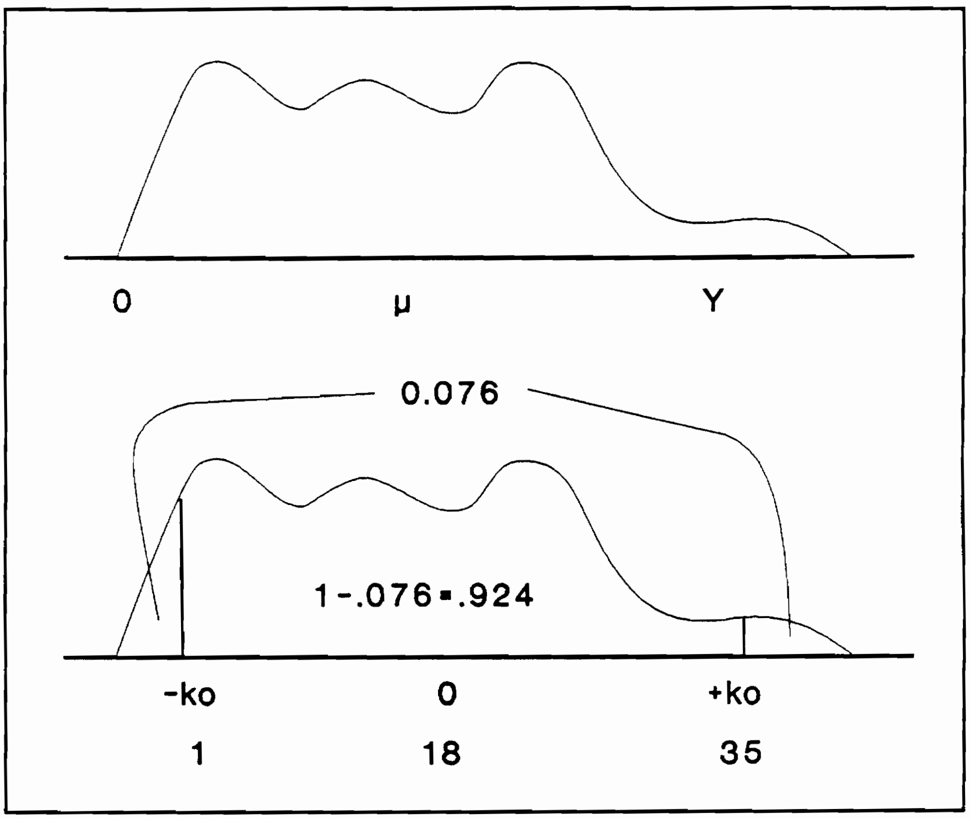


Figure 33. Applying the Tchebysheff's Theorem to Identify Forest Stands that can be Harvested

method 5 was used in this example and the results are shown in Table 18. The third quartile polygon slope descriptor estimated the number of polygons and their associated area in which 75%

Table 18. Comparison of Three Methods of Determining if a Stand can Be Harvested using a Wheeled Skidder

Descriptors	Number of Polygons that can be Harvested	Area (Hectares)
Mean	135	3,837.42
Third Quartile	75	1,744.75
Mean and Standard Deviation	15	266.67

or greater of the polygon area had a slope of less than 35%. As shown in Table 18, if the mean polygon slope estimate was used, it would have seriously overestimated the number of stands and the area that could be harvested when compared to third quartile polygon descriptor estimates. Utilizing both the mean and standard deviation polygon descriptors, the number of polygons and their associated areas that could be harvested were underestimated. This was because Tchebysheff's approach was very conservative, since only two pieces of information were known about the individual cell slope values in the polygon, the mean and standard deviation. Also, the probability value was a combination of both tails, as previously discussed, even though only the probability of one tail was of interest. One hundred and seventy six of the 240 polygons had a k value less than one, which in effect caused a probability of one. This was a result of the large variations of cell slope values (large standard deviations) in the polygons.

For practical applications using models similar to this in a GIS, there is more than one approach that can be taken. If all the individual polygon cell slope values were stored, any polygon slope descriptor could be retrieved. This was the only technique that would allow analysis using many different polygon slope descriptors. For small areas this approach was feasible, but for larger areas there would be a large demand for storage facilities and increased computer processing time. The other approach would be to store the mean and standard deviation of the polygon cell slope values in the GIS and make allowances for the conservativeness of Tchebysheff's approach. This was not possible as shown in the above example because of the conservativeness of Tchebysheff's Theorem and the large cell slope variations (standard deviations) of the polygons. In concept, using Tchebysheff's Theorem looks promising but in application it was not a viable approach. Another approach that was feasible was to store all the quartiles that might be used in analyses. The maximum number of values that had to be stored using this approach was 100, which was substantially less than storing all the individual polygon cell slope values. In this study the average number of cells for a polygon was 319.

Determining the Slope-Steepness Factor of the USLE for a Stand. The Universal Soil Loss Equation (USLE) is widely used to predict long term average soil losses from areas that use specific management practices. The equation was developed from over 40 years of data from plots located throughout the United States (Schwab et al., 1981). The USLE is shown below with a description of its variables.

$$A = 2.24*R*K*L*S*C*P$$

A = average annual soil loss per Mg/ha (metric tons/hectare)

R = rainfall and erosivity index by geographic location

K = soil erodibility factor

L = slope length factor

S = slope steepness factor

C = cover and management factor

P = conservation practice factor

In this hypothetical example, the slope steepness factor was determined for the 240 stands (polygons) in this study using the equation shown below (Schwab, et al., 1981).

$$S = \frac{(0.43 + 0.30s + 0.43s^2)}{6.574}$$

s = slope in percent

The USLE is a one-dimensional equation and before estimating soil loss over an area it requires modification. See Griffen et al. (1988), Dissmeyer and Foster (1984), Beasley et al. (1982), Vold et al. (1985), Dillaha et al. (1982) and Wilson (1986) for a complete discussion of estimating soil loss using the USLE for an area. It was not the scope or purpose of this example to use any of these methods or propose a new method. Only how different methods of calculating the polygon slope and what appropriate polygon slope descriptors should be used for determining the S factor of the USLE was addressed in this example.

As in the previous example, two decisions were required before investigating this problem, the slope method that would be used to determine the cell slope values and which polygon descriptor was most appropriate to meet the objectives of this model. Since this model is interested in averages, the slope method should utilize all its neighbors in calculating the slope value of a cell. Slope methods 7 and 9 met this criteria. Since the difference between these two methods was negligible and slope method 7 was most computatively efficient as previously shown, slope method 7 was used. Slope method 11 was also appropriate, so it was used to calculate the S factor of the USLE, but the effects of the poor performance of this method with increasing fractal dimension was considered in the evaluation. The calculation of the S factor for the USLE was interested in average, so one of the central tendency polygon slope descriptors would be appropriate. The mode polygon slope was not considered because it could not be determined for all the polygons. The median and trim mean polygon slope descriptors were examined in this example since both met the objectives of the model. The reason the trim mean was used instead of the mean was because the trim mean was less sensitive to DEM errors. This assumes the errors are outliers. The median polygon slope descriptor was also used because it was the most robust of the central tendency descriptors.

Table 19 shows the S factors of USLE for all 240 polygons in the study using slope method 11, the trim mean polygon slope descriptor using slope method 7 and the median polygon slope descriptor using slope method 7. The polygons were sorted in ascending order based on fractal dimension. As shown in Table 19, the difference in the S factor between slope method 11 and the other two could be large, especially as fractal dimension increased. An example was polygon 7 (fractal dimension = 2.58, r^2 = 0.5054), where the calculated USLE S factor was 1.03, 31.11 and 28.95, using slope method 11, median polygon slope and trim mean polygon slope, respectively. Slope method 11 was not a viable slope method for this model based on results from this example and the characteristics of this method. The choice between the trim mean and median slope descriptors was diminutive, but the trim mean was chosen because it gave the average slope of the polygon with the added benefit of not being sensitive to extreme values. If a GIS was used to determine USLE, the S factor could be calculated using the trim mean polygon slope descriptor if this descriptor was stored in the attribute database of the GIS for each polygon. This example demonstrates the large differences in results that can occur just by using different polygon slope descriptors.

Summary of Characterizing Slope of a Polygon

As shown by the previous two examples, the slope method and polygon slope descriptor(s) utilized should be based on the model and the objectives of the model. These two hypothetical examples were a small sample of the many models that use slope as a variable and each model had to be treated differently in determining the most appropriate slope method and polygon slope

Table 19. Calculated S Factor for USLE using Different Slope Methods and Descriptors in Slope Percent

Polygon	S Factor (Median)	S Factor (Slope 11)	S Factor (Trim Mean)	Polygon	S Factor (Median)	S Factor (Slope 11)	S Factor (Trim Mean)
126	101.38	97.36	97.09	89	66.78	53.52	64.76
75	57.98	57.71	56.96	73	50.28	25.70	47.05
241	87.79	81.47	88.41	112	77.59	60.38	77.98
92	89.99	69.18	87.68	35	45.99	10.74	49.71
95	76.74	52.25	76.63	210	18.90	10.76	17.39
118	73.24	57.01	73.48	152	62.22	48.27	62.03
85	65.29	42.39	61.06	204	16.30	17.16	16.46
225	42.92	31.83	42.24	111	67.96	43.76	69.12
65	44.20	38.71	44.63	178	70.29	27.20	66.15
72	59.79	56.02	59.67	121	26.35	21.15	25.43
34	133.33	112.16	129.75	161	143.62	138.58	136.12
163	122.46	102.99	134.00	199	105.28	73.11	96.05
62	23.22	17.20	24.13	101	30.43	24.22	33.20
80	40.53	32.00	39.43	177	15.79	11.25	16.71
196	20.66	15.15	17.35	190	46.68	15.65	43.85
164	127.09	104.18	126.97	217	16.95	9.81	17.78
197	20.32	11.92	19.56	125	87.53	77.23	84.58
181	16.29	10.51	17.43	219	60.50	61.38	64.50
78	47.00	26.01	46.07	147	42.59	21.25	43.63
198	82.16	74.91	76.20	195	17.56	10.54	16.77
174	106.12	84.31	93.91	83	46.84	21.58	44.61
148	54.57	46.82	51.88	44	26.74	16.86	25.92
135	23.05	20.97	23.36	63	48.80	35.93	50.02
82	27.25	25.23	28.45	183	18.43	9.46	18.52
187	58.76	55.52	61.37	77	97.61	86.05	102.54
5	134.99	116.31	120.97	4	157.42	145.71	142.03
84	62.75	41.95	64.08	232	80.91	52.37	83.91
60	229.05	195.12	220.79	150	16.95	11.52	15.77
81	26.69	18.34	28.39	185	72.98	26.88	66.28
70	59.08	51.26	61.50	55	30.81	28.90	30.43

Table 19. Calculated S Factor for USLE using Different Slope Methods and Descriptors in Slope Percent (continued)

Polygon	S Factor (Median)	S Factor (Slope 11)	S Factor (Trim Mean)	Polygon	S Factor (Median)	S Factor (Slope 11)	S Factor (Trim Mean)
54	30.21	20.45	30.10	243	55.02	35.44	58.67
144	42.72	22.03	42.50	114	39.96	24.27	47.95
214	24.60	15.47	24.41	64	104.24	67.49	106.39
104	101.49	91.45	110.55	6	51.33	13.43	54.02
165	29.54	10.15	31.56	205	40.28	46.33	40.61
180	54.02	29.45	57.67	173	41.00	7.00	42.26
220	24.44	17.29	26.76	155	28.46	25.11	33.50
37	36.62	21.67	37.49	109	50.82	21.77	52.44
48	67.12	10.16	66.22	146	48.80	25.70	50.46
124	65.49	32.58	73.66	51	71.72	23.03	77.81
2	44.37	33.14	44.76	130	46.44	21.86	43.89
218	47.60	28.38	47.22	100	36.30	26.98	39.64
56	36.84	29.18	36.56	189	30.71	6.92	32.30
90	40.35	21.04	44.36	103	80.22	66.91	80.28
61	102.05	101.44	93.36	141	138.52	113.46	138.93
188	17.90	8.09	20.07	201	31.48	12.71	29.20
46	36.05	15.59	34.00	191	21.58	6.85	21.75
98	86.72	75.75	80.20	96	29.87	11.14	32.48
193	13.98	10.72	13.78	240	118.47	124.28	115.82
113	45.40	54.04	51.89	108	34.72	17.99	35.23
202	59.37	53.18	65.17	172	59.67	39.06	57.91
142	54.27	25.72	62.22	203	57.63	12.69	59.41
58	39.09	16.51	39.44	140	106.05	33.20	103.99
162	74.89	64.75	71.82	97	73.99	68.93	74.90
102	45.75	42.89	51.60	128	56.78	13.62	55.88
45	24.29	6.83	23.99	29	38.88	9.59	40.33
145	18.67	15.25	18.45	76	16.16	8.35	19.57
117	71.93	80.04	83.21	170	53.22	33.76	52.05
179	109.90	102.11	131.39	59	93.12	81.42	91.87
94	32.82	10.56	35.64	93	63.03	31.00	64.69

Table 19. Calculated S Factor for USLE using Different Slope Methods and Descriptors in Slope Percent (continued)

Polygon	S Factor (Median)	S Factor (Slope 11)	S Factor (Trim Mean)	Polygon	S Factor (Median)	S Factor (Slope 11)	S Factor (Trim Mean)
233	37.35	34.60	44.03	27	13.97	2.46	14.93
43	43.00	23.17	41.90	136	74.85	40.71	76.77
50	42.99	52.62	46.30	211	59.00	33.23	65.21
226	102.99	122.23	118.70	229	76.74	6.11	72.98
9	28.49	16.72	29.58	8	61.32	53.63	57.31
159	31.77	15.75	31.75	67	80.82	5.19	83.36
12	36.86	18.58	35.75	88	55.75	16.49	52.76
182	71.54	67.33	68.85	176	59.39	41.13	69.78
143	47.98	14.48	48.82	38	45.88	4.52	46.17
213	76.11	19.07	78.44	127	35.63	5.32	45.12
52	40.71	38.55	43.32	149	47.31	28.30	42.77
49	24.91	7.69	27.29	221	41.59	11.52	44.24
167	33.95	19.93	37.13	209	45.61	31.03	38.71
154	107.13	47.42	105.43	160	54.76	36.83	52.59
86	79.86	62.75	75.99	223	38.77	11.96	40.33
227	27.89	7.66	26.70	129	135.70	81.10	151.01
153	71.11	60.78	81.98	19	41.59	9.98	42.22
134	28.05	28.98	29.55	138	71.33	61.74	64.79
216	54.65	15.03	52.79	212	47.53	46.93	49.00
184	52.77	16.20	54.16	91	27.17	25.85	25.75
157	37.81	7.55	37.15	230	66.20	21.48	67.58
115	38.87	11.47	45.71	106	7.39	0.79	8.63
132	120.26	74.91	114.30	20	19.29	6.07	19.62
15	36.05	12.68	32.95	206	40.80	5.39	43.49
231	93.02	28.30	83.79	69	26.19	9.95	25.52
40	62.79	41.10	66.48	194	122.97	124.62	123.07
208	19.30	3.56	20.80	36	51.08	4.64	57.81
192	67.28	39.16	63.78	207	15.81	1.63	19.95
222	33.26	21.58	32.42	131	72.45	2.15	74.69
32	35.44	16.86	47.45	228	111.08	77.64	99.08

Table 19. Calculated S Factor for USLE using Different Slope Methods and Descriptors in Slope Percent (continued)

Polygon	S Factor (Median)	S Factor (Slope 11)	S Factor (Trim Mean)	Polygon	S Factor (Median)	S Factor (Slope 11)	S Factor (Trim Mean)
122	69.87	82.30	77.32	119	65.00	39.90	65.43
168	34.12	8.80	34.35	175	42.20	11.23	41.03
238	107.87	70.29	110.06	23	28.30	1.69	29.94
79	33.85	6.11	33.37	18	24.99	1.92	24.36
110	40.28	13.83	40.75	22	20.76	0.36	26.66
33	40.35	25.26	38.10	3	50.28	44.00	50.43
156	106.86	115.21	110.83	31	24.44	4.61	25.64
200	120.21	100.46	113.79	235	84.26	53.18	82.62
151	47.81	16.49	48.40	26	0.11	0.16	3.59
39	99.13	51.41	83.22	47	25.29	17.46	28.25
68	32.23	10.41	32.47	158	343.29	1.67	337.95
7	31.11	1.03	28.95	186	172.99	124.11	189.02
17	29.62	1.76	30.61	13	10.66	2.67	11.12
42	89.84	42.19	83.84	1	98.88	56.74	95.13
169	40.19	41.13	37.20	66	19.96	7.96	22.21
123	113.46	86.53	118.60	21	19.56	6.65	19.21
120	68.59	41.92	70.22	57	47.95	61.26	63.52
139	33.14	7.06	38.37	41	150.97	113.85	147.40
215	88.25	15.45	81.93	71	142.91	11.14	118.04
24	7.52	1.16	8.79	137	21.06	5.24	21.48
25	10.72	1.61	10.73	166	31.60	5.20	32.11
133	103.25	81.28	82.44	239	14.93	22.88	22.30
30	15.99	1.11	18.46	234	298.86	242.80	255.80
236	165.80	153.28	154.67	242	158.58	86.34	148.23
28	30.09	14.89	32.41	105	26.56	15.99	27.11
16	24.04	19.11	23.18	116	30.21	1.89	31.51
171	49.45	14.73	50.56	14	16.06	0.72	17.31
11	31.94	1.49	32.52	10	118.81	67.83	109.13
74	179.72	169.38	190.66	53	35.11	34.99	39.57
107	30.21	3.26	29.89	87	22.90	33.32	21.90

descriptor(s). There was no universal polygon slope descriptor(s) or slope method that would be appropriate for all models that use slope as a variable. Also, the characteristics of the slope method and polygon slope descriptor(s) for the topographic area in which they were being applied, must be considered. There were many factors consider and decisions to be made, of which some were ambiguous, in determining the slope method and polygon slope descriptor(s) that was appropriate for a model. Since the number of combinations of slope method and polygon slope descriptor(s) were many, and the particular models that are going to be used in a GIS are unforeseen, the elevation data should be stored in the GIS for practical applications. For a USGS 7½ DEM, this is equivalent to about 1.1Mb per DEM. This would allow extraction of any slope descriptor(s) using any slope method for a polygon based on the model and objectives of the model. Still, the question of how to determine the appropriate slope method and descriptor(s) for a model in practical application must be addressed. Since most GIS users do not have the expertise on slope methods or polygon slope descriptor characteristics or the time to obtain the expertise, this is an appropriate application for an Expert System.

Chapter 5 - SUMMARY AND CONCLUSION

As the applications of Geographic Information Systems mature, from a descriptive tool to a decision making and cumulative effect modeling tool, knowledge of errors and variability of GIS components are becoming increasingly important. The objective of this study was to understand the errors and variability of one component of a GIS, topographic slope. In combination, the study evaluated different methods for determining and characterizing the slope value for natural resource management units, polygons. In accord with this, a new polygon slope method was examined. Also the objective of this work was to describe and show the effects different slope methods and descriptors have upon natural resource models.

The study area is located in Wise and Lee counties of southwestern Virginia. The 240 stands (polygons) used in this study were digitized by the Tennessee Valley Authority for the Jefferson National Forest. The elevation data was taken from the USGS Big Stone Gap 7½ minute DEM, which was created using the Gestalt Photo Mapper II System.

Eight different cell slope methods commonly used in the literature were evaluated to determine if they were different, and if so at what magnitude. Elevation values from all 240 stands (77,855 values) were used in this comparison. All 28 cell slope method pair wise comparisons were statistically different, but six of the comparisons were similar for most practical applications. They had a mean difference of less than one percent. Cell slope values calculated using slope method 3 were always greater than the other seven slope methods. Slope methods 7 and 9 were essentially the same with a mean difference of 0.00007%. Also, slope values calculated using method 6 were similar to slope methods 7 and 9 with a mean difference of 0.20%. There were five slope groups in which the calculated cell slope values were similar on the average. They were slope method 2, slope method 3, slope method 4, slope method 5, and slope methods 1, 6, 7 and 9. This grouping was based on a pair wise mean difference of less than 1% slope value between the methods. Of the 28 pair wise comparisons only 10 of the slope method differences had a normal distribution. The other distributions were skewed or truncated at the zero slope value.

A new polygon slope method was proposed, slope method 11 (Y-method). This slope method fitted a plane through the elevation values of the polygon. This method was different from the other eight slope methods used in this study because it was not based on the aggregation of cell slope values in a polygon. The advantage of this method was that it determined one slope value for a polygon using all the elevation values in a polygon, instead of characterizing slope of a polygon by some type of aggregation of cell slope values. The disadvantage of this method was that it underestimates the polygon slope value when a ridge or steep valley intersects the polygon and information about the distribution of slopes in the polygon are unknown. An added benefit of this method was that the aspect of the polygon could be calculated.

The 240 polygons were categorized into five size categories and six fractal dimension categories to determine if the slope method and polygon slope descriptors were influenced by these characteristics of the polygon. None of the slope methods seemed influenced by area and surface complexity except slope method 11, which seemed to underestimate slope with increasing fractal dimension. The evidence for this conclusion was weak. Of the nine different polygon slope descriptors, mean, median, trim mean, mode, standard deviation, minimum, maximum, first quartile and third quartile, only the standard deviation polygon slope descriptor had a small increase when area and fractal category increased, but this increase was negligible.

For each of the 240 polygons and each of the eight slope methods, plots were made to examine the distributions of the cell slope values in the polygons. The distributions of the cell slope values for the different slope methods were not normal in almost every case. This was considered when evaluating the different polygon slope descriptors.

For most current applications that incorporate slope of a polygon in a model, the mean polygon slope descriptor is used. However, the mean is not always the appropriate polygon slope descriptor. The mean polygon slope descriptor does not always provide the necessary information about the polygon slope that is required for the model that has slope as a variable. This study proposes that the slope method and polygon slope descriptor(s) used in a model should depend on the application and objectives of the model since there is no universal slope method and polygon slope descriptor that can work with all models. There is no universal slope method and polygon slope descriptor(s) because polygon slope is an abstraction, since slope is a point phenomena. There is no correct slope value for a polygon and it must be characterized using polygon slope descriptor(s) since natural resource managers are often interested in the slope of an area (polygon). If a slope method and polygon slope descriptor was chosen arbitrarily, unexpected results could be produced, or worse, logical results produced that were misrepresentations. As shown in the examples of this study, the results produced by different slope methods and polygon slope descriptors can be dramatically different.

It can be foreseen that there are many slope methods/polygon slope descriptor possibilities. In this study alone there were at least 73 different ways to describe the slope of a polygon. To apply this work on an operational basis, an Expert System must be developed, because it is inconceivable to expect users of slope in models to know which slope method and polygon slope descriptor is appropriate for all models. An Expert System (ES) is a computerized advisory program(s) that attempts to imitate or substitute the reasoning processes and knowledge of experts in solving specific types of problems (Turban, 1988). In this case the problem was determining the appropriate slope method and polygon slope descriptor(s) for a particular model. The Expert System could ask a set of questions about the model and the objectives of the model and based on the user responses choose the appropriate slope method(s) and polygon slope descriptor(s). This whole process could be automated. For example, after the user finished responding to the questions of the Expert System, the Expert System would query the user to determine if the user agreed with the Expert System's choice of slope method(s) and polygon slope descriptor(s). If the user approved, the Expert System would calculate the cell slope values and descriptor(s) from the elevation values stored in the GIS and store the descriptor(s) in the GIS database for the appropriate polygons. This system would have the flexibility to work with any model, allowing slope method(s) and descriptor(s) to be chosen based on model objectives, and allowing the user to use the best slope information in the model without becoming an expert in the many different slope methods and polygon slope descriptors. This is an area that needs further research and work.

The ultimate goal of studies that look at components of Geographic Information Systems is to understand the driving factors of these components and how to avoid possible problems and pitfalls while solving the task at hand. As a warning, *beware of the black box syndrome and default values* in Geographic Information Systems, because pretty maps can be obtained on which decisions are made, but based on poor assumptions. Do not be misled just because a Geographic Information System produced the map and results, that it is unquestionably correct.

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APPENDIX A

POLYGON MEANS FOR THE DIFFERENT SLOPE METHODS

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 1 and Fractal Category = 1								
34	45.27	45.32	65.89	53.12	53.47	44.13	43.77	43.77	41.05
65	25.95	27.01	39.62	30.38	30.31	25.79	25.75	25.75	23.96
72	30.55	31.19	43.33	36.61	37.02	29.91	29.72	29.72	28.90
75	29.45	28.71	42.10	34.93	36.77	29.03	28.92	28.92	29.34
80	24.83	25.95	37.87	31.29	29.79	24.09	23.90	23.90	21.75
85	31.34	31.27	45.43	37.71	37.68	30.42	30.14	30.14	25.09
92	36.64	35.79	50.00	41.49	44.63	36.11	35.95	35.95	32.16
95	34.95	34.48	48.30	40.82	41.09	34.09	33.82	33.82	27.90
126	38.22	37.33	56.60	42.83	47.13	38.09	38.05	38.05	38.22
163	45.36	45.99	67.39	51.46	53.07	45.18	45.14	45.14	39.32
164	44.33	44.50	68.36	52.80	50.46	43.67	43.49	43.49	39.55
196	16.16	18.60	27.42	23.43	19.53	15.72	15.65	15.65	14.84
241	36.17	37.07	49.56	42.26	42.74	35.93	35.90	35.90	34.93
Mean	33.78	34.09	49.37	39.93	40.29	33.24	33.09	33.09	30.54
STD	8.66	8.17	12.34	8.98	9.93	8.62	8.60	8.61	7.94
	Area Category = 1 and Fractal Category = 2								
4	46.66	47.39	73.63	54.35	54.58	46.04	45.86	45.87	46.84
55	21.98	24.20	31.08	28.37	26.76	21.32	21.14	21.14	20.65
56	23.45	24.92	32.54	27.72	28.36	23.24	23.19	23.19	20.75
58	25.60	27.67	40.38	34.20	30.61	24.65	24.37	24.37	15.51
61	37.90	38.75	53.58	45.40	43.07	37.41	37.26	37.26	39.02
70	31.25	30.80	42.77	37.76	37.89	30.49	30.27	30.27	27.63
73	26.60	28.67	40.40	32.42	31.78	26.08	25.93	25.93	19.45
77	40.22	41.60	58.21	46.16	47.33	39.81	39.69	39.68	35.91
83	26.99	27.88	40.11	33.50	31.51	26.12	25.86	25.86	17.79
84	32.83	33.93	46.01	40.25	39.62	31.59	31.20	31.20	24.96
89	31.52	33.59	43.98	36.40	38.56	31.04	30.89	30.90	28.24
101	23.39	20.58	37.00	29.41	27.14	22.72	22.54	22.53	18.87
111	33.27	34.58	49.20	40.27	40.35	32.49	32.26	32.26	25.50
113	28.86	29.91	42.26	35.33	35.50	28.42	28.29	28.29	28.38
117	35.85	36.63	52.30	42.24	45.88	35.70	35.66	35.67	34.62

Appendix A. Polygon Means for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 1 and Fractal Category = 2 (continued)								
121	19.66	20.61	32.07	25.60	23.58	19.37	19.32	19.32	17.61
135	19.23	20.46	31.27	25.73	22.22	18.63	18.48	18.48	17.53
142	32.32	32.90	50.56	41.45	39.08	31.35	31.07	31.07	19.46
144	26.32	28.00	42.45	34.99	31.32	25.29	24.99	24.99	17.98
145	16.98	18.99	29.71	24.23	20.52	16.48	16.38	16.38	14.89
147	25.96	27.08	40.17	32.01	30.13	25.55	25.44	25.44	17.65
165	22.52	24.23	34.40	30.85	26.71	21.95	21.80	21.80	12.07
174	38.65	39.01	61.29	49.36	47.76	37.95	37.81	37.81	35.54
185	33.49	35.65	50.30	43.87	38.93	31.84	31.35	31.35	19.90
193	14.96	16.89	24.66	21.76	18.00	14.30	14.15	14.15	12.42
195	16.77	18.60	28.26	24.67	19.99	15.86	15.63	15.63	12.31
198	34.37	35.57	47.67	42.07	40.59	33.64	33.43	33.42	33.48
199	37.57	39.80	53.85	44.74	43.35	37.13	37.02	37.02	33.07
202	31.44	31.33	48.67	36.65	39.03	31.38	31.38	31.38	28.15
204	16.08	18.28	27.33	22.56	19.06	15.59	15.51	15.51	15.82
210	17.69	20.02	29.25	26.85	20.49	16.24	15.87	15.87	12.44
217	17.46	20.17	30.22	25.66	21.02	16.49	16.25	16.25	11.86
219	31.16	30.45	45.74	35.58	39.77	31.05	31.02	31.01	30.27
232	36.05	38.71	53.66	43.17	43.78	35.44	35.27	35.26	27.93
Mean	28.09	29.35	42.50	35.16	33.65	27.43	27.25	27.25	23.37
STD	8.09	7.90	11.18	8.37	9.75	8.14	8.14	8.14	8.94
	Area Category = 1 and Fractal Category = 3								
15	23.59	25.88	38.86	31.40	28.01	22.51	22.20	22.20	13.54
29	26.06	28.10	39.21	33.48	30.36	24.89	24.53	24.52	11.72
40	32.10	33.24	44.22	38.12	38.74	31.65	31.51	31.51	24.70
50	27.56	32.23	50.68	35.45	31.26	26.86	26.66	26.66	28.00
52	26.01	27.58	40.46	31.44	30.44	25.58	25.45	25.44	23.91
64	41.94	43.25	66.18	51.92	49.74	40.40	39.95	39.95	31.76
76	18.79	21.55	31.74	27.30	22.17	17.64	17.33	17.33	10.91
94	23.93	24.89	36.40	29.52	28.56	23.29	23.10	23.11	12.32
97	33.82	34.71	47.16	37.95	41.90	33.50	33.40	33.40	32.10

Appendix A. Polygon Means for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 1 and Fractal Category = 3 (continued)								
146	28.92	30.52	46.99	38.12	34.83	27.84	27.51	27.51	19.45
155	22.88	24.63	36.23	30.61	27.60	22.62	22.58	22.58	19.22
157	24.68	26.80	38.73	33.37	28.68	23.62	23.33	23.33	10.35
159	22.98	25.31	36.98	32.61	26.23	21.92	21.62	21.62	15.14
167	24.92	26.98	37.95	32.88	29.30	23.83	23.53	23.53	17.08
170	28.69	30.85	44.48	37.83	33.33	27.71	27.46	27.46	22.35
179	45.78	44.60	76.25	60.95	55.73	45.41	45.38	45.38	39.15
191	18.95	21.57	32.55	26.63	22.30	18.05	17.82	17.82	9.84
201	21.85	24.43	36.25	31.76	25.12	20.96	20.73	20.73	13.56
208	19.30	22.21	32.64	27.65	22.78	18.37	18.13	18.13	6.97
226	45.35	46.93	69.48	55.27	55.26	44.64	44.43	44.44	42.87
227	22.66	25.59	37.34	32.99	25.98	20.66	20.04	20.04	10.43
231	35.56	38.32	49.66	44.03	43.98	35.27	35.20	35.19	20.43
233	27.69	29.80	40.54	35.48	31.14	26.52	26.18	26.19	22.63
240	41.70	41.27	62.67	49.83	51.45	41.47	41.41	41.41	43.23
243	30.43	31.69	45.13	38.90	36.55	29.86	29.71	29.71	22.91
Mean	28.65	30.52	44.75	37.02	34.06	27.80	27.57	27.57	20.98
STD	7.98	7.31	11.96	8.92	10.15	8.14	8.19	8.19	10.40
	Area Category = 1 and Fractal Category = 4								
8	29.96	30.64	44.11	35.68	34.30	29.29	29.08	29.08	28.27
19	26.75	29.56	39.80	35.56	30.87	25.46	25.08	25.07	11.97
20	18.15	21.00	31.38	26.48	21.53	17.18	16.92	16.92	9.24
38	26.80	28.52	40.19	33.92	32.10	26.28	26.14	26.14	7.91
68	23.06	25.67	38.47	32.07	26.48	22.34	22.16	22.15	12.23
69	20.67	22.50	34.50	28.26	24.51	19.66	19.39	19.39	11.95
79	23.09	24.81	34.75	29.05	27.25	22.24	22.02	22.02	9.27
91	20.20	19.20	30.72	24.66	24.50	19.54	19.34	19.34	19.51
106	8.06	10.52	28.10	16.33	14.13	10.29	11.10	11.10	2.99
122	35.15	35.53	44.44	40.87	38.44	34.30	34.03	34.03	35.11
138	31.38	33.37	49.74	38.64	36.26	30.73	30.53	30.53	30.36
160	28.81	30.48	41.14	34.54	35.09	28.32	28.18	28.18	23.36

Appendix A. Polygon Means for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 1 and Fractal Category = 4 (continued)								
169	24.72	26.96	42.92	32.47	27.47	23.49	23.12	23.12	24.71
176	33.59	35.62	49.13	41.71	39.60	33.03	32.87	32.87	24.71
194	43.23	43.87	63.83	47.81	54.72	42.74	42.59	42.59	43.29
200	41.98	43.00	60.93	50.12	49.66	41.19	40.94	40.94	38.83
207	18.35	22.10	32.36	27.37	22.65	17.60	17.50	17.51	4.55
209	25.81	28.60	41.50	33.72	29.08	24.28	23.88	23.88	21.41
211	31.81	33.12	47.49	38.75	36.48	31.05	30.85	30.85	22.17
212	27.56	27.51	41.35	32.37	34.92	27.30	27.23	27.23	26.42
221	27.92	31.61	45.68	40.69	32.79	26.21	25.71	25.71	12.89
223	25.05	28.59	38.51	33.38	29.74	24.38	24.20	24.20	13.14
228	39.27	39.59	58.85	46.19	46.47	38.71	38.55	38.55	34.09
229	33.89	37.55	51.85	44.35	40.76	33.06	32.82	32.82	9.27
238	41.30	43.97	62.49	48.76	46.32	40.63	40.43	40.42	32.42
Mean	28.26	30.16	43.77	35.75	33.44	27.57	27.39	27.39	20.40
STD	8.31	8.05	9.98	8.20	9.46	8.10	8.03	8.03	11.29
	Area Category = 1 and Fractal Category = 5								
13	13.97	17.52	25.71	22.20	16.49	12.99	12.77	12.78	5.97
22	22.23	26.29	38.77	31.09	26.04	21.48	21.28	21.28	1.80
23	22.83	24.70	37.50	33.08	27.06	21.71	21.40	21.40	4.65
25	13.90	15.67	25.38	22.17	16.45	12.92	12.70	12.70	4.52
30	17.38	19.11	29.08	23.88	20.46	16.74	16.60	16.61	3.67
31	20.86	23.24	34.72	28.66	24.52	19.89	19.63	19.62	7.99
47	22.02	23.85	34.34	30.04	25.76	21.05	20.80	20.80	15.96
133	36.27	38.04	49.74	43.90	43.04	35.20	34.88	34.88	34.89
171	28.67	30.99	46.26	36.94	32.49	27.77	27.50	27.50	14.63
175	26.52	28.52	40.38	34.68	31.17	25.05	24.63	24.63	12.72
215	35.87	36.19	52.50	42.08	39.97	34.98	34.69	34.69	14.99
235	36.39	37.55	49.41	43.51	40.02	35.45	35.15	35.16	28.15
236	48.44	50.70	66.54	55.66	60.99	47.96	47.82	47.82	48.05
Mean	26.57	28.64	40.80	34.45	31.11	25.63	25.37	25.37	15.23
STD	10.20	9.89	11.83	9.85	12.42	10.27	10.27	10.27	13.89

Appendix A. Polygon Means for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 1 and Fractal Category = 6								
14	17.78	20.42	30.86	26.61	20.64	16.50	16.15	16.15	2.83
53	24.97	24.07	39.36	30.58	28.42	24.47	24.33	24.32	22.76
57	31.87	39.16	57.25	41.06	37.19	31.24	31.11	31.12	30.24
87	18.28	18.90	30.60	24.40	21.26	17.87	17.77	17.77	22.20
116	24.79	28.34	38.50	33.47	26.92	22.57	21.87	21.87	4.94
234	62.87	62.80	96.72	72.68	75.37	62.02	61.75	61.75	60.57
239	21.04	25.38	38.10	30.74	23.03	19.10	18.56	18.56	18.33
242	47.32	49.26	66.63	53.56	57.84	47.17	47.13	47.13	35.97
Mean	31.11	33.54	49.75	39.14	36.33	30.12	29.83	29.83	24.73
STD	16.01	15.60	22.81	16.42	19.96	16.28	16.36	16.36	18.38
	Area Category = 2 and Fractal Category = 1								
62	19.86	21.66	31.30	26.08	24.11	19.26	19.11	19.11	15.84
118	33.90	34.54	47.96	39.40	40.32	33.34	33.17	33.17	29.16
181	17.46	19.17	28.15	24.84	20.74	16.92	16.80	16.81	12.29
197	17.51	19.17	27.41	23.23	20.85	17.00	16.88	16.89	13.12
225	25.78	27.43	35.43	32.74	30.24	25.13	24.97	24.98	21.69
Mean	22.90	24.39	34.05	29.26	27.25	22.33	22.19	22.19	18.42
STD	7.02	6.60	8.39	6.72	8.26	7.00	6.98	6.98	7.04
	Area Category = 2 and Fractal Category = 2								
2	27.06	28.10	40.72	34.56	31.73	26.10	25.82	25.82	22.14
5	42.81	42.86	67.60	49.61	51.21	42.18	41.98	41.99	41.81
37	24.69	26.15	38.12	31.89	29.92	23.91	23.69	23.69	17.83
44	20.69	23.06	33.20	28.84	24.95	19.91	19.71	19.71	15.68
45	20.81	23.21	35.88	29.75	23.89	19.27	18.85	18.84	9.83
46	23.34	25.25	35.96	30.39	27.57	22.66	22.47	22.46	15.06
48	32.50	35.66	50.98	41.75	38.35	31.76	31.54	31.54	12.08
60	58.09	58.07	82.42	65.25	69.52	57.55	57.38	57.38	54.26
78	27.40	27.88	38.94	33.88	32.47	26.54	26.29	26.29	19.57
81	21.56	23.20	33.73	27.76	25.84	20.79	20.57	20.57	16.37
82	21.46	22.07	34.71	27.61	25.62	20.98	20.84	20.84	19.27
90	26.58	27.44	40.81	34.40	32.12	25.98	25.81	25.81	17.56

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 2 and Fractal Category = 2 (continued)								
98	34.91	35.70	51.93	39.75	42.19	34.42	34.26	34.26	33.67
102	28.44	29.66	41.68	35.39	34.50	28.00	27.89	27.88	25.24
104	41.06	41.25	57.06	45.59	48.32	40.86	40.80	40.80	37.03
112	34.54	36.40	52.50	40.86	41.65	34.16	34.05	34.05	30.02
124	35.05	37.11	50.70	43.99	40.86	33.70	33.29	33.29	21.95
125	36.29	37.47	52.29	44.33	44.18	35.58	35.38	35.38	34.00
148	28.02	29.02	43.74	33.25	33.13	27.72	27.64	27.65	26.39
150	16.38	18.95	28.01	23.94	19.66	15.52	15.32	15.32	12.89
161	45.22	45.32	65.17	53.02	55.51	44.82	44.72	44.72	45.67
162	33.39	34.37	50.49	38.61	40.86	32.87	32.71	32.72	31.10
177	16.50	18.73	27.78	23.84	19.23	15.92	15.81	15.81	12.73
178	32.00	33.04	47.25	39.55	38.32	31.37	31.18	31.18	20.02
180	30.10	31.81	44.48	37.59	36.20	29.46	29.29	29.29	20.85
187	30.71	31.72	47.10	36.37	37.99	30.32	30.21	30.21	28.77
188	18.60	20.85	30.63	25.48	21.91	17.95	17.78	17.78	10.73
214	19.98	21.92	30.87	27.21	23.80	19.35	19.17	19.17	15.00
218	27.79	30.49	46.12	36.01	31.81	26.77	26.49	26.49	20.46
220	21.91	25.25	36.27	29.98	25.96	21.20	21.04	21.04	15.88
Mean	29.26	30.73	44.57	36.35	34.98	28.59	28.40	28.40	23.46
STD	9.31	8.75	12.40	9.20	11.32	9.40	9.41	9.41	10.93
	Area Category = 2 and Fractal Category = 3								
12	24.40	27.93	38.96	31.82	29.38	23.53	23.31	23.30	16.48
43	25.35	26.67	39.50	32.02	30.80	24.83	24.70	24.70	18.45
49	22.64	25.71	37.32	30.84	27.16	21.72	21.49	21.49	10.45
51	34.74	36.53	49.80	43.03	41.25	34.28	34.16	34.16	18.39
59	37.98	39.89	53.44	47.10	44.49	37.23	37.00	37.00	34.92
86	33.95	35.00	48.56	38.61	41.22	33.46	33.31	33.31	30.61
103	35.23	36.21	53.64	40.00	42.53	34.60	34.40	34.40	31.62
109	28.57	29.96	43.30	35.35	33.44	28.01	27.84	27.84	17.87
115	27.38	28.67	45.66	35.45	32.14	26.60	26.41	26.41	12.86
128	29.37	30.19	42.82	36.39	35.39	28.95	28.83	28.83	14.05

Appendix A. Polygon Means for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 2 and Fractal Category = 3 (continued)								
134	22.51	24.11	37.84	30.90	26.78	22.04	21.93	21.93	20.68
140	40.52	42.05	59.43	49.45	47.96	39.64	39.39	39.39	22.16
182	32.18	32.75	47.43	36.93	40.74	31.85	31.75	31.75	31.72
189	23.45	25.18	35.33	31.01	27.19	22.42	22.13	22.13	9.89
205	26.46	27.51	41.32	34.40	32.31	25.80	25.62	25.63	26.25
216	29.34	32.44	44.99	39.17	34.18	28.40	28.11	28.12	14.78
Mean	29.63	31.30	44.96	37.03	35.44	28.96	28.77	28.77	20.70
STD	5.60	5.39	6.77	5.68	6.74	5.64	5.64	5.64	8.05
	Area Category = 2 and Fractal Category = 4								
17	23.23	25.69	37.56	31.32	27.07	21.83	21.42	21.42	4.75
27	16.06	18.12	27.66	23.31	19.12	15.39	15.24	15.24	5.71
32	29.36	32.29	46.20	37.36	34.34	27.72	27.22	27.22	15.68
33	24.50	25.57	37.19	32.10	29.17	23.74	23.54	23.54	19.28
39	37.25	39.06	60.98	45.66	43.02	35.40	34.80	34.80	27.67
42	37.04	38.40	58.03	45.23	42.86	35.45	34.95	34.95	25.03
88	29.53	30.92	44.21	37.42	35.06	28.29	27.91	27.91	15.50
110	25.93	28.02	39.31	33.48	31.50	25.21	25.01	25.01	14.16
123	42.77	44.78	63.72	49.57	51.90	42.41	42.30	42.30	36.01
136	34.83	35.86	48.26	41.14	41.47	34.17	33.97	33.97	24.58
149	26.57	27.66	40.10	33.61	31.35	25.60	25.32	25.32	20.43
156	41.67	42.76	57.06	48.54	46.66	41.13	40.97	40.97	41.61
168	23.46	26.01	36.19	31.00	27.34	22.63	22.42	22.42	11.21
192	32.34	33.64	46.58	41.37	37.58	31.25	30.94	30.94	24.10
206	26.67	29.24	42.43	34.92	30.48	25.79	25.54	25.54	8.68
222	23.24	25.91	35.98	30.67	27.11	22.57	22.38	22.38	17.79
Mean	29.65	31.50	45.09	37.29	34.75	28.66	28.37	28.37	19.51
STD	7.43	7.18	10.25	7.38	8.61	7.41	7.40	7.40	10.21
	Area Category = 2 and Fractal Category = 5								
11	33.27	34.58	49.20	40.27	40.35	32.49	32.26	32.26	25.50
16	28.86	29.91	42.26	35.33	35.50	28.42	28.29	28.29	28.38
18	35.85	36.63	52.30	42.24	45.88	35.70	35.66	35.67	34.62

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 2 and Fractal Category = 5 (continued)								
28	23.25	25.23	37.13	32.19	27.43	22.19	21.92	21.92	14.71
66	19.33	20.35	32.02	26.32	22.76	18.49	18.28	18.28	10.64
107	22.79	24.63	37.26	31.04	26.55	21.82	21.54	21.54	6.65
119	31.96	32.69	45.80	37.49	39.01	31.36	31.19	31.19	24.33
Mean	22.96	24.62	36.05	30.32	27.23	22.04	21.79	21.79	11.77
STD	4.39	4.12	5.22	4.14	5.57	4.47	4.49	4.49	7.30
	Area Category = 2 and Fractal Category = 6								
21	18.54	20.80	33.38	27.90	21.79	17.56	17.33	17.33	9.69
41	47.20	47.94	68.87	54.26	56.37	46.41	46.17	46.16	41.36
166	23.27	24.61	38.94	31.69	27.07	22.59	22.42	22.42	8.52
Mean	29.67	31.12	47.06	37.95	35.08	28.85	28.64	28.63	19.86
STD	15.36	14.70	19.09	14.25	18.63	15.41	15.39	15.39	18.63
	Area Category = 3 and Fractal Category = 2								
54	21.79	23.21	33.09	27.89	25.56	21.28	21.15	21.15	17.31
63	28.14	29.06	40.09	33.59	34.01	27.61	27.46	27.46	23.07
152	31.09	31.95	47.05	36.35	37.30	30.58	30.43	30.43	26.80
183	17.78	20.06	29.30	25.60	21.11	16.98	16.79	16.79	11.64
Mean	24.70	26.07	37.38	30.86	29.50	24.11	23.96	23.96	19.71
STD	6.03	5.41	7.84	4.97	7.46	6.14	6.15	6.15	6.64
	Area Category = 3 and Fractal Category = 3								
6	30.46	33.97	49.80	38.87	36.41	29.32	28.98	28.98	13.95
9	21.96	24.82	36.92	29.83	25.61	21.26	21.10	21.10	15.61
93	31.95	33.09	46.44	39.09	38.08	31.22	31.00	31.00	21.40
96	23.13	25.10	37.59	30.31	27.02	22.37	22.16	22.16	12.67
100	25.11	26.64	37.56	30.84	29.98	24.66	24.54	24.54	19.94
108	24.01	25.78	37.71	30.76	28.66	23.48	23.34	23.34	16.21
114	28.14	29.94	42.76	35.32	33.77	27.57	27.41	27.41	18.89
130	26.26	27.72	40.25	33.38	31.11	25.51	25.30	25.30	17.91
132	41.60	42.75	57.61	49.66	48.59	41.15	41.02	41.02	33.48
141	46.20	47.21	64.04	52.49	57.44	45.86	45.76	45.76	41.29
143	28.18	28.98	41.62	34.94	33.57	27.32	27.07	27.07	14.50

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 3 and Fractal Category = 3 (continued)								
153	36.09	38.08	54.80	42.51	42.86	35.77	35.68	35.68	30.12
154	40.62	42.15	56.92	49.38	48.77	39.88	39.66	39.67	26.56
172	29.84	31.02	44.76	35.89	35.93	29.39	29.26	29.26	24.07
173	26.30	28.33	40.01	34.63	31.25	25.42	25.18	25.17	9.95
184	29.39	30.89	43.35	36.45	35.01	28.68	28.49	28.49	15.36
203	30.93	32.73	46.55	38.84	37.07	30.28	30.10	30.10	13.55
213	35.23	37.17	52.72	43.37	41.53	34.55	34.36	34.36	16.70
Mean	30.86	32.58	46.19	38.14	36.81	30.20	30.02	30.02	20.12
STD	6.74	6.54	8.10	6.92	8.36	6.82	6.84	6.84	8.17
	Area Category = 3 and Fractal Category = 4								
7	21.94	24.38	35.45	29.62	25.96	20.88	20.58	20.59	3.50
36	30.68	32.50	47.46	38.34	36.09	29.79	29.52	29.52	8.02
67	36.29	37.98	53.62	44.50	42.62	35.50	35.27	35.27	8.51
127	26.90	28.21	41.30	33.71	32.14	26.44	26.32	26.32	8.62
129	48.42	48.63	70.46	55.47	58.33	48.06	47.96	47.96	34.85
131	34.84	36.90	50.45	42.85	40.23	33.90	33.61	33.61	5.30
151	27.93	29.52	40.68	34.58	32.89	27.11	26.87	26.87	15.50
230	33.25	34.92	48.87	41.64	39.08	32.17	31.85	31.85	17.75
Mean	32.53	34.13	48.53	40.09	38.42	31.73	31.50	31.50	12.76
STD	7.94	7.44	10.67	8.02	9.63	8.08	8.12	8.12	10.14
	Area Category = 3 and Fractal Category = 5								
1	39.61	42.07	62.62	47.76	47.36	38.40	38.03	38.03	29.09
3	28.65	31.08	48.20	36.19	33.89	27.99	27.83	27.83	25.57
24	12.70	13.83	23.18	20.05	15.12	12.01	11.86	11.86	3.75
26	8.56	9.96	16.27	13.43	10.54	8.23	8.17	8.17	0.93
74	54.10	54.69	78.49	59.44	64.75	53.93	53.88	53.88	50.53
120	33.07	34.23	48.61	38.15	39.93	32.66	32.53	32.53	24.95
158	72.16	72.11	97.47	79.85	85.51	71.58	71.40	71.40	4.62
186	54.41	55.11	76.48	61.89	64.39	53.84	53.66	53.66	43.20
Mean	37.91	39.14	56.41	44.59	45.19	37.33	37.17	37.17	22.83
STD	21.77	21.29	27.93	22.23	25.75	21.78	21.76	21.76	18.55

Appendix A. Polygon Means for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 3 and Fractal Category = 6								
71	42.44	41.68	63.45	49.68	50.22	41.64	41.39	41.39	12.67
105	21.14	21.98	33.98	27.77	25.17	20.31	20.09	20.09	15.26
Mean	31.79	31.83	48.71	38.73	37.69	30.97	30.74	30.74	13.97
STD	15.07	13.93	20.84	15.49	17.71	15.08	15.06	15.06	1.83
	Area Category = 4 and Fractal Category = 2								
190	26.29	27.89	39.14	32.83	31.07	25.66	25.50	25.50	15.09
	Area Category = 4 and Fractal Category = 5								
139	25.21	27.24	38.98	32.66	29.76	24.51	24.32	24.32	10.00
	Area Category = 4 and Fractal Category = 6								
10	41.14	42.53	62.27	48.94	48.92	39.06	40.14	40.14	31.84
137	19.62	21.87	33.36	27.34	22.92	18.53	18.25	18.25	8.55
Mean	30.38	32.20	47.81	38.14	35.92	28.79	29.19	29.19	20.20
STD	15.22	14.61	20.45	15.27	18.38	14.52	15.48	15.48	16.47
	Area Category = 5 and Fractal Category = 2								
35	28.40	30.00	42.60	35.39	34.32	27.80	27.64	27.64	12.43

APPENDIX B

POLYGON MEDIANS FOR THE DIFFERENT SLOPE METHODS

Appendix B. Polygon Medians for the Different Slope Methods

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 1 and Fractal Category = 1								
34	46.28	47.26	66.67	52.70	53.73	44.82	44.79	44.80	41.05
65	26.03	26.87	40.00	30.73	29.95	25.67	25.63	25.65	23.96
72	30.18	31.62	43.33	36.82	36.72	30.26	29.87	29.90	28.90
75	29.91	30.18	43.33	35.43	37.49	29.31	29.41	29.40	29.34
80	24.89	26.87	36.67	31.45	31.07	24.68	24.53	24.55	21.75
85	31.84	33.00	46.67	37.71	38.59	31.23	31.23	31.20	25.09
92	38.37	36.82	50.00	42.43	46.59	37.12	36.73	36.70	32.16
95	35.04	35.90	50.00	40.55	41.23	34.04	33.89	33.90	27.90
126	39.12	38.01	56.67	42.69	45.96	38.96	39.01	39.00	38.22
163	43.46	44.85	63.33	49.55	51.11	43.05	42.91	42.90	39.32
164	44.26	45.83	66.67	52.07	51.61	43.80	43.72	43.70	39.55
196	17.56	19.72	26.67	24.04	20.45	17.52	17.40	17.40	14.84
241	36.06	36.06	50.00	42.56	41.72	36.14	36.28	36.25	34.93
Mean	34.08	34.85	49.23	39.90	40.48	33.58	33.49	33.49	30.54
STD	8.41	8.08	11.88	8.51	9.62	8.18	8.19	8.19	7.94
	Area Category = 1 and Fractal Category = 2								
4	49.28	49.55	76.67	55.48	56.19	49.08	48.70	48.70	46.84
55	21.70	24.83	30.00	28.67	26.33	21.39	21.34	21.30	20.65
56	23.57	25.39	30.00	27.49	29.27	23.51	23.37	23.40	20.75
58	26.22	27.18	40.00	33.33	28.94	24.62	24.08	24.05	15.51
61	40.07	41.77	56.67	49.22	46.28	39.88	39.14	39.10	39.02
70	30.73	30.18	43.33	36.06	37.75	29.33	29.69	29.70	27.63
73	27.94	28.67	43.33	33.33	33.71	27.47	27.36	27.40	19.45
77	38.91	40.14	56.67	43.46	46.37	38.37	38.27	38.30	35.91
83	27.49	28.58	40.00	33.00	31.82	26.67	26.40	26.40	17.79
84	32.06	34.32	45.00	38.01	39.51	31.41	30.61	30.60	24.96
89	31.84	33.33	43.33	37.27	38.87	31.58	31.59	31.60	28.24
101	22.76	21.92	40.00	29.81	26.89	21.44	21.20	21.20	18.87
111	33.08	34.80	46.67	39.51	39.05	32.44	31.87	31.85	25.50
113	26.61	28.28	40.00	30.73	31.64	26.16	25.98	25.95	28.38
117	33.71	33.50	46.67	38.01	42.43	33.18	32.80	32.80	34.62

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 1 and Fractal Category = 2 (continued)								
121	20.07	21.08	33.33	24.27	24.07	20.04	19.70	19.70	17.61
135	19.44	21.08	30.00	26.03	22.45	18.42	18.40	18.40	17.53
142	30.73	33.33	50.00	40.69	36.07	28.78	28.44	28.40	19.46
144	26.09	28.67	43.33	34.80	31.82	25.34	25.19	25.20	17.98
145	17.16	19.44	30.00	24.04	20.34	16.76	16.52	16.50	14.89
147	25.50	26.87	40.00	30.73	30.00	25.39	25.15	25.20	17.65
165	21.73	23.57	33.33	28.67	24.78	21.06	20.88	20.90	12.07
174	39.51	38.01	60.00	47.73	50.12	40.07	39.92	39.90	35.54
185	35.36	37.04	50.00	44.60	39.35	33.54	33.04	33.00	19.90
193	15.37	16.67	23.33	21.34	17.32	14.59	14.24	14.20	12.42
195	16.88	18.86	30.00	24.27	20.41	16.32	16.01	16.00	12.31
198	35.87	38.01	50.00	42.69	42.81	35.39	35.08	35.05	33.48
199	40.31	41.77	56.67	47.73	45.73	40.14	39.76	39.80	33.07
202	30.53	30.73	48.33	36.44	36.67	30.03	29.77	29.75	28.15
204	16.67	17.95	26.67	22.36	19.33	15.32	15.41	15.40	15.82
210	18.41	20.00	26.67	26.03	21.15	16.79	16.63	16.65	12.44
217	16.50	19.44	30.00	26.03	20.41	16.01	15.72	15.70	11.86
219	30.60	30.73	46.67	35.43	38.51	30.17	30.05	30.00	30.27
232	36.82	40.14	53.33	43.46	43.35	35.05	34.81	34.80	27.93
Mean	28.22	29.58	42.35	34.73	33.52	27.52	27.27	27.26	23.37
STD	8.42	8.21	11.63	8.64	9.99	8.54	8.49	8.49	8.94
	Area Category = 1 and Fractal Category = 3								
15	24.27	26.87	36.67	31.45	29.27	23.84	23.11	23.10	13.54
29	25.77	27.49	38.34	33.00	30.80	24.37	24.02	24.00	11.72
40	30.39	31.62	43.33	37.27	37.03	30.65	30.62	30.65	24.70
50	25.44	28.67	43.33	31.45	29.15	24.51	25.27	25.30	28.00
52	24.78	26.87	40.00	31.09	28.94	24.79	24.58	24.60	23.91
64	40.52	41.97	63.33	49.39	48.63	39.60	39.56	39.60	31.76
76	17.40	21.34	30.00	26.87	20.00	15.79	15.34	15.30	10.91
94	22.67	24.04	33.33	28.28	27.49	22.31	22.03	22.00	12.32
97	33.44	34.32	46.67	37.71	41.52	33.16	33.27	33.25	32.10

Appendix B. Polygon Medians for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 1 and Fractal Category = 3 (continued)								
146	28.77	30.18	46.67	36.06	33.56	27.11	26.95	26.90	19.45
155	21.92	23.33	33.33	26.87	25.85	20.83	20.49	20.50	19.22
157	25.63	26.87	40.00	33.33	29.15	24.56	23.68	23.70	10.35
159	23.21	25.39	33.33	33.00	25.87	22.40	21.67	21.70	15.14
167	24.09	24.27	36.67	32.23	28.60	22.75	22.42	22.40	17.08
170	29.81	31.62	43.33	38.01	35.04	28.78	28.16	28.20	22.35
179	40.85	39.58	63.33	47.73	48.03	40.87	40.63	40.65	39.15
191	19.44	23.33	33.33	26.87	22.16	17.97	17.79	17.80	9.84
201	22.24	24.04	36.67	31.62	25.63	21.63	21.57	21.60	13.56
208	18.33	20.28	30.00	26.03	20.62	17.04	16.81	16.80	6.97
226	39.23	40.55	56.67	44.85	49.82	39.32	39.32	39.30	42.87
227	21.70	26.03	33.33	31.62	25.11	20.33	20.28	20.25	10.43
231	37.45	39.02	50.00	43.33	46.76	37.48	37.35	37.40	20.43
233	25.06	27.49	36.67	32.92	28.19	23.63	23.53	23.50	22.63
240	41.67	41.23	66.67	50.44	51.96	42.25	42.20	42.20	43.23
243	28.77	30.46	41.67	37.27	35.29	28.56	28.64	28.65	22.91
Mean	27.71	29.47	42.27	35.15	32.98	26.98	26.77	26.77	20.98
STD	7.27	6.50	10.50	7.10	9.57	7.71	7.80	7.81	10.40
	Area Category = 1 and Fractal Category = 4								
8	31.45	30.73	46.67	35.67	34.70	30.45	30.26	30.25	28.27
19	26.87	29.81	40.00	35.43	30.73	25.53	24.85	24.80	11.97
20	17.95	21.34	30.00	26.03	21.33	17.10	16.80	16.80	9.24
38	26.35	28.28	36.67	31.62	31.75	26.33	26.12	26.10	7.91
68	22.36	24.04	36.67	30.73	25.93	21.73	21.83	21.80	12.23
69	20.88	22.36	33.33	28.67	24.21	19.52	19.64	19.60	11.95
79	23.86	25.39	33.33	29.81	27.16	22.98	22.38	22.40	9.27
91	21.34	19.44	30.00	24.27	24.66	20.25	20.01	20.00	19.51
106	6.67	12.02	26.67	14.91	12.80	9.32	10.24	10.20	2.99
122	33.54	33.99	40.00	40.69	36.57	32.43	32.32	32.30	35.11
138	32.36	34.80	50.00	38.01	38.41	32.45	32.66	32.70	30.36
160	28.53	30.18	40.00	34.32	34.68	28.73	28.57	28.60	23.36

Appendix B. Polygon Medians for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 1 and Fractal Category = 4 (continued)								
169	25.98	27.18	40.00	32.23	28.61	24.37	24.42	24.40	24.71
176	30.73	33.75	46.67	38.01	36.67	30.53	29.77	29.75	24.71
194	43.88	42.69	63.33	47.56	55.32	43.07	43.00	43.00	43.29
200	42.69	41.23	60.00	45.83	52.99	42.63	42.51	42.50	38.83
207	16.67	21.08	30.00	26.87	19.76	15.37	15.17	15.20	4.55
209	28.53	30.73	43.33	34.32	30.80	26.87	26.04	26.00	21.41
211	31.31	32.83	46.67	38.01	36.57	30.05	29.67	29.70	22.17
212	27.59	27.89	43.33	31.62	34.19	26.87	26.59	26.60	26.42
221	26.80	30.45	43.33	40.62	31.87	25.12	24.85	24.85	12.89
223	26.06	28.48	36.67	34.16	29.65	24.51	23.98	23.95	13.14
228	42.28	41.50	60.00	47.56	48.13	40.83	40.85	40.80	34.09
229	35.63	40.00	53.33	45.03	43.25	34.88	33.89	33.90	9.27
238	41.70	43.84	63.33	48.53	46.31	40.31	40.25	40.20	32.42
Mean	28.48	30.16	42.93	35.22	33.48	27.69	27.47	27.46	20.40
STD	8.74	7.89	10.64	8.14	10.15	8.48	8.41	8.41	11.29
	Area Category = 1 and Fractal Category = 5								
13	13.99	17.48	26.67	21.34	15.90	12.92	12.38	12.35	5.97
22	18.63	21.34	33.33	26.03	21.70	17.50	17.44	17.40	1.80
23	21.70	23.57	33.33	29.81	25.93	20.91	20.43	20.40	4.65
25	13.02	16.67	23.33	22.36	15.46	12.50	12.42	12.40	4.52
30	16.41	18.86	30.00	23.57	17.80	15.37	15.26	15.30	3.67
31	20.62	23.57	33.33	28.28	23.89	19.33	18.96	19.00	7.99
47	19.51	22.36	30.00	28.67	23.63	19.27	19.29	19.30	15.96
133	40.21	40.69	46.67	46.37	49.01	39.99	39.37	39.35	34.89
171	29.15	31.45	46.67	38.01	33.17	27.51	27.13	27.10	14.63
175	27.13	28.58	40.00	35.12	31.91	25.17	25.04	25.05	12.72
215	36.95	36.58	56.67	41.97	41.60	36.50	36.37	36.35	14.99
235	37.27	38.01	50.00	42.69	41.52	35.78	35.53	35.50	28.15
236	50.03	50.28	70.00	54.46	63.49	50.11	49.99	50.00	48.05
Mean	26.51	28.42	40.00	33.74	31.15	25.60	25.35	25.35	15.23
STD	11.48	10.33	13.40	10.30	14.34	11.68	11.67	11.67	13.89

Appendix B. Polygon Medians for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 1 and Fractal Category = 6								
14	16.67	20.00	30.00	26.87	18.63	15.37	15.29	15.30	2.83
53	25.39	24.04	40.00	30.73	27.34	23.33	22.80	22.80	22.76
57	30.73	38.01	63.33	39.02	32.83	27.70	26.71	26.70	30.24
87	18.63	19.44	30.00	25.39	22.17	18.63	18.34	18.30	22.20
116	24.61	26.87	36.67	33.00	26.33	22.15	21.12	21.10	4.94
234	64.83	64.72	96.67	74.01	77.97	66.67	67.24	67.20	60.57
239	19.79	26.35	36.67	32.14	19.79	16.06	14.73	14.75	18.33
242	49.94	50.77	66.67	55.48	57.84	49.57	48.88	48.90	35.97
Mean	31.32	33.78	50.00	39.58	35.36	29.94	29.39	29.38	24.73
STD	17.15	16.29	23.57	16.81	21.28	18.43	18.77	18.77	18.38
	Area Category = 2 and Fractal Category = 1								
62	19.00	21.08	30.00	25.39	23.21	18.75	18.47	18.50	15.84
118	33.33	34.16	46.67	38.87	39.74	33.15	33.10	33.10	29.16
181	16.67	17.95	26.67	23.81	18.95	15.42	15.41	15.40	12.29
197	17.95	19.44	26.67	23.57	20.62	17.49	17.25	17.20	13.12
225	26.03	28.28	36.67	33.00	30.00	25.37	25.25	25.30	21.69
Mean	22.60	24.18	33.34	28.93	26.50	22.04	21.90	21.90	18.42
STD	7.01	6.84	8.50	6.76	8.52	7.24	7.28	7.30	7.04
	Area Category = 2 and Fractal Category = 2								
2	26.87	28.48	40.00	34.32	31.31	25.89	25.68	25.70	22.14
5	45.98	44.85	70.00	50.88	55.00	44.92	45.07	45.10	41.81
37	24.61	25.39	36.67	30.73	29.58	23.68	23.30	23.30	17.83
44	20.48	22.36	31.67	27.49	24.71	20.02	19.85	19.90	15.68
45	21.08	23.57	36.67	28.67	24.07	19.30	18.90	18.90	9.83
46	23.57	25.39	33.33	29.81	27.74	23.10	23.11	23.10	15.06
48	32.06	35.90	50.00	41.23	36.38	31.73	31.67	31.70	12.08
60	58.93	57.54	83.33	65.66	70.15	58.88	58.82	58.85	54.26
78	27.31	28.28	40.00	33.33	32.21	26.68	26.44	26.45	19.57
81	21.08	23.33	33.33	26.87	24.77	20.15	19.83	19.85	16.37
82	20.28	21.34	33.33	26.03	24.21	20.11	20.04	20.00	19.27
90	25.50	26.87	36.67	32.83	30.69	24.65	24.47	24.45	17.56

Appendix B. Polygon Medians for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 2 and Fractal Category = 2 (continued)								
98	35.90	37.27	53.33	40.55	43.73	35.95	36.05	36.00	33.67
102	26.35	28.58	36.67	34.32	31.38	26.12	26.08	26.05	25.24
104	39.51	40.28	56.67	43.46	47.97	39.18	39.03	39.00	37.03
112	35.16	35.43	53.33	40.14	40.62	34.20	34.08	34.10	30.02
124	33.37	37.27	50.00	43.46	39.48	32.09	31.28	31.30	21.95
125	35.98	38.01	53.33	45.34	44.00	36.29	36.22	36.20	34.00
148	29.15	30.18	45.00	33.33	33.93	28.79	28.52	28.55	26.39
150	16.41	18.86	26.67	23.57	19.65	15.50	15.72	15.70	12.89
161	46.28	46.67	66.67	53.60	56.85	46.43	46.50	46.50	45.67
162	34.20	34.32	50.00	38.01	41.67	33.72	33.48	33.50	31.10
177	16.41	19.44	26.67	24.04	18.93	15.33	15.16	15.20	12.73
178	32.98	33.75	46.67	40.14	39.58	32.57	32.42	32.45	20.02
180	30.05	33.33	43.33	38.01	34.76	28.89	28.38	28.40	20.85
187	30.05	31.45	46.67	35.90	37.56	29.54	29.61	29.60	28.77
188	16.88	20.14	26.67	23.57	19.49	16.18	16.17	16.15	10.73
214	20.07	21.34	30.00	26.87	23.63	19.33	19.02	19.00	15.00
218	27.13	30.73	46.67	35.43	30.81	26.77	26.61	26.60	20.46
220	20.04	23.57	30.00	28.28	23.63	19.09	18.96	19.00	15.88
Mean	29.12	30.80	43.78	35.86	34.62	28.50	28.35	28.35	23.46
STD	9.79	9.01	13.55	9.65	11.97	9.99	10.03	10.03	10.93
	Area Category = 2 and Fractal Category = 3								
12	23.86	26.77	36.67	29.81	29.27	23.74	23.37	23.40	16.48
43	26.22	26.87	40.00	31.54	31.45	25.63	25.28	25.30	18.45
49	20.34	22.36	33.33	26.87	23.83	19.56	19.15	19.15	10.45
51	33.04	34.56	46.67	41.77	36.97	32.81	32.75	32.75	18.39
59	38.48	41.23	56.67	47.73	43.81	37.43	37.37	37.40	34.92
86	35.16	35.43	50.00	38.01	42.96	34.87	34.58	34.60	30.61
103	35.43	36.06	53.33	40.14	42.88	34.90	34.66	34.70	31.62
109	28.33	30.00	43.33	34.80	32.72	27.70	27.51	27.50	17.87
115	25.03	26.77	43.33	33.33	29.73	24.54	24.01	24.00	12.86
128	30.05	31.45	43.33	37.27	35.85	29.50	29.10	29.10	14.05

Appendix B. Polygon Medians for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 2 and Fractal Category = 3 (continued)								
134	20.34	22.36	33.33	26.03	24.30	20.60	20.34	20.30	20.68
140	40.62	41.23	56.67	48.07	47.83	40.25	39.91	39.90	22.16
182	33.33	33.50	48.34	37.27	42.35	33.09	32.71	32.70	31.72
189	22.67	23.57	33.33	30.73	26.93	21.55	21.30	21.30	9.89
205	25.22	26.03	36.67	30.73	30.91	24.59	24.45	24.50	26.25
216	30.05	33.00	45.00	39.02	34.70	28.95	28.54	28.55	14.78
Mean	29.26	30.70	43.75	35.82	34.78	28.73	28.44	28.45	20.70
STD	6.30	6.11	7.90	6.61	7.42	6.29	6.32	6.33	8.05
	Area Category = 2 and Fractal Category = 4								
17	23.39	26.03	36.67	31.45	26.93	21.45	20.91	20.90	4.75
27	15.09	16.67	23.33	21.34	17.56	14.30	14.24	14.20	5.71
32	24.78	28.48	40.00	33.00	28.87	23.19	22.91	22.90	15.68
33	25.87	26.03	36.67	31.45	29.84	24.76	24.47	24.50	19.28
39	40.31	40.55	60.00	45.34	46.19	39.18	38.57	38.60	27.67
42	38.04	40.00	56.67	44.85	44.39	36.75	36.70	36.70	25.03
88	30.05	31.45	43.33	37.27	36.11	28.99	28.83	28.80	15.50
110	25.06	27.49	36.67	33.33	30.32	24.58	24.45	24.45	14.16
123	41.70	43.46	63.33	48.07	51.03	41.25	41.29	41.30	36.01
136	34.28	35.43	46.67	40.69	41.23	33.74	33.47	33.45	24.58
149	28.38	28.67	40.00	34.32	32.68	26.93	26.53	26.50	20.43
156	40.99	41.77	53.33	47.14	44.74	40.09	40.06	40.10	41.61
168	23.86	26.87	36.67	30.73	28.14	22.67	22.47	22.50	11.21
192	33.29	34.32	46.67	41.77	37.75	32.48	31.71	31.70	24.10
206	25.44	27.49	40.00	33.99	30.21	24.67	24.61	24.60	8.68
222	23.21	25.39	33.33	28.67	26.93	22.24	22.18	22.20	17.79
Mean	29.61	31.26	43.33	36.46	34.56	28.58	28.34	28.34	19.51
STD	7.73	7.36	10.61	7.53	8.97	7.84	7.83	7.84	10.21
	Area Category = 2 and Fractal Category = 5								
11	23.21	24.27	36.67	30.73	26.30	22.00	21.73	21.70	4.33
16	19.44	21.34	30.00	25.39	23.09	18.63	18.80	18.80	16.72
18	20.34	23.57	33.33	27.89	23.60	19.39	19.18	19.20	4.99

Appendix B. Polygon Medians for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 2 and Fractal Category = 5 (continued)								
28	22.39	23.81	36.67	28.67	27.15	21.17	21.08	21.10	14.71
66	19.00	19.72	30.00	26.03	21.20	17.63	17.10	17.10	10.64
107	22.36	24.04	36.67	28.67	26.06	21.25	21.12	21.10	6.65
119	31.71	33.33	43.33	38.01	39.38	31.41	31.16	31.20	24.33
Mean	22.64	24.30	35.24	29.34	26.68	21.64	21.45	21.46	11.77
STD	4.31	4.32	4.66	4.22	5.98	4.59	4.58	4.59	7.30
	Area Category = 2 and Fractal Category = 6								
21	17.00	20.00	30.00	26.03	21.21	16.75	16.92	16.90	9.69
41	49.24	49.55	70.00	56.86	58.45	48.14	47.69	47.70	41.36
166	22.42	25.39	36.67	30.73	25.63	21.81	21.61	21.60	8.52
Mean	29.55	31.65	45.56	37.87	35.10	28.90	28.74	28.73	19.86
STD	17.26	15.74	21.43	16.61	20.34	16.85	16.58	16.59	18.63
	Area Category = 3 and Fractal Category = 2								
54	21.67	23.57	33.33	26.87	25.25	21.25	21.12	21.10	17.31
63	27.74	29.81	40.00	33.00	33.56	26.99	26.95	26.90	23.07
152	30.73	31.45	46.67	35.43	36.92	30.56	30.48	30.50	26.80
183	17.56	20.00	30.00	25.39	20.14	16.73	16.41	16.40	11.64
Mean	24.43	26.21	37.50	30.17	28.97	23.88	23.74	23.73	19.71
STD	5.93	5.35	7.39	4.81	7.66	6.12	6.23	6.23	6.64
	Area Category = 3 and Fractal Category = 3								
6	30.05	32.83	46.67	36.82	34.82	28.44	27.65	27.60	13.95
9	21.34	24.27	36.67	28.67	24.38	20.66	20.50	20.50	15.61
93	31.84	33.33	46.67	39.02	37.58	30.76	30.68	30.70	21.40
96	21.73	24.04	36.67	28.48	25.25	21.29	21.00	21.00	12.67
100	23.57	25.39	36.67	28.67	28.08	23.25	23.19	23.20	19.94
108	23.15	24.27	36.67	28.28	26.95	22.58	22.67	22.70	16.21
114	25.00	26.87	40.00	31.54	30.27	24.54	24.35	24.30	18.89
130	27.13	28.48	40.00	33.33	31.53	26.70	26.28	26.30	17.91
132	42.69	43.84	56.67	49.55	49.55	42.30	42.52	42.50	33.48
141	45.92	47.38	63.33	52.70	56.87	45.86	45.66	45.65	41.29
143	27.59	28.67	40.00	34.80	32.72	26.98	26.72	26.70	14.50

Appendix B. Polygon Medians for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 3 and Fractal Category = 3 (continued)								
153	33.54	35.43	50.00	39.02	40.62	32.87	32.61	32.60	30.12
154	40.35	42.43	53.33	50.77	48.35	40.35	40.11	40.10	26.56
172	30.18	31.45	46.67	35.90	36.57	29.87	29.84	29.80	24.07
173	26.35	28.48	40.00	35.43	30.60	25.07	24.67	24.70	9.95
184	29.11	30.73	43.33	34.80	34.30	28.29	28.04	28.00	15.36
203	30.05	32.83	43.33	37.71	35.39	29.36	29.32	29.30	13.55
213	34.36	36.06	50.00	42.16	40.21	33.86	33.75	33.70	16.70
Mean	30.22	32.04	44.82	37.09	35.78	29.61	29.42	29.41	20.12
STD	7.03	6.89	7.60	7.56	8.76	7.17	7.22	7.21	8.17
	Area Category = 3 and Fractal Category = 4								
7	22.42	24.27	36.67	28.67	26.69	21.62	21.44	21.40	3.50
36	29.11	30.73	46.67	36.82	34.08	27.99	27.58	27.60	8.02
67	35.90	38.01	53.33	44.85	42.61	35.04	34.79	34.80	8.51
127	23.69	26.67	36.67	30.73	27.91	23.10	22.97	23.00	8.62
129	45.03	44.72	63.33	50.44	53.66	45.28	45.19	45.20	34.85
131	34.20	35.98	46.67	41.77	38.46	33.19	32.92	32.90	5.30
151	27.59	30.00	40.00	33.50	32.19	26.80	26.67	26.70	15.50
230	33.33	34.80	50.00	41.77	38.08	32.02	31.45	31.50	17.75
Mean	31.41	33.15	46.67	38.57	36.71	30.63	30.38	30.39	12.76
STD	7.34	6.60	9.08	7.46	8.72	7.58	7.59	7.59	10.14
	Area Category = 3 and Fractal Category = 5								
1	39.76	40.69	60.00	46.43	47.67	38.86	38.52	38.50	29.09
3	27.74	30.73	46.67	35.43	33.40	27.62	27.36	27.40	25.57
24	10.00	7.45	23.33	20.28	13.74	10.09	10.33	10.30	3.75
26	0.00	0.00	3.33	0.00	1.18	0.59	0.56	0.60	0.93
74	52.17	52.70	76.67	56.76	62.28	52.06	52.06	52.05	50.53
120	32.36	33.50	46.67	37.27	38.64	32.17	32.02	32.00	24.95
158	73.09	73.11	96.67	80.28	85.85	72.26	72.09	72.10	4.62
186	51.85	52.07	73.33	57.35	62.32	51.40	51.07	51.10	43.20
Mean	35.87	36.28	53.33	41.73	43.13	35.63	35.50	35.51	22.83
STD	23.77	24.14	30.13	24.61	27.56	23.38	23.29	23.29	18.55

Appendix B. Polygon Medians for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9	Slope Method 11
	Area Category = 3 and Fractal Category = 6								
71	46.93	45.34	66.67	53.80	55.00	46.51	46.39	46.40	12.67
105	21.08	21.34	33.33	28.28	24.75	20.31	19.78	19.80	15.26
Mean	34.01	33.34	50.00	41.04	39.88	33.41	33.08	33.10	13.97
STD	18.28	16.97	23.57	18.05	21.39	18.53	18.81	18.81	1.83
	Area Category = 4 and Fractal Category = 2								
190	27.13	28.67	40.00	33.33	31.82	26.52	26.35	26.40	15.09
	Area Category = 4 and Fractal Category = 5								
139	23.21	26.03	36.67	30.73	27.08	22.28	22.14	22.10	10.00
	Area Category = 4 and Fractal Category = 6								
10	43.33	43.84	63.33	49.55	49.46	41.39	42.26	42.30	31.84
137	18.63	21.34	33.33	26.87	22.11	17.92	17.57	17.60	8.55
Mean	30.98	32.59	48.33	38.21	35.79	29.66	29.92	29.95	20.20
STD	17.47	15.91	21.21	16.04	19.34	16.60	17.46	17.47	16.47
	Area Category = 5 and Fractal Category = 2								
35	27.13	28.67	40.00	33.99	32.02	26.35	26.15	26.20	12.43

APPENDIX C

POLYGON FIRST QUARTILE (25%) FOR THE DIFFERENT SLOPE METHODS

Appendix C. Polygon First Quartile (25%) for the Different Slope Methods

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 1							
34	36.62	34.72	56.67	44.72	43.92	36.88	37.16	37.15
65	23.17	23.57	36.67	26.87	26.72	22.88	22.97	22.93
72	25.44	26.03	36.67	31.45	30.62	25.53	25.61	25.60
75	25.87	23.57	40.00	30.73	32.03	26.09	25.99	25.98
80	18.90	19.58	30.00	26.03	22.78	19.03	18.69	18.70
85	26.87	26.35	40.00	33.50	33.29	26.42	26.14	26.15
92	33.33	31.62	40.00	38.01	40.19	33.02	32.72	32.70
95	30.23	30.18	43.33	35.43	34.88	30.06	29.45	29.45
126	32.87	31.45	49.17	37.27	39.62	32.15	32.09	32.08
163	37.79	37.27	53.33	43.33	44.39	37.98	37.98	38.00
164	35.81	33.87	55.83	46.31	40.56	35.29	35.01	35.00
196	10.54	13.00	23.33	18.86	15.13	10.96	11.03	11.03
241	30.63	30.73	40.00	36.06	35.92	30.65	30.37	30.40
Mean	28.31	27.84	41.92	34.51	33.85	28.23	28.09	28.09
STD	7.73	6.73	9.80	7.88	8.54	7.60	7.60	7.60
	Area Category = 1 and Fractal Category = 2							
4	37.32	35.42	63.33	44.06	45.44	36.40	36.19	36.22
55	17.72	18.86	26.67	24.04	21.24	17.18	16.96	17.00
56	20.34	21.28	26.67	24.27	24.75	20.72	21.14	21.18
58	18.63	21.34	33.33	28.53	23.15	18.32	18.46	18.43
61	23.21	24.27	33.33	31.45	27.23	23.01	23.36	23.40
70	24.16	22.85	40.00	31.62	29.39	24.30	24.16	24.15
73	23.27	24.27	33.33	28.67	27.57	22.25	22.29	22.25
77	32.68	33.17	46.67	38.87	37.08	32.34	32.29	32.30
83	21.34	21.34	33.33	28.48	25.69	20.42	20.01	20.00
84	26.72	28.67	36.67	33.33	30.79	25.17	24.92	24.90
89	29.11	30.32	40.00	33.33	35.49	28.80	28.47	28.50
101	19.31	13.00	29.17	23.27	21.83	18.34	18.08	18.08
111	25.94	27.49	40.00	34.80	32.04	25.17	25.67	25.68
113	19.75	20.28	33.33	26.66	24.13	20.28	20.60	20.60
117	29.58	29.81	40.00	33.33	38.22	29.60	29.93	29.95

Appendix C. Polygon First Quartile (25%) for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 2 (continued)							
121	15.09	14.91	26.67	21.34	18.37	15.69	15.65	15.65
135	15.37	14.91	26.67	21.34	18.63	15.29	15.11	15.10
142	21.67	21.34	36.67	30.73	25.87	20.98	20.88	20.90
144	20.07	21.08	33.33	29.81	24.66	19.76	19.91	19.90
145	12.69	14.14	23.33	21.08	16.41	12.87	13.45	13.40
147	21.05	21.21	35.00	26.03	25.21	20.64	20.57	20.55
165	17.00	17.48	26.67	24.83	19.88	16.39	16.57	16.60
174	25.00	24.16	40.00	31.09	30.74	25.34	25.21	25.20
185	22.59	26.03	39.17	36.06	26.28	20.94	19.99	19.98
193	11.79	13.33	20.00	18.86	14.53	11.74	11.33	11.30
195	13.13	13.74	23.33	19.44	15.41	12.51	12.19	12.20
198	27.89	28.81	36.67	37.38	31.77	25.73	24.97	24.95
199	30.73	33.99	50.00	37.71	36.59	31.23	31.47	31.50
202	24.05	24.10	40.00	28.96	29.87	24.04	24.14	24.15
204	12.13	13.33	23.33	19.44	14.58	12.15	12.22	12.20
210	13.10	14.33	23.33	21.34	15.94	12.35	11.85	11.85
217	11.18	12.02	23.33	18.86	14.29	11.07	10.94	10.90
219	24.78	23.57	40.00	29.81	32.72	24.42	25.34	25.30
232	27.14	28.67	40.00	33.75	32.76	26.53	26.14	26.15
Mean	21.63	22.16	34.22	28.60	26.13	21.23	21.19	21.19
STD	6.48	6.60	9.00	6.49	7.78	6.36	6.40	6.41
	Area Category = 1 and Fractal Category = 3							
15	17.56	18.70	30.00	25.39	20.31	16.35	16.11	16.10
29	20.41	21.34	30.00	28.48	23.70	19.34	19.04	19.05
40	25.17	26.51	36.67	30.73	29.46	24.31	24.22	24.25
50	17.35	21.21	35.00	26.03	21.49	16.77	17.44	17.40
52	21.28	23.09	33.33	26.03	24.65	21.32	21.15	21.18
64	31.54	32.53	53.33	40.59	38.31	31.40	31.52	31.53
76	12.02	13.74	23.33	21.34	14.58	11.35	10.95	10.93
94	18.37	19.15	28.34	24.04	23.18	18.46	18.83	18.85
97	30.73	31.45	43.33	34.32	38.60	30.87	31.00	31.03

Appendix C. Polygon First Quartile (25%) for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 3 (continued)							
146	20.85	21.34	36.67	30.73	25.17	20.64	19.96	19.95
155	15.55	16.67	26.67	21.08	19.95	15.98	15.90	15.90
157	17.40	20.81	32.50	28.48	21.61	17.16	16.70	16.68
159	15.37	17.95	30.00	25.39	17.95	15.09	15.57	15.60
167	15.46	17.95	26.67	24.27	18.52	14.51	14.44	14.40
170	20.28	23.45	36.67	32.83	25.24	19.85	19.41	19.40
179	33.99	33.33	50.00	38.91	39.28	33.06	33.50	33.45
191	12.88	14.91	26.67	22.66	15.00	12.76	12.28	12.28
201	15.59	16.67	30.00	26.03	18.28	15.06	14.98	15.00
208	12.27	13.74	23.33	20.48	14.93	12.14	11.73	11.73
226	34.34	35.11	50.00	40.21	41.89	33.96	33.88	33.90
227	15.30	17.00	30.00	26.66	17.26	13.34	13.23	13.25
231	27.13	30.00	40.00	37.27	33.85	26.63	26.03	26.00
233	17.40	20.28	26.67	26.87	19.64	16.24	15.63	15.60
240	33.21	27.58	50.00	40.21	38.19	33.11	32.87	32.85
243	21.33	22.66	33.33	29.81	26.69	21.73	21.77	21.78
Mean	20.91	22.29	34.50	29.15	25.11	20.46	20.33	20.32
STD	7.05	6.27	8.75	6.28	8.51	7.14	7.22	7.23
	Area Category = 1 and Fractal Category = 4							
8	24.55	24.27	36.67	30.73	27.59	24.00	24.19	24.23
19	17.95	21.08	30.00	28.48	23.09	18.19	17.89	17.90
20	12.13	14.04	23.33	22.36	14.32	11.50	11.22	11.20
38	20.34	21.34	33.33	27.49	25.06	20.62	20.65	20.60
68	16.07	17.00	30.00	24.04	19.47	15.87	15.68	15.65
69	13.02	14.91	26.67	22.36	16.69	13.03	12.92	12.90
79	18.03	20.28	26.67	25.39	21.63	17.72	17.55	17.58
91	15.09	13.33	23.33	19.44	18.10	14.35	14.54	14.50
106	3.73	7.45	23.33	12.02	10.14	5.89	7.31	7.30
122	25.93	26.87	33.33	30.73	27.96	24.84	24.66	24.70
138	26.72	28.67	43.33	35.43	30.64	26.17	25.61	25.60
160	23.57	24.27	33.33	28.48	27.16	22.76	22.31	22.30

Appendix C. Polygon First Quartile (25%) for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 4 (continued)							
169	18.54	23.39	36.67	28.28	22.77	18.33	18.78	18.75
176	21.86	23.57	33.33	30.32	27.23	21.86	21.71	21.70
194	39.86	40.14	56.67	42.69	51.22	39.88	39.80	39.83
200	33.43	33.21	50.00	38.98	38.86	33.68	33.13	33.15
207	9.72	13.74	20.00	18.86	13.74	9.66	10.02	10.00
209	15.37	20.00	36.67	28.48	17.44	14.55	14.28	14.30
211	24.78	25.39	36.67	30.73	28.72	24.61	24.45	24.50
212	21.92	20.88	33.33	28.08	27.23	22.08	22.21	22.20
221	18.41	23.33	36.67	31.62	22.93	17.93	18.02	18.00
223	19.00	23.33	30.00	28.08	24.11	18.75	19.22	19.23
228	26.43	27.03	43.33	34.44	30.75	24.78	24.48	24.45
229	22.90	29.04	43.33	37.27	27.19	23.41	22.84	22.88
238	32.36	34.80	50.00	41.23	38.64	33.13	33.12	33.10
Mean	20.87	22.85	34.80	29.04	25.31	20.70	20.66	20.66
STD	7.79	7.29	9.13	7.09	8.82	7.68	7.48	7.49
	Area Category = 1 and Fractal Category = 5							
13	8.33	13.74	20.00	18.63	9.44	6.13	5.86	5.85
22	13.44	14.91	23.33	21.34	16.12	13.18	13.25	13.30
23	15.72	16.67	26.67	24.04	18.92	15.04	14.97	15.00
25	7.45	6.67	16.67	14.53	9.32	7.18	7.22	7.20
30	10.54	13.33	20.00	18.86	13.49	10.17	10.20	10.20
31	14.24	16.67	26.67	23.57	16.41	13.24	12.79	12.80
47	12.69	14.91	23.33	21.08	14.91	12.61	12.02	12.00
133	23.78	26.87	36.67	31.62	26.97	21.86	20.90	20.88
171	19.51	21.08	36.67	30.73	22.36	18.50	18.87	18.90
175	18.80	20.00	30.00	27.49	22.38	17.67	16.77	16.78
215	27.54	30.32	44.17	36.24	33.69	27.66	27.83	27.85
235	27.26	27.18	36.67	36.67	30.40	27.17	26.60	26.60
236	40.10	42.29	53.33	44.72	51.08	40.21	40.33	40.38
Mean	18.42	20.36	30.32	26.89	21.96	17.74	17.51	17.52
STD	9.26	9.30	10.67	8.70	11.53	9.52	9.56	9.57

Appendix C. Polygon First Quartile (25%) for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 6							
14	11.18	13.74	23.33	21.08	12.80	9.81	9.46	9.50
53	17.72	16.67	30.00	25.39	21.18	18.27	18.47	18.50
57	16.67	21.34	33.33	23.57	20.65	17.33	18.39	18.40
87	13.44	12.02	23.33	20.28	16.67	14.73	14.82	14.80
116	14.19	19.44	26.67	24.16	16.26	12.74	12.61	12.65
234	53.37	54.00	83.33	63.46	62.65	51.86	51.36	51.40
239	10.00	16.23	29.17	25.05	12.34	10.13	10.41	10.43
242	39.12	41.70	53.33	46.91	50.12	39.79	40.25	40.25
Mean	21.96	24.39	37.81	31.24	26.58	21.83	21.97	21.99
STD	15.67	15.13	20.74	15.53	18.96	15.45	15.36	15.36
	Area Category = 2 and Fractal Category = 1							
62	13.44	14.91	23.33	19.44	16.50	12.65	12.23	12.20
118	27.13	28.28	40.00	32.87	32.22	27.24	26.85	26.83
181	11.79	13.74	20.00	18.86	14.98	12.15	12.01	12.00
197	14.24	14.91	23.33	19.44	17.04	14.25	13.90	13.90
225	20.07	20.28	26.67	26.87	23.21	18.98	18.80	18.80
Mean	17.33	18.42	26.67	23.50	20.79	17.05	16.76	16.75
STD	6.30	6.07	7.82	6.20	7.12	6.30	6.27	6.27
	Area Category = 2 and Fractal Category = 2							
2	20.88	20.28	33.33	28.67	24.61	20.50	20.07	20.10
5	35.24	33.17	56.67	41.43	40.35	34.63	34.47	34.45
37	19.51	20.00	30.00	26.03	24.49	19.76	19.69	19.68
44	14.34	16.67	23.33	22.36	16.48	13.13	12.76	12.78
45	14.19	16.67	30.00	24.16	16.37	13.45	12.89	12.90
46	17.00	19.44	26.67	24.83	20.41	16.53	16.76	16.75
48	23.15	28.28	40.00	35.43	26.59	22.67	22.22	22.20
60	49.96	49.22	67.50	56.60	58.95	48.85	48.50	48.50
78	19.93	20.21	30.00	26.87	23.80	19.57	19.41	19.38
81	16.67	16.67	26.67	23.57	19.83	16.18	15.98	15.95
82	17.72	16.67	30.00	22.36	21.18	17.41	17.28	17.30
90	19.00	17.95	30.00	25.87	22.64	18.80	18.95	18.98

Appendix C. Polygon First Quartile (25%) for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 2 (continued)							
98	29.67	30.73	46.67	35.43	33.21	29.02	28.81	28.80
102	19.49	21.08	33.33	26.87	24.47	20.17	20.35	20.38
104	35.38	35.90	50.00	39.02	40.97	35.07	34.97	35.00
112	28.67	30.73	43.33	34.32	34.22	28.52	28.07	28.05
124	26.09	26.87	40.00	34.32	30.21	24.86	24.41	24.40
125	25.03	24.27	40.00	33.17	30.86	25.01	25.02	25.00
148	23.53	23.92	36.67	28.67	27.41	23.01	23.20	23.20
150	12.02	13.74	23.33	19.44	15.00	11.33	11.25	11.20
161	33.65	31.62	46.67	40.65	40.06	32.18	32.35	32.37
162	28.67	29.81	43.33	34.80	35.71	29.45	29.21	29.23
177	12.13	13.94	23.33	20.28	15.42	12.41	12.45	12.45
178	25.43	26.82	36.67	33.33	30.30	25.30	25.59	25.60
180	20.05	21.34	32.50	27.49	24.09	19.57	19.46	19.45
187	24.36	26.03	40.00	30.73	31.16	25.01	24.90	24.93
188	13.44	13.74	23.33	19.44	15.64	13.04	12.93	12.93
214	15.37	17.00	26.67	22.85	19.08	15.45	15.57	15.60
218	20.14	21.34	36.67	28.67	22.64	19.34	19.22	19.25
220	14.96	17.00	26.67	22.36	18.33	14.74	14.60	14.63
Mean	22.52	23.37	35.78	29.67	26.82	22.16	22.04	22.05
STD	8.40	7.92	10.52	8.05	9.75	8.30	8.28	8.28
	Area Category = 2 and Fractal Category = 3							
12	17.78	20.28	30.00	25.39	20.32	16.86	16.57	16.60
43	20.30	21.34	30.00	26.87	24.62	19.94	19.46	19.43
49	13.36	16.67	26.67	22.36	16.45	12.95	12.92	12.90
51	25.05	26.67	36.67	33.33	29.15	24.81	24.65	24.68
59	24.27	26.87	40.00	35.98	29.39	23.47	23.49	23.50
86	30.62	31.54	43.33	35.43	35.77	30.38	30.41	30.45
103	29.53	31.45	43.33	34.80	35.61	29.30	29.15	29.10
109	23.57	23.57	36.67	29.81	27.26	23.16	23.21	23.20
115	13.44	16.67	26.67	24.04	16.42	13.03	12.72	12.73
128	20.05	20.28	33.33	28.43	23.86	19.80	19.68	19.70

Appendix C. Polygon First Quartile (25%) for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 3 (continued)							
134	16.69	16.67	30.00	23.69	20.74	17.18	17.37	17.40
140	30.80	31.62	46.67	40.35	36.46	30.52	29.95	29.93
182	27.89	28.28	40.00	32.96	35.76	27.70	27.67	27.68
189	15.74	17.00	26.67	23.57	18.37	15.32	14.63	14.65
205	20.07	20.00	31.67	26.87	23.98	19.50	19.37	19.40
216	20.55	24.04	36.67	33.00	25.02	20.33	20.37	20.40
Mean	21.86	23.31	34.90	29.80	26.20	21.51	21.35	21.36
STD	5.80	5.52	6.48	5.43	6.96	5.84	5.87	5.86
	Area Category = 2 and Fractal Category = 4							
17	14.91	17.00	30.00	25.39	17.44	13.80	13.49	13.45
27	10.14	12.02	20.00	17.95	11.75	9.47	9.08	9.05
32	19.00	20.28	30.00	26.03	23.18	18.42	17.99	18.00
33	19.48	19.44	30.00	26.87	23.17	19.21	19.45	19.50
39	30.05	33.00	53.33	40.14	33.33	26.58	26.32	26.30
42	30.05	28.67	46.67	37.94	35.15	28.37	27.21	27.18
88	22.67	23.57	36.67	31.45	26.98	21.62	21.37	21.40
110	16.67	17.00	26.67	24.04	19.40	15.87	15.53	15.55
123	34.68	35.43	50.00	40.69	40.93	34.18	34.29	34.30
136	28.75	30.18	43.33	35.43	35.77	28.78	28.59	28.60
149	18.41	18.86	30.00	26.87	21.44	17.29	16.90	16.90
156	31.84	33.42	43.33	37.71	36.72	32.02	31.85	31.85
168	17.89	20.28	30.00	26.03	20.74	16.88	17.35	17.38
192	21.73	23.57	33.33	31.45	24.21	20.09	20.05	20.03
206	17.84	20.28	30.00	26.03	20.62	16.49	16.52	16.50
222	17.95	20.00	30.00	26.03	22.17	17.58	18.16	18.20
Mean	22.00	23.31	35.21	30.00	25.81	21.04	20.88	20.89
STD	6.98	6.83	9.35	6.62	8.17	6.96	6.92	6.92
	Area Category = 2 and Fractal Category = 5							
11	16.75	17.95	26.67	24.27	18.76	15.47	15.43	15.45
16	14.34	14.91	23.33	21.34	17.70	14.10	13.78	13.80
18	14.98	17.00	26.67	23.92	16.80	13.79	13.50	13.48

Appendix C. Polygon First Quartile (25%) for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 5 (continued)							
28	17.40	17.71	26.67	24.21	21.16	16.73	16.59	16.60
66	11.79	13.74	23.33	20.07	14.33	11.15	11.11	11.10
107	15.00	17.00	26.67	24.27	17.72	13.76	13.44	13.40
119	27.74	26.87	40.00	31.45	33.78	27.94	27.78	27.80
Mean	16.86	17.88	27.62	24.22	20.04	16.13	15.95	15.95
STD	5.13	4.25	5.68	3.60	6.40	5.48	5.49	5.51
	Area Category = 2 and Fractal Category = 6							
21	9.72	12.02	23.33	19.44	12.58	9.59	9.25	9.20
41	41.47	38.01	56.67	47.73	48.80	40.83	40.47	40.43
166	12.02	13.74	26.67	21.34	15.84	12.43	12.36	12.35
Mean	21.07	21.26	35.56	29.50	25.74	20.95	20.69	20.66
STD	17.70	14.53	18.36	15.81	20.04	17.27	17.19	17.19
	Area Category = 3 and Fractal Category = 2							
54	16.67	17.00	26.67	22.36	20.21	16.88	16.90	16.90
63	23.63	23.57	33.33	28.67	27.93	23.64	23.47	23.45
152	26.35	26.87	40.00	31.45	30.32	25.65	25.61	25.60
183	12.69	13.74	23.33	21.08	15.37	12.43	12.47	12.48
Mean	19.84	20.30	30.83	25.89	23.46	19.65	19.61	19.61
STD	6.27	5.99	7.39	4.97	6.90	6.10	6.03	6.02
	Area Category = 3 and Fractal Category = 3							
6	19.48	23.57	36.67	29.81	22.64	18.25	18.12	18.10
9	14.91	17.95	26.67	23.57	17.62	14.52	14.56	14.55
93	21.67	23.57	33.33	30.73	25.06	20.90	20.74	20.70
96	16.50	17.00	30.00	23.57	19.15	15.83	15.64	15.60
100	18.63	19.44	30.00	24.04	22.32	18.83	18.72	18.75
108	16.67	19.44	30.00	23.57	20.62	16.97	16.90	16.90
114	18.63	19.44	30.00	24.04	22.39	18.47	18.50	18.50
130	21.08	22.36	33.33	28.48	24.49	20.76	20.74	20.70
132	33.75	34.80	46.67	42.69	40.16	33.84	33.92	33.90
141	35.16	35.43	46.67	40.69	42.58	34.49	34.42	34.43
143	20.31	21.08	33.33	28.28	24.51	19.81	19.44	19.40

Appendix C. Polygon First Quartile (25%) for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 3 and Fractal Category = 3 (continued)							
153	26.70	26.87	40.00	33.00	31.92	26.34	26.22	26.20
154	28.58	30.18	40.00	37.71	34.13	28.38	27.93	27.95
172	24.61	25.39	36.67	30.73	29.86	24.27	24.36	24.40
173	16.59	20.00	30.00	26.03	19.83	15.74	15.45	15.40
184	22.67	24.04	36.67	28.67	27.18	22.47	22.56	22.60
203	21.73	24.04	36.67	30.73	26.87	21.25	21.12	21.10
213	25.93	27.49	40.00	33.33	30.80	25.37	25.15	25.20
Mean	22.42	24.01	35.37	29.98	26.78	22.03	21.92	21.91
STD	5.78	5.33	5.73	5.81	7.00	5.82	5.83	5.84
	Area Category = 3 and Fractal Category = 4							
7	15.72	17.95	30.00	24.04	18.30	14.73	14.44	14.40
36	21.34	23.57	33.33	29.81	25.47	21.12	20.88	20.90
67	26.87	28.67	40.00	35.90	31.16	26.09	25.85	25.80
127	18.63	18.86	30.00	24.27	22.17	18.49	18.22	18.20
129	33.08	33.33	46.67	38.87	38.69	32.77	33.21	33.20
131	21.73	24.10	33.33	30.73	25.18	21.22	20.89	20.90
151	21.92	23.57	33.33	28.67	26.06	21.62	21.57	21.60
230	23.57	24.27	36.67	32.83	27.28	23.10	22.78	22.80
Mean	22.86	24.29	35.42	30.64	26.79	22.39	22.23	22.23
STD	5.27	4.95	5.62	5.19	6.09	5.34	5.54	5.54
	Area Category = 3 and Fractal Category = 5							
1	31.11	33.25	53.33	40.14	37.69	30.78	30.31	30.30
3	17.56	20.00	33.33	25.39	21.76	17.43	17.69	17.65
24	0.00	0.00	3.33	0.00	1.18	0.59	0.56	0.60
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	43.46	43.46	63.33	48.07	51.00	43.48	43.53	43.58
120	27.49	28.48	40.00	33.00	32.34	27.20	27.21	27.20
158	60.12	58.97	80.00	67.08	70.35	60.21	60.24	60.23
186	44.78	44.72	60.00	49.55	52.06	44.60	44.52	44.50
Mean	28.06	28.61	41.67	32.90	33.30	28.04	28.01	28.01
STD	21.51	21.16	28.51	23.75	24.88	21.41	21.39	21.38

Appendix C. Polygon First Quartile (25%) for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 3 and Fractal Category = 6							
71	30.60	28.28	53.33	39.02	35.96	29.35	29.31	29.33
105	14.34	14.14	26.67	22.36	17.72	14.25	14.14	14.10
Mean	22.47	21.21	40.00	30.69	26.84	21.80	21.73	21.71
STD	11.50	10.00	18.85	11.78	12.90	10.68	10.73	10.77
	Area Category = 4 and Fractal Category = 2							
190	18.41	20.00	30.00	26.03	21.83	18.15	17.99	18.00
	Area Category = 4 and Fractal Category = 5							
139	17.16	18.86	30.00	24.04	20.62	16.87	16.71	16.70
	Area Category = 4 and Fractal Category = 6							
10	31.70	32.83	50.00	40.55	36.51	28.22	30.66	30.68
137	10.14	12.02	23.33	18.86	11.79	9.43	9.14	9.15
Mean	20.92	22.43	36.67	29.71	24.15	18.83	19.90	19.91
STD	15.25	14.71	18.86	15.34	17.48	13.29	15.22	15.22
	Area Category = 5 and Fractal Category = 2							
35	20.14	21.34	33.33	28.28	23.83	19.59	19.44	19.40

APPENDIX D

POLYGON THIRD QUARTILE (75%) FOR THE DIFFERENT SLOPE METHODS

Appendix D. Polygon Third Quartile (75%) for the Different Slope Methods

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 1							
34	54.42	55.78	76.67	60.92	64.39	53.11	52.50	52.47
65	29.11	30.73	43.33	33.33	33.71	28.50	28.48	28.48
72	35.36	37.27	50.00	41.77	43.73	34.67	34.26	34.30
75	33.67	34.80	46.67	38.87	42.31	33.01	32.76	32.78
80	31.00	33.00	46.67	37.71	37.75	30.42	30.19	30.18
85	35.36	37.05	50.00	40.42	42.43	34.35	34.33	34.35
92	40.69	40.28	60.00	44.85	50.04	40.09	40.06	40.10
95	40.07	40.62	53.33	44.72	47.99	38.95	38.45	38.45
126	43.12	42.69	63.33	47.38	55.85	43.44	43.42	43.40
163	53.71	55.92	80.00	59.86	61.72	53.40	52.97	53.00
164	53.17	55.26	80.00	61.28	60.68	52.03	51.63	51.65
196	21.67	24.55	33.33	28.48	24.66	20.35	20.48	20.45
241	42.49	44.82	60.00	49.89	52.74	43.01	42.75	42.73
Mean	39.53	40.98	57.18	45.34	47.54	38.87	38.64	38.64
STD	10.01	9.88	14.65	10.40	11.69	10.09	9.94	9.94
	Area Category = 1 and Fractal Category = 2							
4	57.47	58.97	86.67	62.89	65.51	56.32	56.08	56.05
55	26.87	29.90	36.67	33.33	32.34	25.58	25.26	25.30
56	26.43	28.48	36.67	30.73	32.12	25.83	25.80	25.83
58	31.34	33.50	46.67	40.25	38.03	29.78	29.56	29.55
61	51.91	52.07	70.00	58.21	57.29	51.35	51.30	51.30
70	36.86	38.01	46.67	44.47	45.44	36.73	36.32	36.30
73	31.84	33.33	46.67	35.43	37.75	31.27	31.13	31.15
77	46.04	49.78	65.00	51.85	54.89	46.06	45.96	45.95
83	31.84	33.33	46.67	37.27	38.48	31.17	30.78	30.75
84	38.87	40.18	53.33	44.88	46.45	37.39	36.89	36.90
89	34.68	37.94	46.67	40.14	43.18	34.23	34.13	34.13
101	28.97	28.33	44.17	36.06	33.80	27.42	26.93	26.90
111	39.75	42.23	56.67	46.52	47.86	38.17	37.76	37.75
113	33.41	38.22	47.50	42.83	42.90	34.09	33.93	33.95
117	41.16	40.69	63.33	54.06	52.55	41.06	41.17	41.15

Appendix D. Polygon Third Quartile (75%) for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 2 (continued)							
121	24.44	26.03	36.67	28.67	28.91	23.67	23.58	23.60
135	23.15	26.03	36.67	29.81	25.50	22.28	22.36	22.40
142	41.67	41.77	63.33	48.07	49.68	39.73	38.79	38.80
144	32.83	36.06	50.00	40.69	38.89	31.36	31.04	31.00
145	20.88	24.04	33.33	28.28	24.07	19.53	19.54	19.50
147	30.87	32.23	43.33	35.98	35.18	30.13	29.83	29.85
165	27.13	30.73	40.00	35.90	32.02	26.44	26.24	26.25
174	51.69	50.22	76.67	59.75	64.49	50.43	50.69	50.70
185	45.34	45.15	60.00	53.52	52.68	42.43	41.76	41.72
193	18.03	21.34	30.00	24.27	21.70	17.01	16.75	16.70
195	20.55	23.51	33.33	28.62	24.97	19.67	19.69	19.68
198	42.64	43.74	56.67	47.73	51.12	42.06	41.82	41.80
199	46.93	48.07	63.33	52.17	53.03	45.77	45.58	45.60
202	38.88	38.87	59.17	43.46	48.49	38.80	38.67	38.68
204	19.51	23.57	33.33	26.03	23.15	18.98	18.80	18.80
210	21.73	24.27	33.33	30.73	25.07	20.32	20.16	20.18
217	23.57	27.49	40.00	31.45	27.64	21.73	21.61	21.60
219	37.27	38.01	53.33	42.16	48.59	37.66	37.86	37.90
232	45.98	49.22	66.67	52.17	55.92	45.23	44.80	44.80
Mean	34.43	36.33	50.07	41.13	41.17	33.52	33.31	33.31
STD	10.36	9.64	13.87	10.39	12.37	10.40	10.38	10.38
	Area Category = 1 and Fractal Category = 3							
15	29.32	31.62	46.67	37.27	35.18	27.51	27.20	27.15
29	31.81	33.00	46.67	38.01	36.26	29.43	29.14	29.15
40	40.83	42.45	53.33	46.67	48.68	40.47	40.46	40.43
50	34.47	42.23	65.00	42.23	40.65	34.07	33.62	33.65
52	30.73	32.87	50.00	35.90	36.08	29.50	29.49	29.50
64	53.02	51.90	76.67	60.09	60.79	49.89	49.13	49.17
76	25.05	28.67	40.00	31.62	28.65	23.55	23.04	23.03
94	27.13	31.09	41.67	34.32	33.24	26.53	26.44	26.45
97	37.45	38.66	53.33	41.77	46.34	36.39	36.20	36.18

Appendix D. Polygon Third Quartile (75%) for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 3 (continued)							
146	36.57	37.49	56.67	43.40	44.69	35.25	34.88	34.90
155	28.51	30.18	46.67	39.58	35.65	28.32	28.03	[illegible]3.00
157	31.71	34.32	46.67	38.87	36.69	30.65	30.10	30.05
159	30.64	33.33	46.67	38.01	33.42	28.35	28.09	28.10
167	36.06	36.59	46.67	40.69	40.32	33.84	32.88	32.88
170	37.23	38.01	51.67	43.33	41.85	36.30	35.88	35.85
179	52.83	47.64	86.67	62.02	65.13	51.80	51.50	51.50
191	25.35	27.49	36.67	31.45	29.15	24.11	23.77	23.78
201	28.36	31.62	43.33	38.44	32.28	26.14	26.12	26.10
208	25.33	27.49	40.00	33.00	29.24	23.74	22.91	22.90
226	47.73	49.55	76.67	56.86	59.40	47.04	46.96	46.95
227	29.87	33.33	43.33	40.14	33.44	27.43	26.59	26.60
231	44.28	47.73	56.67	52.17	55.80	44.54	44.48	44.50
233	36.06	38.01	53.33	42.69	40.15	35.08	34.47	34.50
240	53.97	53.44	75.00	61.37	67.68	53.24	53.13	53.10
243	38.98	40.55	55.83	47.38	46.34	37.64	37.78	37.80
Mean	35.73	37.57	53.43	43.09	42.28	34.43	34.09	34.09
STD	8.79	7.64	13.04	8.98	11.45	8.94	9.00	9.00
	Area Category = 1 and Fractal Category = 4							
8	35.38	36.21	53.33	40.28	40.47	35.19	35.06	35.05
19	35.16	38.01	46.67	41.77	40.59	34.32	34.05	34.10
20	23.73	27.03	40.00	31.45	27.00	22.09	22.19	22.18
38	33.21	34.80	46.67	39.02	38.77	32.24	32.06	32.10
68	29.49	33.00	46.67	38.87	32.86	27.99	27.39	27.35
69	27.34	30.18	43.33	34.32	32.18	26.09	25.52	25.50
79	28.53	30.73	43.33	33.33	34.36	27.46	27.06	27.03
91	25.44	25.39	36.67	29.81	32.02	24.76	24.66	24.70
106	12.13	14.91	33.33	22.36	18.33	13.24	13.66	13.70
122	44.00	45.34	56.67	50.88	49.47	43.50	42.61	42.60
138	38.04	40.14	56.67	43.33	43.72	36.68	36.59	36.60
160	33.71	35.43	50.00	38.01	40.47	32.50	32.56	32.60

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 4 (continued)							
169	30.64	34.07	50.00	37.71	33.26	29.91	30.14	30.10
176	43.13	46.07	60.00	51.99	49.21	42.14	41.94	41.92
194	46.96	48.07	70.00	50.88	58.91	46.84	46.38	46.40
200	51.86	52.23	73.33	61.28	60.70	51.13	51.15	51.17
207	25.44	30.00	43.33	34.32	29.15	22.68	22.22	22.20
209	33.08	35.43	50.00	38.87	38.37	32.80	31.82	31.80
211	40.31	41.77	60.00	46.31	45.35	40.31	40.37	40.40
212	32.06	32.83	46.67	37.27	40.44	31.32	31.41	31.45
221	37.27	43.74	55.83	49.47	43.33	34.20	33.68	33.70
223	31.18	34.32	46.67	38.01	36.18	30.18	30.37	30.38
228	49.50	50.00	72.50	54.90	59.42	49.49	49.54	49.50
229	44.57	47.58	60.00	51.75	51.09	42.13	41.75	41.78
238	52.97	53.44	76.67	57.35	55.19	51.32	50.67	50.70
Mean	35.41	37.63	52.73	42.14	41.23	34.42	34.19	34.20
STD	9.69	9.23	11.46	9.45	10.68	9.66	9.57	9.58
	Area Category = 1 and Fractal Category = 5							
13	19.46	23.57	30.00	26.24	22.78	18.57	18.41	18.43
22	25.22	29.81	43.33	33.33	28.67	23.75	23.45	23.40
23	28.37	30.00	43.33	37.27	32.79	26.24	25.78	25.75
25	19.48	22.36	30.00	27.49	22.53	18.48	18.19	18.20
30	24.04	25.39	36.67	30.73	27.13	23.05	22.80	22.80
31	26.87	30.18	43.33	35.90	30.82	27.04	26.72	26.70
47	31.62	33.33	46.67	38.01	34.22	30.33	30.32	30.30
133	49.18	49.55	66.67	55.18	58.65	48.32	47.83	47.83
171	37.27	38.87	56.67	43.46	42.36	36.12	35.78	35.80
175	34.08	36.82	50.00	40.28	39.52	33.22	32.60	32.58
215	43.62	44.66	63.33	49.55	49.74	42.96	43.22	43.22
235	43.69	44.15	58.33	50.44	48.67	42.72	42.45	42.45
236	57.13	57.49	76.67	62.63	72.42	56.37	56.54	56.57
Mean	33.85	35.86	49.62	40.81	39.25	32.86	32.62	32.62
STD	11.72	10.66	14.15	11.00	14.81	11.82	11.90	11.91

Appendix D. Polygon Third Quartile (75%) for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 6							
14	23.86	26.87	40.00	31.45	26.69	22.09	21.14	21.10
53	29.81	30.73	50.00	35.43	34.70	29.75	29.67	29.70
57	48.07	56.67	83.33	56.67	54.16	46.40	45.86	45.90
87	23.57	25.39	36.67	28.67	26.06	22.09	21.44	21.40
116	33.52	36.36	48.33	41.77	36.58	30.49	29.22	29.20
234	73.29	75.04	110.00	82.57	88.74	72.15	71.51	71.55
239	30.66	34.32	50.00	36.36	33.69	29.89	29.15	29.20
242	54.63	56.96	76.67	60.09	67.24	54.56	54.18	54.15
Mean	39.68	42.79	61.88	46.63	45.98	38.43	37.77	37.78
STD	17.53	17.92	25.56	18.44	22.31	17.75	17.85	17.86
	Area Category = 2 and Fractal Category = 1							
62	25.44	28.48	40.00	31.45	30.91	24.87	24.80	24.80
118	40.58	42.16	53.33	46.31	47.87	39.71	39.54	39.50
181	20.34	24.27	33.33	28.67	24.14	19.45	19.50	19.48
197	21.08	23.57	30.00	26.87	24.66	20.07	20.03	20.00
225	31.31	33.99	43.33	38.01	36.93	31.01	30.76	30.80
Mean	27.75	30.49	40.00	34.26	32.90	27.02	26.93	26.92
STD	8.40	7.73	9.13	7.95	9.86	8.47	8.38	8.38
	Area Category = 2 and Fractal Category = 2							
2	33.08	35.43	50.00	40.28	39.48	31.78	31.55	31.60
5	52.31	52.43	76.67	57.83	62.64	51.44	51.26	51.25
37	29.53	30.73	43.33	35.90	34.64	28.33	28.09	28.10
44	26.76	28.48	40.00	32.87	32.21	26.22	26.06	26.05
45	27.14	30.73	43.33	35.43	31.04	24.86	24.39	24.40
46	28.94	31.09	43.33	35.90	33.75	28.31	27.76	27.75
48	41.97	44.47	60.00	48.53	48.46	41.16	40.86	40.90
60	66.99	68.72	96.67	74.54	80.96	66.04	65.84	65.85
78	33.89	35.43	46.67	40.55	39.88	32.56	31.70	31.70
81	26.16	28.67	36.67	31.62	31.82	25.10	24.66	24.65
82	24.04	26.87	36.67	30.73	28.94	23.64	23.45	23.40
90	34.36	34.80	46.67	41.37	41.30	33.52	33.04	33.03

Appendix D. Polygon Third Quartile (75%) for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 2 (continued)							
98	41.25	42.43	60.00	44.85	51.09	40.79	40.64	40.65
102	36.15	38.01	50.00	44.75	44.76	35.40	34.84	34.83
104	46.96	47.38	66.67	50.77	53.79	47.13	47.18	47.20
112	40.21	41.77	60.00	45.10	49.58	39.89	39.81	39.80
124	44.88	47.14	60.00	53.44	52.12	43.33	42.69	42.70
125	47.55	49.55	66.67	54.93	58.29	46.67	46.33	46.35
148	33.75	34.32	50.00	37.79	39.55	33.15	33.13	33.10
150	20.34	24.04	30.00	27.49	23.18	19.18	18.89	18.90
161	58.31	59.00	83.33	66.67	72.43	57.77	58.08	58.03
162	37.79	38.87	56.67	42.43	46.37	36.97	36.71	36.70
177	20.07	23.81	33.33	26.87	22.14	18.98	18.89	18.90
178	39.62	40.59	56.67	46.43	47.30	38.63	38.54	38.53
180	40.18	41.23	56.67	47.14	48.15	39.55	39.33	39.30
187	36.59	38.01	56.67	41.77	44.91	35.83	35.81	35.80
188	21.67	25.39	36.67	30.73	24.34	20.43	19.86	19.85
214	23.95	26.87	36.67	30.73	28.04	22.52	22.38	22.35
218	35.87	39.76	56.67	42.69	40.39	34.49	34.20	34.18
220	25.06	29.53	40.00	33.00	29.86	24.50	24.34	24.33
Mean	35.84	37.85	52.56	42.44	42.71	34.94	34.68	34.67
STD	11.23	10.56	15.23	11.20	13.99	11.36	11.43	11.43
	Area Category = 2 and Fractal Category = 3							
12	30.04	33.87	43.33	37.27	35.43	28.77	28.91	28.90
43	30.71	32.83	46.67	36.97	37.19	30.43	30.28	30.25
49	26.09	30.18	40.00	33.33	32.58	26.00	26.10	26.08
51	44.61	46.88	60.00	50.77	51.84	44.30	44.22	44.25
59	51.91	53.60	66.67	58.21	60.85	52.12	51.65	51.65
86	37.79	40.14	53.33	41.97	47.17	37.34	37.26	37.25
103	41.26	41.77	60.00	44.85	50.59	40.39	40.37	40.40
109	34.10	36.67	50.00	40.28	39.53	33.19	33.07	33.05
115	42.16	40.41	62.50	48.85	50.03	41.89	41.17	41.20
128	38.40	39.02	53.33	44.97	46.25	38.32	38.39	38.43

Appendix D. Polygon Third Quartile (75%) for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 3 (continued)							
134	24.74	27.34	39.17	30.73	28.94	24.14	24.06	24.08
140	50.69	50.88	70.00	56.91	58.56	50.30	50.12	50.10
182	37.08	38.87	53.33	40.96	47.17	36.70	36.66	36.63
189	30.60	33.00	43.33	36.06	35.55	29.31	28.93	28.95
205	30.03	31.09	43.33	36.06	36.86	29.02	28.95	28.95
216	36.58	41.77	53.33	47.14	43.03	35.53	35.31	35.33
Mean	36.67	38.64	52.40	42.83	43.85	36.11	35.96	35.97
STD	8.04	7.37	9.48	8.02	9.25	8.25	8.16	8.16
	Area Category = 2 and Fractal Category = 4							
17	30.73	33.00	46.67	38.01	35.71	29.29	28.69	28.70
27	20.55	23.51	33.33	26.87	24.30	19.25	19.16	19.18
32	38.37	40.69	60.00	47.73	43.24	35.48	34.36	34.40
33	30.05	31.45	43.33	36.37	35.63	29.01	28.37	28.40
39	45.34	47.14	70.00	50.99	53.99	44.21	44.00	44.00
42	45.86	48.07	70.00	52.07	53.36	43.66	43.63	43.63
88	35.90	37.71	50.00	43.84	42.96	34.68	34.40	34.40
110	34.47	37.27	46.67	40.59	42.90	33.63	33.34	33.33
123	50.69	52.70	76.67	56.57	60.64	50.76	50.57	50.60
136	40.18	42.29	53.33	46.43	46.63	38.94	38.55	38.53
149	33.87	35.43	50.00	40.55	40.88	32.69	32.43	32.45
156	52.07	52.07	70.00	56.96	56.22	51.01	50.30	50.30
168	29.86	31.62	43.33	37.27	34.70	28.30	28.00	28.00
192	43.34	43.75	60.00	50.00	50.15	41.59	41.40	41.40
206	35.57	38.01	53.33	42.30	40.29	34.85	34.51	34.55
222	26.72	30.18	40.00	33.33	30.82	25.58	25.30	25.30
Mean	37.10	39.06	54.17	43.74	43.28	35.81	35.44	35.45
STD	8.75	8.27	12.50	8.44	9.88	8.83	8.83	8.83
	Area Category = 2 and Fractal Category = 5							
11	30.03	32.23	43.33	36.06	35.03	28.82	28.57	28.60
16	24.70	26.67	36.67	29.81	30.07	23.85	23.90	23.90
18	26.93	28.48	40.00	31.62	30.65	25.02	24.59	24.58

Appendix D. Polygon Third Quartile (75%) for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 5 (continued)							
28	28.34	29.81	43.33	35.43	33.47	27.58	27.13	27.10
66	26.35	26.87	40.00	32.83	30.05	25.76	25.49	25.45
107	28.38	30.73	43.33	37.27	33.69	26.70	26.63	26.60
119	37.01	39.02	53.33	42.63	44.44	36.12	35.92	35.90
Mean	28.82	30.54	42.86	35.09	33.91	27.69	27.46	27.45
STD	3.99	4.24	5.24	4.24	5.04	4.06	4.05	4.05
	Area Category = 2 and Fractal Category = 6							
21	25.00	27.49	43.33	34.32	28.28	23.93	23.57	23.60
41	56.57	58.21	83.33	63.25	66.70	55.57	55.32	55.28
166	31.78	34.16	46.67	39.58	35.90	30.42	30.35	30.35
Mean	37.78	39.95	57.78	45.72	43.63	36.64	36.41	36.41
STD	16.62	16.16	22.19	15.41	20.34	16.71	16.72	16.68
	Area Category = 3 and Fractal Category = 2							
54	26.67	28.48	40.00	31.45	31.07	25.52	25.42	25.40
63	32.19	34.32	46.67	37.27	38.89	31.32	31.30	31.30
152	35.90	37.71	53.33	40.69	43.39	35.37	35.02	35.00
183	21.92	26.03	33.33	29.81	25.50	20.52	20.15	20.13
Mean	29.17	31.64	43.33	34.81	34.71	28.18	27.97	27.96
STD	6.14	5.34	8.61	5.06	7.97	6.52	6.54	6.55
	Area Category = 3 and Fractal Category = 3							
6	38.91	42.43	60.00	46.31	46.93	37.48	36.87	36.90
9	28.67	31.45	46.67	35.43	32.74	27.16	26.45	26.45
93	41.77	42.69	60.00	48.07	50.33	40.91	40.83	40.80
96	28.48	31.45	43.33	36.06	33.17	27.51	27.44	27.40
100	30.41	33.33	43.33	36.06	35.94	29.63	29.47	29.48
108	29.11	30.73	43.33	34.32	34.64	27.85	27.34	27.30
114	35.04	40.28	53.33	46.43	42.38	34.57	33.91	33.90
130	31.84	33.99	46.67	38.01	38.15	31.11	30.86	30.90
132	51.34	52.70	70.00	56.96	58.35	50.21	49.55	49.60
141	57.93	58.31	80.00	64.12	72.47	57.44	57.38	57.40
143	35.50	37.05	50.00	42.16	41.71	34.27	33.91	33.90

Appendix D. Polygon Third Quartile (75%) for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 3 and Fractal Category = 3 (continued)							
153	43.30	47.38	66.67	49.78	51.64	42.86	42.48	42.50
154	53.44	54.26	73.33	61.37	64.32	52.36	51.87	51.90
172	35.16	36.82	53.33	40.69	42.34	34.59	34.52	34.50
173	35.84	37.27	50.00	42.69	42.05	34.34	34.19	34.20
184	35.61	38.01	50.00	43.46	41.73	34.28	34.25	34.28
203	38.48	40.55	56.67	45.34	46.19	38.01	37.84	37.80
213	44.13	46.67	66.67	52.70	52.40	43.23	43.14	43.10
Mean	38.61	40.85	56.30	45.55	45.97	37.66	37.35	37.35
STD	8.66	8.20	11.14	8.80	10.82	8.76	8.77	8.78
	Area Category = 3 and Fractal Category = 4							
7	28.33	30.73	43.33	34.80	33.56	27.13	26.72	26.70
36	40.03	42.43	60.00	46.31	46.59	39.18	38.79	38.80
67	46.34	47.38	63.33	52.70	54.10	45.54	45.22	45.20
127	34.20	36.75	50.00	43.01	40.47	33.49	33.75	33.75
129	64.72	64.03	90.00	71.57	76.23	64.17	64.13	64.10
131	47.76	49.22	66.67	54.26	54.77	47.08	46.78	46.80
151	33.54	35.90	46.67	40.14	39.48	32.15	31.94	31.90
230	43.24	44.72	60.00	50.88	51.69	41.85	41.76	41.80
Mean	42.27	43.89	60.00	49.21	49.61	41.32	41.14	41.13
STD	11.29	10.26	14.69	11.19	13.16	11.49	11.53	11.53
	Area Category = 3 and Fractal Category = 5							
1	46.93	49.55	70.00	53.95	56.77	45.34	44.78	44.80
3	38.89	40.62	63.33	45.10	44.39	37.10	36.76	36.75
24	22.67	24.04	38.34	30.73	25.46	21.34	20.74	20.75
26	17.95	19.44	34.17	28.53	21.24	16.91	16.84	16.83
74	65.38	66.23	93.33	71.34	77.19	65.33	65.34	65.33
120	38.01	40.14	53.33	42.69	46.19	37.24	37.30	37.30
158	84.82	85.37	116.67	94.39	100.89	84.09	84.06	84.08
186	62.61	64.12	90.00	71.57	75.19	61.55	61.13	61.10
Mean	47.16	48.69	69.90	54.79	55.91	46.11	45.87	45.87
STD	22.66	22.34	28.61	22.78	27.27	22.92	23.00	23.00

Appendix D. Polygon Third Quartile (75%) for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 3 and Fractal Category = 6							
71	55.40	55.26	76.67	61.19	66.02	54.34	54.20	54.20
105	27.74	28.67	43.33	33.33	32.07	26.31	25.95	25.93
Mean	41.57	41.96	60.00	47.26	49.04	40.33	40.07	40.06
STD	19.56	18.80	23.57	19.70	24.00	19.82	19.97	19.99
	Area Category = 4 and Fractal Category = 2							
190	34.36	35.90	50.00	40.28	40.20	33.73	33.58	33.60
	Area Category = 4 and Fractal Category = 5							
139	31.84	34.32	46.67	40.14	37.47	30.85	30.65	30.70
	Area Category = 4 and Fractal Category = 6							
10	51.48	52.70	73.33	57.54	62.04	50.18	50.54	50.50
137	26.93	30.73	43.33	34.80	31.58	25.89	25.47	25.45
Mean	39.21	41.72	58.33	46.17	46.81	38.04	38.01	37.98
STD	17.36	15.54	21.21	16.08	21.54	17.18	17.73	17.71
	Area Category = 5 and Fractal Category = 2							
35	35.63	37.27	50.00	41.77	42.46	34.59	34.36	34.40

APPENDIX E

MINIMUM SLOPE VALUE OF THE POLYGON FOR THE DIFFERENT SLOPE METHODS

Appendix E. Minimum Slope Value of the Polygon for the Different Slope Methods

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 1							
34	12.13	7.45	26.67	24.27	12.58	8.50	6.69	6.70
65	14.91	10.00	23.33	18.86	18.60	14.55	14.44	14.40
72	5.00	7.45	23.33	20.28	9.65	6.87	7.56	7.60
75	15.37	3.33	23.33	21.34	15.46	13.55	12.97	13.00
80	1.67	3.33	13.33	10.54	5.00	2.95	3.73	3.70
85	2.36	3.33	23.33	17.95	7.26	4.75	5.56	5.60
92	12.13	12.02	26.67	21.34	18.63	15.32	16.41	16.40
95	15.37	3.33	23.33	22.36	15.72	11.93	10.79	10.80
126	22.42	13.33	30.00	26.03	29.15	23.69	22.84	22.80
163	18.41	12.02	40.00	27.49	28.04	23.01	24.55	24.50
164	15.37	12.02	26.67	24.27	18.33	14.92	14.79	14.80
196	0.00	3.33	10.00	3.33	1.18	0.59	0.79	0.80
241	3.33	3.33	6.67	7.45	4.86	1.18	1.67	1.70
Mean	10.65	7.25	22.82	18.89	14.19	10.91	10.98	10.98
STD	7.28	4.13	8.70	7.37	8.60	7.59	7.57	7.55
	Area Category = 1 and Fractal Category = 2							
4	5.00	7.45	23.33	17.95	9.50	6.90	7.56	7.60
55	7.07	6.67	13.33	12.02	11.55	8.98	8.68	8.70
56	10.67	7.45	16.67	17.00	16.58	12.69	12.69	12.70
58	3.33	3.33	13.33	13.74	5.27	4.17	4.48	4.50
61	9.43	3.33	20.00	14.91	9.72	8.33	8.01	8.00
70	5.00	7.45	23.33	19.44	9.65	6.87	7.56	7.60
73	0.00	9.43	16.67	14.14	3.73	1.86	2.48	2.50
77	21.08	16.67	30.00	26.87	23.36	21.80	21.57	21.60
83	2.36	3.33	16.67	9.43	5.27	3.33	3.93	3.90
84	10.67	0.00	16.67	16.67	12.53	10.42	9.51	9.50
89	11.79	12.02	23.33	14.14	17.44	13.55	14.14	14.10
101	13.44	9.43	20.00	21.08	16.33	14.59	14.96	15.00
111	10.54	4.71	23.33	19.44	15.32	12.15	13.02	13.00
113	8.50	6.67	16.67	16.67	13.79	9.72	9.89	9.90
117	23.21	22.36	26.67	24.27	26.30	23.33	23.33	23.30

Appendix E. Minimum Slope Value of the Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 2 (continued)							
121	1.67	0.00	13.33	9.43	4.86	1.77	2.78	2.80
135	2.36	3.33	13.33	10.54	6.12	4.49	4.75	4.70
142	3.73	4.71	13.33	9.43	6.77	3.77	4.48	4.50
144	6.87	3.33	16.67	12.02	8.90	5.92	6.21	6.20
145	2.36	3.33	16.67	7.45	6.87	4.49	5.27	5.30
147	6.87	4.71	20.00	16.67	10.21	9.20	8.33	8.30
165	1.67	0.00	13.33	7.45	2.04	1.18	1.24	1.20
174	1.67	0.00	13.33	3.33	3.73	1.77	1.24	1.20
185	0.00	3.33	16.67	12.02	5.27	3.17	2.00	2.00
193	3.33	0.00	13.33	7.45	6.77	3.95	3.24	3.20
195	1.67	0.00	10.00	3.33	5.77	2.12	2.00	2.00
198	10.00	3.33	20.00	16.67	10.61	8.37	7.86	7.90
199	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
202	14.91	13.74	23.33	19.44	18.60	14.55	14.44	14.40
204	1.67	0.00	10.00	3.33	5.77	2.12	2.83	2.80
210	3.33	3.33	10.00	12.02	4.86	0.83	1.24	1.20
217	0.00	3.33	6.67	4.71	4.08	1.32	0.00	0.00
219	16.67	12.02	26.67	19.44	21.34	17.72	17.89	17.90
232	5.27	3.33	20.00	7.45	7.73	4.75	3.73	3.70
Mean	6.62	5.33	16.93	12.91	9.87	7.33	7.36	7.36
STD	6.06	5.26	6.25	6.44	6.38	6.07	6.10	6.10
	Area Category = 1 and Fractal Category = 3							
15	6.01	3.33	16.67	16.67	7.91	7.10	7.31	7.30
29	6.01	3.33	20.00	14.91	6.01	3.77	3.73	3.70
40	11.79	7.45	16.67	14.91	15.77	11.33	11.25	11.20
50	6.01	3.33	20.00	17.95	6.87	6.35	5.47	5.50
52	8.50	6.67	23.33	14.14	8.66	6.87	6.33	6.30
64	12.69	3.33	26.67	24.27	14.14	2.95	2.78	2.80
76	0.00	3.33	10.00	4.71	4.71	1.67	1.57	1.60
94	3.33	6.67	20.00	14.14	8.33	5.34	5.91	5.90
97	13.44	9.43	23.33	19.44	18.89	15.72	16.49	16.50

Appendix E. Minimum Slope Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 3 (continued)							
146	4.71	3.33	20.00	13.33	4.86	3.95	3.93	3.90
155	3.33	4.71	10.00	7.45	8.90	7.07	7.03	7.00
157	3.33	0.00	13.33	9.43	4.86	1.86	2.22	2.20
159	1.67	0.00	13.33	16.67	6.01	4.25	3.89	3.90
167	3.33	4.71	10.00	9.43	3.54	1.77	1.76	1.80
170	1.67	3.33	10.00	7.45	2.89	1.18	0.56	0.60
179	1.67	0.00	10.00	3.33	1.67	0.83	0.56	0.60
191	1.67	0.00	10.00	7.45	4.08	1.86	2.00	2.00
201	3.73	3.33	10.00	10.54	4.08	1.86	2.00	2.00
208	1.67	3.33	10.00	7.45	2.64	1.77	1.24	1.20
226	10.54	9.43	26.67	25.39	11.61	10.03	10.00	10.00
227	6.01	3.33	13.33	7.45	7.82	5.07	3.33	3.30
231	3.73	7.45	20.00	14.91	7.55	5.56	6.21	6.20
233	4.71	0.00	10.00	4.71	4.71	3.00	2.48	2.50
240	1.67	4.71	16.67	7.45	7.45	4.17	5.24	5.20
243	6.01	0.00	20.00	16.67	7.73	6.37	6.69	6.70
Mean	5.09	3.78	16.00	12.41	7.27	4.87	4.80	4.80
STD	3.71	2.87	5.69	5.91	4.16	3.55	3.72	3.71
	Area Category = 1 and Fractal Category = 4							
8	1.67	3.33	13.33	16.67	2.04	0.59	0.56	0.60
19	5.27	4.71	16.67	13.74	9.20	5.83	4.04	4.00
20	1.67	0.00	13.33	4.71	2.64	1.32	1.24	1.20
38	1.67	3.33	16.67	12.02	1.67	1.32	1.24	1.20
68	5.27	0.00	13.33	10.54	6.12	4.49	4.23	4.20
69	3.33	0.00	10.00	7.45	4.08	3.17	2.78	2.80
79	1.67	3.33	10.00	7.45	4.86	0.00	0.00	0.00
91	3.33	3.33	10.00	9.43	5.53	3.58	3.14	3.10
106	1.67	0.00	23.33	10.54	7.55	5.03	5.80	5.80
122	10.54	12.02	16.67	16.67	16.12	14.55	15.41	15.40
138	5.00	3.33	20.00	17.95	5.14	1.86	0.79	0.80
160	6.87	3.33	16.67	12.02	7.26	6.72	6.78	6.80

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 4 (continued)							
169	3.73	3.33	23.33	16.67	3.73	2.12	1.67	1.70
176	6.87	3.33	16.67	13.74	6.87	5.56	5.47	5.50
194	7.45	24.27	46.67	32.83	8.90	7.75	7.90	7.90
200	7.45	10.54	16.67	14.14	8.90	7.12	7.03	7.00
207	3.33	0.00	10.00	7.45	5.27	0.59	1.76	1.80
209	3.33	10.54	13.33	12.02	4.86	1.86	2.22	2.20
211	3.73	0.00	10.00	12.02	5.53	1.18	0.79	0.80
212	12.69	6.67	20.00	16.67	18.37	14.84	15.73	15.70
221	1.67	3.33	20.00	20.28	5.00	3.00	3.38	3.40
223	1.67	4.71	16.67	12.02	2.64	1.18	0.79	0.80
228	5.27	6.67	20.00	16.67	7.73	4.75	3.73	3.70
229	5.27	3.33	13.33	16.67	6.87	4.71	4.78	4.80
238	12.13	14.91	30.00	21.34	15.68	13.60	14.20	14.20
Mean	4.90	5.13	17.47	14.07	6.90	4.67	4.62	4.62
STD	3.24	5.64	7.83	5.72	4.26	4.25	4.52	4.52
	Area Category = 1 and Fractal Category = 5							
13	1.67	0.00	6.67	6.67	3.91	1.18	2.00	2.00
22	0.00	3.33	13.33	9.43	1.67	0.83	1.11	1.10
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	3.33	3.33	10.00	4.71	3.91	1.18	1.11	1.10
31	0.00	0.00	10.00	0.00	2.36	0.59	0.00	0.00
47	0.00	0.00	10.00	7.45	3.73	1.32	1.24	1.20
133	5.00	4.71	13.33	14.14	7.45	5.56	4.75	4.70
171	1.67	3.33	13.33	14.14	1.67	1.32	1.24	1.20
175	2.36	3.33	10.00	10.54	2.89	1.18	1.76	1.80
215	10.14	14.91	16.67	17.00	12.96	10.87	10.96	11.00
235	10.00	6.67	23.33	13.33	10.67	8.25	7.47	7.50
236	6.87	10.00	10.00	14.14	6.87	2.95	2.29	2.30
Mean	3.16	3.82	10.51	8.58	4.47	2.71	2.61	2.61
STD	3.74	4.51	6.21	6.00	3.97	3.40	3.26	3.28

Appendix E. Minimum Slope Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 6							
14	1.67	0.00	10.00	9.43	2.36	1.32	0.79	0.80
53	8.33	4.71	13.33	9.43	10.00	8.44	8.20	8.20
57	10.54	12.02	16.67	14.91	15.63	10.82	11.18	11.20
87	3.33	0.00	10.00	9.43	5.53	3.58	3.14	3.10
116	3.73	3.33	13.33	13.74	4.86	4.17	3.51	3.50
234	31.71	21.34	53.33	37.27	33.75	30.64	29.62	29.60
239	3.33	4.71	13.33	10.54	5.27	2.43	1.11	1.10
242	16.41	14.91	36.67	26.87	21.44	16.21	16.15	16.10
Mean	9.88	7.63	20.83	16.45	12.36	9.70	9.21	9.20
STD	10.09	7.67	15.71	10.24	10.75	9.82	9.82	9.82
	Area Category = 2 and Fractal Category = 1							
62	4.71	3.33	10.00	7.45	5.14	2.43	2.78	2.80
118	12.02	3.33	23.33	17.00	16.87	13.04	12.20	12.20
181	2.36	0.00	10.00	7.45	3.91	2.95	3.14	3.10
197	1.67	0.00	10.00	9.43	6.12	1.67	2.99	3.00
225	1.67	0.00	13.33	3.33	7.73	3.73	4.48	4.50
Mean	4.49	1.33	13.33	8.93	7.95	4.76	5.12	5.12
STD	4.39	1.82	5.77	5.03	5.18	4.69	4.01	4.01
	Area Category = 2 and Fractal Category = 2							
2	1.67	0.00	13.33	12.02	4.86	3.44	3.93	3.90
5	6.01	3.33	16.67	17.00	7.07	5.89	4.97	5.00
37	6.67	3.33	13.33	13.74	9.72	6.01	6.01	6.00
44	0.00	0.00	10.00	10.54	3.73	2.12	1.57	1.60
45	2.36	0.00	13.33	4.71	2.89	0.59	1.11	1.10
46	1.67	3.33	13.33	10.54	2.36	1.86	2.00	2.00
48	5.27	3.33	23.33	18.86	6.12	5.07	5.03	5.00
60	16.50	23.57	43.33	37.27	19.26	16.01	15.89	15.90
78	5.00	3.33	16.67	12.02	8.90	8.01	8.20	8.20
81	1.67	0.00	13.33	4.71	5.89	4.60	4.78	4.80
82	2.36	4.71	10.00	10.00	2.36	1.32	1.11	1.10
90	1.67	4.71	20.00	13.74	5.00	3.33	3.89	3.90

Appendix E. Minimum Slope Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 2 (continued)							
98	1.67	3.33	20.00	14.91	6.01	3.54	4.34	4.30
102	3.33	0.00	13.33	7.45	6.01	2.12	1.24	1.20
104	8.98	6.67	26.67	10.54	13.44	11.12	11.88	11.90
112	7.07	7.45	23.33	17.95	9.65	7.75	8.01	8.00
124	1.67	3.33	23.33	10.54	3.73	3.17	2.99	3.00
125	2.36	0.00	13.33	14.14	4.86	2.43	2.78	2.80
148	1.67	3.33	10.00	10.54	7.45	6.07	6.50	6.50
150	0.00	0.00	10.00	10.54	2.36	1.77	1.57	1.60
161	3.33	0.00	10.00	9.43	3.54	1.77	1.76	1.80
162	2.36	13.33	23.33	13.74	2.36	1.86	1.76	1.80
177	2.36	0.00	13.33	9.43	2.89	2.12	2.22	2.20
178	5.00	3.33	13.33	10.54	7.55	5.43	3.93	3.90
180	0.00	0.00	10.00	7.45	4.86	2.43	3.24	3.20
187	7.45	9.43	20.00	14.91	8.90	7.75	7.90	7.90
188	1.67	0.00	10.00	7.45	6.12	4.71	4.48	4.50
214	3.73	0.00	13.33	7.45	5.00	3.73	4.04	4.00
218	1.67	3.33	6.67	7.45	4.08	3.00	2.78	2.80
220	3.33	3.33	10.00	10.54	4.71	1.32	0.79	0.80
Mean	3.62	3.55	15.89	12.01	6.06	4.34	4.36	4.36
STD	3.34	4.95	7.36	5.93	3.62	3.30	3.37	3.37
	Area Category = 2 and Fractal Category = 3							
12	2.36	3.33	10.00	10.54	5.27	1.32	0.79	0.80
43	0.00	3.33	13.33	12.02	3.73	1.32	2.29	2.30
49	1.67	0.00	10.00	7.45	3.73	1.67	1.24	1.20
51	1.67	0.00	20.00	10.54	3.73	1.18	1.11	1.10
59	6.87	3.33	16.67	13.74	9.72	8.33	8.01	8.00
86	1.67	6.67	23.33	10.54	2.04	1.18	1.24	1.20
103	1.67	3.33	20.00	4.71	2.04	1.32	1.24	1.20
109	6.01	0.00	16.67	16.67	8.66	6.01	5.50	5.50
115	1.67	3.33	10.00	4.71	3.91	1.67	2.29	2.30
128	1.67	3.33	10.00	4.71	2.64	1.77	2.00	2.00

Appendix E. Minimum Slope Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 3 (continued)							
134	3.73	4.71	13.33	9.43	5.27	4.49	4.75	4.70
140	6.87	6.67	26.67	17.95	10.61	8.19	6.50	6.50
182	9.43	4.71	20.00	17.95	14.58	12.98	12.53	12.50
189	2.36	0.00	10.00	10.54	3.73	1.77	1.24	1.20
205	1.67	3.33	16.67	12.02	5.00	2.64	3.38	3.40
216	1.67	3.33	16.67	16.67	5.00	3.00	3.56	3.60
Mean	3.19	3.09	15.83	11.26	5.60	3.68	3.60	3.59
STD	2.64	2.15	5.24	4.50	3.50	3.47	3.21	3.21
	Area Category = 2 and Fractal Category = 4							
17	1.67	0.00	10.00	7.45	2.36	0.83	0.79	0.80
27	0.00	3.33	6.67	4.71	2.36	1.18	1.11	1.10
32	1.67	3.33	13.33	10.54	5.00	3.33	3.89	3.90
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	1.67	3.33	30.00	16.67	4.25	2.64	1.57	1.60
42	2.36	0.00	16.67	13.33	2.36	1.32	1.11	1.10
88	0.00	3.33	13.33	13.74	4.86	2.43	3.24	3.20
110	1.67	3.33	10.00	7.45	5.27	1.77	0.00	0.00
123	13.44	4.71	23.33	24.04	16.12	13.36	13.44	13.40
136	12.69	3.33	26.67	14.91	16.58	13.45	13.74	13.70
149	3.33	0.00	6.67	7.45	3.54	1.32	1.76	1.80
156	5.27	6.67	20.00	14.91	5.53	3.95	3.51	3.50
168	1.67	3.33	10.00	7.45	2.04	1.18	0.56	0.60
192	0.00	0.00	13.33	10.00	4.86	1.32	2.22	2.20
206	2.36	3.33	13.33	10.54	5.00	3.73	4.04	4.00
222	7.45	3.33	13.33	12.02	9.72	7.45	6.71	6.70
Mean	3.45	2.58	14.17	10.95	5.62	3.70	3.61	3.60
STD	4.25	1.99	7.75	5.53	4.70	4.17	4.28	4.26
	Area Category = 2 and Fractal Category = 5							
11	1.67	0.00	10.00	7.45	2.89	1.86	2.22	2.20
16	1.67	0.00	10.00	12.02	4.71	2.36	2.36	2.40
18	1.67	0.00	13.33	9.43	2.89	1.18	1.24	1.20

Appendix E. Minimum Slope Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 5 (continued)							
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	3.73	0.00	10.00	4.71	4.08	3.17	2.99	3.00
107	1.67	3.33	10.00	7.45	3.54	2.50	2.22	2.20
119	7.07	3.33	16.67	12.02	11.67	8.70	8.33	8.30
Mean	2.50	0.95	10.00	7.58	4.25	2.82	2.77	2.76
STD	2.29	1.62	5.09	4.25	3.60	2.79	2.64	2.63
	Area Category = 2 and Fractal Category = 6							
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	5.27	4.71	10.00	12.02	6.01	4.29	4.04	4.00
166	1.67	0.00	10.00	7.45	1.67	1.32	1.24	1.20
Mean	2.31	1.57	6.67	6.49	2.56	1.87	1.76	1.73
STD	2.69	2.72	5.77	6.07	3.10	2.20	2.07	2.05
	Area Category = 3 and Fractal Category = 2							
54	1.67	3.33	10.00	7.45	4.86	3.17	3.24	3.20
63	6.87	4.71	20.00	13.33	10.93	8.98	8.78	8.80
152	8.50	7.45	20.00	16.67	11.73	8.37	8.50	8.50
183	1.67	0.00	10.00	7.45	4.08	1.18	2.00	2.00
Mean	4.68	3.87	15.00	11.23	7.90	5.43	5.63	5.63
STD	3.54	3.10	5.77	4.57	3.99	3.85	3.51	3.53
	Area Category = 3 and Fractal Category = 3							
6	1.67	3.33	13.33	7.45	2.04	0.59	0.56	0.60
9	1.67	0.00	10.00	7.45	4.86	2.95	2.83	2.80
93	1.67	3.33	10.00	9.43	1.67	1.32	1.24	1.20
96	0.00	0.00	13.33	4.71	3.54	0.59	2.00	2.00
100	2.36	3.33	16.67	9.43	2.89	1.67	1.76	1.80
108	2.36	0.00	16.67	9.43	3.91	2.43	3.51	3.50
114	1.67	3.33	16.67	13.74	8.42	6.72	7.24	7.20
130	1.67	0.00	6.67	3.33	2.89	0.59	0.56	0.60
132	3.33	6.67	16.67	14.14	4.86	3.33	2.99	3.00
141	3.73	4.71	16.67	12.02	5.77	2.50	2.99	3.00
143	0.00	0.00	10.00	4.71	2.36	0.59	0.00	0.00

Appendix E. Minimum Slope Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 3 and Fractal Category = 3 (continued)							
153	7.07	3.33	13.33	13.74	11.12	8.84	8.50	8.50
154	2.36	0.00	16.67	12.02	8.33	4.71	3.56	3.60
172	5.27	0.00	13.33	14.14	6.12	3.73	5.03	5.00
173	0.00	0.00	6.67	7.45	4.86	1.32	1.24	1.20
184	3.33	0.00	10.00	9.43	5.27	3.17	2.48	2.50
203	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
213	1.67	3.33	13.33	9.43	3.73	2.64	2.29	2.30
Mean	2.16	1.69	12.17	8.95	4.54	2.59	2.65	2.66
STD	1.95	2.21	4.73	4.15	2.82	2.38	2.39	2.38
	Area Category = 3 and Fractal Category = 4							
7	0.00	0.00	6.67	3.33	2.04	0.83	1.24	1.20
36	1.67	0.00	13.33	12.02	3.33	1.32	0.79	0.80
67	1.67	0.00	13.33	10.00	3.91	1.67	2.29	2.30
127	1.67	0.00	10.00	7.45	2.64	1.77	2.00	2.00
129	0.00	3.33	10.00	7.45	4.25	2.95	3.38	3.40
131	1.67	3.33	10.00	7.45	4.86	0.83	0.56	0.60
151	3.73	3.33	16.67	12.02	3.73	1.32	2.00	2.00
230	3.33	3.33	13.33	12.02	8.16	3.73	2.78	2.80
Mean	1.72	1.67	11.67	8.97	4.12	1.80	1.88	1.89
STD	1.34	1.78	3.09	3.11	1.86	1.03	0.97	0.97
	Area Category = 3 and Fractal Category = 5							
1	0.00	0.00	16.67	10.54	5.27	2.64	2.48	2.50
3	1.67	3.33	10.00	4.71	2.36	0.83	0.79	0.80
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	20.34	13.33	33.33	24.04	25.87	20.63	20.43	20.40
120	6.01	7.45	16.67	16.67	8.66	6.51	6.67	6.70
158	16.50	3.33	30.00	30.73	25.25	19.48	20.49	20.50
186	3.73	0.00	13.33	12.02	3.73	1.77	1.24	1.20
Mean	6.03	3.43	15.00	12.34	8.89	6.48	6.51	6.51
STD	8.00	4.80	12.21	11.08	10.67	8.64	8.87	8.87

Appendix E. Minimum Slope Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 3 and Fractal Category = 6							
71	2.36	0.00	13.33	10.54	2.36	1.32	1.11	1.10
105	1.67	0.00	6.67	7.45	3.54	1.67	2.00	2.00
Mean	2.02	0.00	10.00	9.00	2.95	1.50	1.56	1.55
STD	0.49	0.00	4.71	2.18	0.83	0.25	0.63	0.64
	Area Category = 4 and Fractal Category = 2							
190	0.00	0.00	3.33	3.33	2.04	0.59	0.56	0.60
	Area Category = 4 and Fractal Category = 5							
139	0.00	0.00	3.33	3.33	2.36	0.83	1.57	1.60
	Area Category = 4 and Fractal Category = 6							
10	1.67	0.00	13.33	12.02	5.27	2.50	2.99	3.00
137	0.00	0.00	3.33	0.00	1.67	0.00	0.00	0.00
Mean	0.84	0.00	8.33	6.01	3.47	1.25	1.50	1.50
STD	1.18	0.00	7.07	8.50	2.55	1.77	2.11	2.12
	Area Category = 5 and Fractal Category = 2							
35	1.67	0.00	6.67	4.71	1.67	0.83	0.56	0.60

APPENDIX F

MAXIMUM SLOPE VALUE OF THE POLYGON FOR THE DIFFERENT SLOPE METHODS

Appendix F. Maximum Slope Value of the Polygon for the Different Slope Methods

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 1							
34	74.33	91.04	106.67	91.04	93.82	71.95	71.16	71.20
65	37.27	43.46	56.67	46.43	40.47	35.87	35.45	35.50
72	46.43	50.77	66.67	50.77	58.63	44.97	44.79	44.80
75	40.14	44.47	60.00	52.70	49.82	37.94	37.48	37.50
80	42.20	46.43	56.67	47.73	48.99	38.41	37.19	37.20
85	52.31	55.18	73.33	58.31	65.17	50.31	49.80	49.80
92	45.98	50.44	70.00	54.26	56.79	45.39	45.96	46.00
95	53.44	59.07	66.67	59.07	63.99	51.67	51.11	51.10
126	54.82	67.49	80.00	68.72	67.61	51.16	49.94	49.90
163	74.48	75.57	106.67	76.01	85.71	72.77	72.20	72.20
164	71.80	75.57	106.67	77.53	85.71	70.83	71.23	71.20
196	29.49	33.33	43.33	40.14	34.03	26.17	25.30	25.30
241	58.33	64.72	90.00	64.72	70.64	58.33	58.33	58.30
Mean	52.39	58.27	75.64	60.57	63.18	50.44	50.00	50.00
STD	14.35	16.07	21.06	14.51	17.89	14.72	14.86	14.85
	Area Category = 1 and Fractal Category = 2							
4	81.26	91.04	113.33	92.44	105.20	79.46	79.96	80.00
55	35.04	43.46	50.00	43.46	43.56	35.04	35.04	35.00
56	33.75	38.87	53.33	40.14	42.88	32.73	32.39	32.40
58	51.34	52.70	73.33	52.70	62.04	48.92	48.12	48.10
61	63.46	68.39	96.67	73.11	76.30	62.17	61.74	61.70
70	51.77	56.67	60.00	57.54	59.27	49.42	49.09	49.10
73	37.79	42.43	56.67	43.46	46.23	37.20	37.00	37.00
77	69.36	72.11	100.00	76.01	87.88	68.07	68.26	68.30
83	54.67	59.63	80.00	66.67	59.68	52.70	52.08	52.10
84	68.39	70.71	100.00	73.11	79.87	66.65	66.07	66.10
89	45.28	46.67	56.67	48.53	55.11	43.16	42.46	42.50
101	32.87	29.81	53.33	37.71	37.62	33.05	33.13	33.10
111	54.59	58.31	76.67	59.35	67.18	51.90	51.36	51.40
113	61.28	63.25	80.00	67.08	74.47	57.26	55.92	55.90
117	56.03	68.72	86.67	68.72	71.55	54.49	53.98	54.00

Appendix F. Maximum Slope Value of the Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 2 (continued)							
121	42.16	57.06	56.67	59.07	42.83	41.94	41.88	41.90
135	33.33	40.14	53.33	40.14	41.40	33.02	33.01	33.00
142	76.74	73.64	106.67	80.28	89.39	70.43	68.34	68.30
144	45.98	50.00	70.00	55.18	52.61	40.73	38.99	39.00
145	27.49	36.06	50.00	40.14	34.01	26.15	26.12	26.10
147	42.49	47.14	60.00	54.67	46.23	41.55	41.25	41.20
165	50.03	57.06	60.00	58.21	58.03	47.09	46.12	46.10
174	124.91	164.18	226.67	231.42	124.91	106.43	102.22	102.20
185	69.06	63.25	96.67	88.57	78.27	67.34	67.04	67.00
193	26.87	30.18	43.33	33.00	30.75	23.88	22.88	22.90
195	34.80	42.43	43.33	42.43	34.80	30.05	30.39	30.40
198	50.69	53.85	80.00	62.89	61.51	49.46	49.53	49.50
199	56.67	59.63	80.00	62.89	61.60	53.18	52.03	52.00
202	54.21	50.88	86.67	66.00	62.92	51.32	50.38	50.40
204	32.06	34.32	46.67	37.27	33.40	27.42	27.90	27.90
210	41.80	60.83	63.33	64.38	47.30	35.16	33.89	33.90
217	40.14	44.85	63.33	56.76	45.23	36.54	36.54	36.50
219	46.93	48.53	63.33	52.17	58.71	44.54	43.75	43.70
232	63.42	69.36	93.33	69.36	76.50	59.53	59.30	59.30
Mean	51.67	57.24	75.88	63.38	60.27	48.76	48.18	48.18
STD	19.11	23.38	33.00	33.17	21.32	17.22	16.78	16.78
	Area Category = 1 and Fractal Category = 3							
15	41.77	49.22	63.33	52.70	51.22	39.43	39.27	39.30
29	48.59	66.67	76.67	66.67	63.80	49.03	49.17	49.20
40	51.34	54.97	66.67	56.76	62.32	50.53	50.26	50.30
50	62.41	68.72	90.00	68.72	69.40	58.61	57.35	57.30
52	45.03	51.85	66.67	51.85	55.91	44.34	44.11	44.10
64	88.58	138.12	136.67	152.06	103.03	74.95	70.51	70.50
76	47.14	52.70	70.00	62.00	53.03	44.34	43.47	43.50
94	41.67	49.55	63.33	53.75	51.02	41.85	42.05	42.10
97	50.44	51.75	63.33	51.75	56.32	47.14	46.04	46.00

Appendix F. Maximum Slope Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 3 (continued)							
146	52.33	69.36	96.67	73.18	65.61	52.02	52.28	52.30
155	47.05	62.27	70.00	62.27	56.48	45.19	44.57	44.60
157	44.72	49.55	63.33	50.77	51.11	40.93	40.65	40.60
159	43.46	48.07	60.00	52.17	48.42	43.01	42.89	42.90
167	46.67	56.76	63.33	58.21	57.23	45.42	45.59	45.60
170	50.99	83.60	113.33	84.39	56.87	50.01	50.20	50.20
179	147.43	325.30	260.00	325.30	160.58	113.29	102.31	102.30
191	36.06	38.87	50.00	40.69	43.49	33.75	33.75	33.70
201	40.31	49.22	63.33	49.22	44.22	37.68	37.91	37.90
208	51.77	60.09	83.33	60.09	61.82	52.81	53.16	53.20
226	139.20	158.46	193.33	163.47	177.17	134.67	133.17	133.20
227	44.00	58.21	66.67	59.63	53.39	41.64	41.29	41.30
231	62.00	66.42	100.00	80.69	73.57	59.68	58.90	58.90
233	63.09	65.74	90.00	68.64	70.50	61.16	61.33	61.30
240	75.30	80.55	126.67	85.18	95.48	73.61	73.05	73.00
243	59.68	63.33	90.00	73.18	65.45	54.21	53.82	53.80
Mean	59.24	76.77	91.47	80.13	69.90	55.57	54.68	54.68
STD	27.84	58.34	47.06	58.64	32.93	23.11	21.69	21.69
	Area Category = 1 and Fractal Category = 4							
8	51.67	59.63	66.67	59.63	64.07	50.01	49.46	49.50
19	49.47	60.09	76.67	65.74	56.48	47.45	47.00	47.00
20	33.50	53.75	70.00	53.75	40.82	31.11	30.62	30.60
38	55.03	60.09	70.00	61.46	64.75	52.96	52.27	52.30
68	46.70	63.33	73.33	65.49	52.82	46.20	46.12	46.10
69	38.37	42.43	53.33	43.46	47.74	36.91	36.79	36.80
79	37.79	42.43	56.67	42.43	46.23	37.20	37.00	37.00
91	32.06	44.72	53.33	44.72	38.51	31.23	31.04	31.00
106	17.72	16.67	36.67	23.57	22.14	17.92	18.03	18.00
122	58.31	62.89	83.33	68.72	58.76	53.75	52.88	52.90
138	49.94	51.75	66.67	53.85	56.08	47.73	46.99	47.00
160	54.82	57.06	76.67	59.63	70.74	53.31	52.82	52.80

Appendix F. Maximum Slope Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 4 (continued)							
169	38.91	49.55	70.00	49.55	43.35	37.42	37.23	37.20
176	74.26	80.62	110.00	89.44	88.71	71.31	70.35	70.30
194	59.49	67.49	83.33	67.49	72.13	54.91	53.47	53.50
200	68.03	81.38	113.33	84.13	77.49	67.75	67.66	67.70
207	42.06	50.11	73.33	55.18	53.20	41.61	41.46	41.50
209	46.96	50.88	70.00	52.70	46.96	45.10	44.48	44.50
211	53.75	70.87	76.67	70.87	61.51	51.17	50.31	50.30
212	48.53	49.55	66.67	55.48	60.00	44.80	43.57	43.60
221	57.28	64.12	70.00	66.42	66.18	52.67	51.19	51.20
223	46.31	49.22	66.67	54.67	54.31	45.02	44.59	44.60
228	74.48	73.11	116.67	82.80	88.59	74.40	74.37	74.40
229	60.67	69.60	86.67	69.60	74.47	56.93	55.87	55.90
238	62.00	66.42	100.00	80.69	67.41	59.68	58.90	58.90
Mean	50.32	57.51	75.47	60.86	58.94	48.34	47.78	47.78
STD	13.21	13.85	18.80	14.84	15.46	12.76	12.61	12.62
	Area Category = 1 and Fractal Category = 5							
13	30.00	32.83	43.33	36.06	34.82	26.68	25.58	25.60
22	78.03	84.85	110.00	84.85	91.84	74.30	73.11	73.10
23	67.27	113.14	100.00	113.14	67.27	55.64	52.17	52.20
25	47.38	71.26	73.33	84.13	49.07	39.13	36.94	36.90
30	36.55	35.43	53.33	40.14	42.34	36.06	36.06	36.10
31	44.13	50.99	56.67	52.70	53.76	41.18	40.75	40.70
47	50.61	53.75	66.67	54.26	61.85	47.38	46.89	46.90
133	62.74	81.17	86.67	81.17	70.36	61.93	61.67	61.70
171	53.44	57.06	70.00	59.07	65.32	52.16	51.74	51.70
175	53.36	63.25	80.00	71.34	61.31	51.03	50.37	50.40
215	55.88	59.07	70.00	61.28	58.31	53.76	53.06	53.10
235	63.09	65.74	90.00	68.64	70.50	61.16	61.33	61.30
236	85.41	128.80	133.33	128.80	103.43	80.81	79.27	79.30
Mean	55.99	69.03	79.49	71.97	63.86	52.40	51.46	51.46
STD	15.51	27.70	24.68	26.78	18.52	15.07	15.00	15.01

Appendix F. Maximum Slope Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 6							
14	41.23	43.46	60.00	47.73	51.11	39.73	39.23	39.20
53	42.16	47.73	60.00	47.73	48.12	41.95	41.92	41.90
57	61.87	69.36	90.00	69.36	65.45	58.53	57.42	57.40
87	30.73	38.01	46.67	38.01	36.67	29.47	29.07	29.10
116	52.17	52.70	73.33	58.97	52.17	47.89	46.46	46.50
234	86.10	99.11	126.67	99.11	101.22	81.49	81.21	81.20
239	45.03	49.22	66.67	52.70	50.04	43.63	43.50	43.50
242	77.55	84.98	96.67	85.70	94.82	73.30	71.97	72.00
Mean	54.61	60.57	77.50	62.41	62.45	52.00	51.35	51.35
STD	19.17	21.76	25.74	20.94	23.35	17.78	17.61	17.61
	Area Category = 2 and Fractal Category = 1							
62	46.93	60.00	60.00	61.46	53.39	44.45	43.62	43.60
118	55.90	60.09	80.00	64.38	70.74	54.04	53.78	53.80
181	55.18	58.21	73.33	61.19	57.88	54.23	53.91	53.90
197	28.38	37.71	46.67	37.71	34.70	28.28	28.28	28.30
225	48.45	53.75	63.33	62.00	62.66	46.29	45.98	46.00
Mean	46.97	53.95	64.67	57.35	55.87	45.46	45.11	45.12
STD	11.12	9.44	12.82	11.05	13.47	10.58	10.47	10.47
	Area Category = 2 and Fractal Category = 2							
2	55.40	65.74	76.67	65.74	64.07	51.76	51.07	51.10
5	71.57	86.67	113.33	86.67	84.75	67.34	67.37	67.40
37	55.40	107.13	110.00	116.43	70.45	48.59	50.44	50.40
44	48.79	71.26	70.00	72.80	56.61	42.90	42.20	42.20
45	41.67	50.00	63.33	52.70	48.92	38.48	37.60	37.60
46	46.96	52.07	70.00	52.70	51.96	45.66	45.23	45.20
48	59.74	65.66	83.33	65.66	78.06	59.97	60.04	60.00
60	85.00	88.76	116.67	88.76	106.37	82.01	81.01	81.00
78	50.03	56.67	70.00	57.54	62.78	48.10	47.56	47.60
81	42.69	51.75	63.33	51.75	52.61	40.32	39.71	39.70
82	51.13	57.54	83.33	68.72	66.33	50.77	50.77	50.80
90	52.07	80.62	93.33	87.24	62.78	48.10	47.56	47.60

Appendix F. Maximum Slope Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 2 (continued)							
98	50.14	56.96	70.00	56.96	63.17	48.61	48.59	48.60
102	55.88	58.97	83.33	63.68	68.15	51.39	51.17	51.20
104	70.26	71.96	96.67	77.75	84.14	66.76	65.61	65.60
112	55.90	80.14	80.00	80.14	70.74	54.04	53.78	53.80
124	65.93	68.72	90.00	69.60	71.50	63.54	62.75	62.70
125	68.52	73.11	103.33	75.57	82.46	64.95	63.76	63.80
148	47.38	50.00	70.00	52.07	54.61	45.43	45.22	45.20
150	38.33	56.76	56.67	57.54	47.64	35.25	34.56	34.60
161	76.83	82.80	110.00	84.13	97.80	75.48	75.21	75.20
162	51.45	55.48	76.67	58.31	64.70	50.31	50.59	50.60
177	34.36	42.69	60.00	45.34	38.89	33.38	33.06	33.10
178	55.70	60.37	80.00	62.27	64.47	53.70	53.52	53.50
180	61.87	64.12	80.00	66.42	73.48	60.59	60.16	60.20
187	59.49	67.49	76.67	67.49	72.13	54.91	53.39	53.40
188	53.75	73.64	83.33	73.64	60.93	52.68	52.33	52.30
214	46.79	50.11	60.00	51.85	53.39	43.91	42.95	43.00
218	52.97	65.66	80.00	65.66	62.78	48.89	48.79	48.80
220	73.18	77.75	113.33	77.75	84.75	72.32	72.03	72.00
Mean	55.97	66.35	82.78	68.43	67.38	53.34	52.93	52.94
STD	11.64	14.23	17.33	14.93	14.85	11.69	11.64	11.63
	Area Category = 2 and Fractal Category = 3							
12	55.40	62.89	93.33	62.89	70.74	53.85	53.70	53.70
43	52.31	52.70	73.33	58.31	62.66	48.59	47.35	47.40
49	73.67	82.80	113.33	82.80	93.04	72.36	71.93	71.90
51	67.54	73.79	90.00	73.79	85.40	65.89	65.89	65.90
59	65.93	68.72	90.00	74.54	78.93	64.33	63.79	63.80
86	52.31	55.88	73.33	59.63	65.17	50.31	49.80	49.80
103	55.03	62.89	80.00	62.89	68.66	53.86	53.48	53.50
109	49.02	52.70	70.00	54.26	61.17	48.34	48.12	48.10
115	59.11	64.38	100.00	66.16	76.05	58.36	58.57	58.60
128	55.70	62.00	86.67	62.00	70.33	55.70	55.70	55.70

Appendix F. Maximum Slope Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 3 (continued)							
134	86.47	149.26	140.00	149.26	95.98	71.42	66.81	66.80
140	86.04	149.07	133.33	149.07	97.98	74.86	71.69	71.70
182	45.77	51.75	63.33	53.85	59.17	45.33	45.27	45.30
189	57.47	60.09	73.33	60.09	60.31	56.40	56.05	56.00
205	98.56	120.83	126.67	120.83	115.69	89.18	88.36	88.40
216	57.28	64.12	70.00	64.12	66.18	52.67	51.19	51.20
Mean	63.60	77.12	92.29	78.41	76.72	60.09	59.23	59.24
STD	15.18	32.61	24.15	31.89	16.52	11.97	11.51	11.51
	Area Category = 2 and Fractal Category = 4							
17	55.40	54.26	80.00	58.97	68.72	54.85	54.67	54.70
27	61.69	83.53	100.00	87.69	61.69	53.04	50.38	50.40
32	72.80	91.04	106.67	91.04	84.64	64.39	63.49	63.50
33	55.40	77.82	80.00	77.82	57.15	44.92	42.23	42.20
39	66.42	70.08	86.67	71.26	81.85	63.88	63.06	63.10
42	62.83	64.72	90.00	68.64	73.57	62.15	61.94	61.90
88	51.48	53.75	73.33	60.09	61.04	47.53	47.03	47.00
110	58.71	60.09	83.33	64.03	72.63	58.24	58.09	58.10
123	73.11	106.87	126.67	109.19	94.64	72.50	72.56	72.60
136	56.69	58.31	80.00	63.42	66.79	52.93	52.65	52.60
149	61.49	57.35	93.33	68.64	68.73	61.14	61.03	61.00
156	91.67	103.82	136.67	117.85	103.52	81.94	79.04	79.00
168	55.18	58.21	73.33	58.21	55.79	54.23	53.91	53.90
192	68.03	81.38	103.33	82.33	76.02	67.75	67.66	67.70
206	54.26	60.00	73.33	63.25	61.51	51.17	50.31	50.30
222	58.52	67.99	93.33	71.80	73.99	56.18	55.40	55.40
Mean	62.73	71.83	92.50	75.89	72.64	59.18	58.34	58.34
STD	10.08	17.21	18.60	17.76	13.29	9.54	9.58	9.59
	Area Category = 2 and Fractal Category = 5							
11	61.28	68.39	90.00	68.39	72.20	59.51	58.93	58.90
16	34.68	43.46	53.33	43.46	45.28	34.06	34.11	34.10
18	48.10	47.14	63.33	53.75	56.48	42.25	40.51	40.50

Appendix F. Maximum Slope Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 5 (continued)							
28	61.33	92.20	90.00	98.99	61.33	48.92	44.79	44.80
66	46.49	63.33	73.33	65.49	47.93	44.27	43.57	43.60
107	57.98	64.38	73.33	64.38	60.31	55.61	54.82	54.80
119	50.80	56.57	73.33	56.57	63.54	50.80	50.80	50.80
Mean	51.52	62.21	73.81	64.43	58.15	47.92	46.79	46.79
STD	9.61	16.09	13.26	17.45	9.26	8.57	8.59	8.58
	Area Category = 2 and Fractal Category = 6							
21	75.46	122.57	110.00	122.57	75.46	62.05	57.62	57.60
41	69.06	80.62	96.67	80.62	84.38	66.18	65.74	65.70
166	64.33	68.72	96.67	68.72	72.28	63.00	62.56	62.60
Mean	69.62	90.64	101.11	90.64	77.37	63.74	61.97	61.97
STD	5.59	28.29	7.70	28.29	6.27	2.16	4.09	4.09
	Area Category = 3 and Fractal Category = 2							
54	50.61	56.67	70.00	56.67	50.61	45.89	45.23	45.20
63	53.15	54.26	76.67	56.57	65.61	52.02	51.64	51.60
152	53.18	59.63	83.33	62.89	65.17	50.88	50.24	50.20
183	58.55	56.67	63.33	60.83	65.89	55.40	54.37	54.40
Mean	53.87	56.81	73.33	59.24	61.82	51.05	50.37	50.35
STD	3.34	2.20	8.61	3.14	7.48	3.94	3.83	3.85
	Area Category = 3 and Fractal Category = 3							
6	74.48	87.50	113.33	87.50	88.53	73.81	73.96	74.00
9	48.45	59.63	70.00	59.63	51.45	48.08	47.96	48.00
93	58.97	66.42	86.67	66.42	71.75	57.21	56.62	56.60
96	56.76	66.75	70.00	70.08	66.79	53.36	52.23	52.20
100	58.31	60.09	83.33	62.89	73.75	57.02	56.60	56.60
108	61.12	64.72	90.00	68.72	76.40	59.11	58.44	58.40
114	70.08	71.80	93.33	73.11	84.92	65.66	64.19	64.20
130	55.20	58.31	80.00	60.09	64.31	49.95	48.21	48.20
132	73.18	77.53	103.33	80.28	81.66	71.40	70.82	70.80
141	81.26	87.69	120.00	93.39	105.91	79.95	79.79	79.80
143	59.63	61.28	80.00	64.12	72.76	56.29	55.18	55.20

Appendix F. Maximum Slope Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 3 and Fractal Category = 3 (continued)							
153	79.06	88.07	116.67	88.07	92.40	78.12	77.81	77.80
154	78.97	76.96	100.00	86.54	91.20	75.90	74.89	74.90
172	54.97	68.72	83.33	77.75	61.51	49.63	48.10	48.10
173	58.55	60.37	73.33	62.27	70.19	54.94	55.04	55.00
184	59.63	68.72	96.67	72.11	72.76	56.57	56.57	56.60
203	71.20	87.50	96.67	87.50	86.50	68.33	67.44	67.40
213	72.36	90.25	113.33	93.87	89.86	70.24	69.53	69.50
Mean	65.12	72.35	92.78	75.24	77.93	62.53	61.85	61.85
STD	9.90	11.47	15.94	11.83	13.31	10.44	10.61	10.62
	Area Category = 3 and Fractal Category = 4							
7	47.20	50.00	70.00	54.67	52.00	44.96	44.38	44.40
36	66.42	71.96	96.67	73.18	81.85	63.88	63.06	63.10
67	68.39	81.10	100.00	84.33	81.86	67.43	67.43	67.40
127	59.56	81.17	83.33	81.17	76.02	58.24	57.80	57.80
129	112.46	121.66	140.00	121.66	129.71	110.91	110.39	110.40
131	78.97	84.98	136.67	86.54	91.20	75.90	74.89	74.90
151	53.57	56.67	70.00	58.21	65.57	50.94	50.08	50.10
230	69.06	80.28	93.33	81.10	81.70	63.78	62.03	62.00
Mean	69.45	78.48	98.75	80.11	82.49	67.01	66.26	66.26
STD	19.99	21.56	26.90	20.57	22.57	20.17	20.23	20.22
	Area Category = 3 and Fractal Category = 5							
1	91.80	101.54	120.00	102.03	117.24	90.13	89.60	89.60
3	77.21	93.87	113.33	95.97	96.11	73.81	73.07	73.10
24	54.26	85.70	100.00	108.53	54.26	44.80	41.65	41.60
26	61.33	92.20	90.00	98.99	61.33	48.92	45.90	45.90
74	97.99	110.81	143.33	110.81	114.85	93.29	91.72	91.70
120	59.07	67.49	80.00	68.72	72.83	57.72	57.27	57.30
158	115.77	123.69	156.67	134.99	146.33	112.97	112.05	112.00
186	115.21	124.54	160.00	137.03	137.06	108.98	106.91	106.90
Mean	84.08	99.98	120.42	107.13	100.00	78.83	77.27	77.26
STD	24.80	19.43	30.31	21.97	34.60	26.55	27.04	27.04

Appendix F. Maximum Slope Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 3 and Fractal Category = 6							
71	70.26	84.85	110.00	84.85	83.27	67.89	68.03	68.00
105	48.10	50.77	66.67	50.77	58.71	45.33	44.45	44.40
Mean	59.18	67.81	88.34	67.81	70.99	56.61	56.24	56.20
STD	15.67	24.10	30.64	24.10	17.37	15.95	16.67	16.69
	Area Category = 4 and Fractal Category = 2							
190	68.01	69.60	90.00	73.11	83.89	64.85	63.80	63.80
	Area Category = 4 and Fractal Category = 5							
139	65.34	79.23	93.33	79.23	78.05	63.12	62.52	62.50
	Area Category = 4 and Fractal Category = 6							
10	75.46	110.35	130.00	110.35	92.06	140.28	71.37	71.40
137	60.09	64.12	83.33	67.49	64.47	56.67	55.92	55.90
Mean	67.78	87.24	106.67	88.92	78.27	98.48	63.65	63.65
STD	10.87	32.69	33.00	30.31	19.51	59.12	10.92	10.96
	Area Category = 5 and Fractal Category = 2							
35	70.18	79.23	93.33	93.39	87.82	69.41	69.16	69.20

APPENDIX G

STANDARD DEVIATION OF SLOPE VALUES IN THE POLYGON

FOR THE DIFFERENT SLOPE METHODS

Appendix G. Standard Deviation of Slope Values of the Polygon for the Different Slope Methods

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 1							
34	12.98	14.32	16.18	12.56	16.43	12.85	12.91	12.91
65	4.48	6.03	6.55	4.99	4.61	4.03	3.94	3.94
72	7.29	8.69	8.49	7.00	9.36	6.70	6.60	6.60
75	5.34	7.90	6.76	5.76	6.64	4.87	4.80	4.80
80	8.36	9.57	9.98	7.66	9.64	8.04	7.96	7.97
85	7.69	9.14	9.94	6.18	9.00	7.13	7.02	7.02
92	5.99	7.71	9.38	5.29	7.37	5.49	5.40	5.40
95	7.64	9.99	8.29	7.09	9.01	7.21	7.16	7.16
126	6.80	8.59	10.42	8.02	9.66	6.70	6.70	6.69
163	11.53	12.74	16.68	11.74	12.27	10.82	10.62	10.62
164	13.04	15.11	18.42	12.15	14.00	12.76	12.69	12.69
196	7.03	7.81	7.37	6.82	7.08	6.17	6.02	6.02
241	11.08	11.87	15.13	10.99	13.28	11.05	10.98	10.98
Mean	8.40	9.96	11.05	8.17	9.87	7.99	7.91	7.91
STD	2.84	2.75	4.09	2.72	3.31	2.94	2.95	2.95
	Area Category = 1 and Fractal Category = 2							
4	15.25	16.76	18.83	15.21	17.49	14.67	14.51	14.51
55	5.98	8.06	8.01	6.29	6.76	5.34	5.24	5.24
56	4.37	5.30	7.00	4.50	5.06	4.03	3.99	3.98
58	9.88	10.25	11.57	8.18	11.51	9.10	8.89	8.89
61	15.25	15.50	19.83	14.79	16.32	15.13	15.12	15.11
70	9.04	11.18	7.89	8.42	10.46	8.50	8.41	8.40
73	6.79	6.32	8.91	4.96	8.27	6.86	6.95	6.94
77	10.61	11.91	15.83	10.58	13.29	10.51	10.51	10.51
83	9.17	9.74	11.81	8.45	10.12	8.70	8.60	8.60
84	10.71	11.30	13.64	10.32	12.89	10.35	10.30	10.30
89	6.03	6.23	6.58	5.31	7.28	5.52	5.43	5.44
101	6.39	7.83	10.12	5.95	6.97	5.90	5.76	5.75
111	9.60	10.69	12.00	8.42	10.94	8.65	8.38	8.38
113	12.05	13.27	14.60	12.92	14.75	11.06	10.77	10.77
117	8.05	10.26	14.12	11.60	10.46	7.86	7.84	7.84

Appendix G. Standard Deviation of Slope Values of the Polygon for the Different Slope Methods

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 2 (continued)							
121	7.09	8.43	8.49	7.82	7.62	6.62	6.52	6.53
135	5.76	7.65	7.99	5.46	5.93	5.50	5.50	5.50
142	14.56	14.00	18.46	14.44	18.49	14.23	14.15	14.15
144	8.30	10.02	10.69	8.19	9.26	7.44	7.26	7.26
145	5.40	7.12	6.82	5.89	5.53	4.59	4.47	4.47
147	7.64	8.51	8.61	7.62	8.14	7.07	6.93	6.93
165	8.78	10.09	9.91	9.07	10.32	8.33	8.27	8.27
174	19.96	21.50	32.48	28.72	23.04	18.98	18.79	18.80
185	14.49	13.13	16.49	12.57	17.39	14.28	14.25	14.25
193	4.47	6.48	6.16	4.94	4.68	3.80	3.76	3.76
195	6.11	7.90	7.81	6.51	6.64	5.67	5.63	5.63
198	10.02	10.83	13.00	8.56	12.53	10.01	10.05	10.06
199	12.08	11.60	14.40	11.68	13.13	11.49	11.34	11.34
202	8.95	9.31	12.94	9.11	11.74	8.70	8.66	8.66
204	5.86	7.37	6.99	6.05	5.53	4.99	4.83	4.83
210	6.93	9.18	9.74	8.60	7.51	6.37	6.30	6.30
217	8.13	9.71	10.95	8.93	9.26	7.51	7.37	7.37
219	7.85	9.16	10.21	7.97	10.14	7.54	7.46	7.46
232	13.09	13.56	15.90	12.31	15.96	12.59	12.46	12.46
Mean	9.25	10.30	12.02	9.42	10.75	8.76	8.67	8.67
STD	3.60	3.34	5.22	4.50	4.41	3.60	3.58	3.59
	Area Category = 1 and Fractal Category = 3							
15	8.01	9.83	10.77	7.82	9.18	7.30	7.16	7.17
29	8.19	10.03	11.13	8.43	9.57	7.91	7.89	7.89
40	9.89	10.39	11.16	9.77	11.57	9.54	9.47	9.47
50	13.29	15.67	20.29	13.04	14.68	12.97	12.90	12.90
52	7.31	8.14	10.71	7.17	8.46	6.75	6.65	6.65
64	14.50	17.84	19.76	17.86	17.44	14.02	13.95	13.95
76	9.23	10.14	11.25	9.69	10.28	8.78	8.72	8.72
94	7.85	8.62	10.15	8.18	8.74	7.33	7.21	7.21
97	5.22	6.13	7.48	5.24	6.39	4.75	4.65	4.64

Appendix G. Standard Deviation of Slope Values of the Polygon for the Different Slope Methods

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 3 (continued)							
146	10.49	12.62	14.08	12.06	12.97	10.10	10.06	10.06
155	9.92	11.93	13.33	12.45	10.77	9.45	9.33	9.33
157	9.23	10.21	10.28	8.16	10.03	8.89	8.80	8.80
159	8.60	10.30	10.47	8.03	9.60	8.23	8.18	8.18
167	11.18	11.80	12.72	10.70	13.32	11.09	11.08	11.08
170	10.55	12.59	14.27	10.01	11.63	10.47	10.44	10.44
179	25.23	35.85	47.71	46.22	29.74	22.73	22.28	22.28
191	7.96	8.08	8.26	6.89	8.64	7.29	7.13	7.13
201	8.74	10.02	11.20	8.35	9.33	8.44	8.42	8.43
208	10.08	11.27	14.06	10.58	11.62	9.94	9.93	9.93
226	20.50	23.72	33.74	27.61	25.76	19.75	19.54	19.54
227	9.65	10.84	11.70	10.17	10.29	8.38	8.17	8.17
231	13.11	13.18	15.18	11.71	16.05	12.75	12.66	12.66
233	13.03	13.84	16.34	12.52	14.13	13.12	13.16	13.16
240	14.78	16.69	18.51	14.71	19.17	14.42	14.35	14.34
243	11.37	13.26	15.38	11.92	13.32	10.97	10.89	10.89
Mean	11.12	12.92	15.20	12.37	12.91	10.61	10.52	10.52
STD	4.27	6.00	8.59	8.32	5.41	4.02	3.97	3.97
	Area Category = 1 and Fractal Category = 4							
8	8.69	9.77	10.36	8.11	10.01	8.52	8.52	8.52
19	10.96	11.23	12.50	10.61	11.59	10.06	9.84	9.85
20	7.59	9.32	10.00	7.48	8.48	6.94	6.78	6.78
38	9.76	10.43	11.49	9.00	11.51	9.55	9.51	9.51
68	9.54	11.05	12.58	10.45	10.05	9.01	8.87	8.87
69	8.86	9.51	10.26	7.76	10.19	8.39	8.29	8.29
79	7.84	7.88	10.02	6.46	9.25	7.72	7.67	7.67
91	6.97	8.48	9.37	7.62	8.39	6.67	6.64	6.64
106	5.41	5.50	5.04	5.29	4.95	4.44	4.11	4.11
122	11.82	11.98	16.03	13.04	11.62	10.50	10.10	10.10
138	9.00	9.16	8.90	6.16	10.23	8.89	8.89	8.90
160	8.66	9.42	11.21	8.94	11.08	8.18	8.09	8.09

Appendix G. Standard Deviation of Slope Values of the Polygon for the Different Slope Methods

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 4 (continued)							
169	8.28	9.68	9.02	6.19	8.95	8.43	8.59	8.59
176	15.58	15.74	20.04	15.97	17.39	14.79	14.59	14.59
194	5.94	6.63	7.68	6.60	7.83	5.77	5.78	5.78
200	13.34	15.29	17.66	15.80	15.94	13.05	13.00	13.00
207	10.66	11.06	13.80	11.49	13.01	10.31	10.18	10.18
209	10.96	9.53	11.84	9.39	11.46	10.78	10.67	10.67
211	11.21	12.13	15.08	10.80	11.71	10.90	10.80	10.80
212	6.95	8.53	9.17	6.90	8.47	6.31	6.16	6.17
221	11.97	13.37	13.06	10.42	13.54	10.83	10.53	10.53
223	9.06	8.79	11.41	7.72	10.10	8.82	8.79	8.79
228	15.44	14.95	20.43	13.85	18.56	15.39	15.40	15.40
229	13.49	13.25	12.48	10.40	16.64	12.99	12.85	12.85
238	12.10	11.66	16.45	10.73	11.56	11.28	11.07	11.07
Mean	10.00	10.57	12.23	9.49	11.30	9.54	9.43	9.43
STD	2.71	2.57	3.72	2.92	3.17	2.67	2.67	2.67
	Area Category = 1 and Fractal Category = 5							
13	7.05	7.07	8.32	6.07	8.13	6.94	6.92	6.92
22	15.15	17.21	22.73	15.63	17.23	14.51	14.32	14.32
23	10.83	15.67	16.07	16.63	11.97	9.71	9.51	9.51
25	9.35	12.41	14.88	14.11	9.89	8.07	7.79	7.79
30	8.50	8.26	10.98	7.71	9.46	8.30	8.23	8.23
31	9.50	10.88	10.83	9.73	11.32	9.22	9.17	9.17
47	11.96	12.68	14.78	11.72	13.91	11.89	11.86	11.86
133	15.23	14.69	17.68	13.97	17.85	15.25	15.28	15.28
171	11.19	11.85	13.83	10.18	12.30	10.94	10.90	10.90
175	10.20	11.29	12.75	10.42	12.37	10.08	10.07	10.08
215	11.29	10.39	14.61	10.75	11.51	11.04	10.97	10.97
235	13.79	13.43	14.62	13.17	14.21	13.52	13.47	13.47
236	15.44	16.86	20.62	18.63	19.25	14.93	14.80	14.80
Mean	11.50	12.51	14.82	12.21	13.03	11.11	11.02	11.02
STD	2.71	3.07	3.92	3.58	3.36	2.75	2.76	2.76

Appendix G. Standard Deviation of Slope Values of the Polygon for the Different Slope Methods

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 6							
14	8.97	9.41	11.02	7.90	10.49	8.70	8.69	8.68
53	8.98	10.45	11.70	8.60	9.23	8.41	8.26	8.26
57	16.73	18.19	24.59	17.33	17.73	15.99	15.71	15.71
87	7.23	9.28	9.58	6.73	7.26	6.32	6.11	6.11
116	12.08	11.77	14.42	11.26	11.75	11.08	10.84	10.84
234	13.86	17.61	16.48	12.15	16.36	13.02	12.78	12.78
239	11.87	11.24	13.19	9.73	12.48	11.54	11.43	11.43
242	11.25	11.77	13.79	11.21	13.59	10.61	10.45	10.45
Mean	11.37	12.46	14.35	10.61	12.36	10.71	10.53	10.53
STD	3.03	3.49	4.66	3.28	3.51	2.99	2.95	2.95
	Area Category = 2 and Fractal Category = 1							
62	8.23	9.36	11.08	8.66	9.98	8.05	8.02	8.02
118	9.09	10.24	11.50	8.93	10.80	8.66	8.59	8.59
181	8.51	9.04	10.25	9.32	9.22	8.03	7.94	7.94
197	5.25	6.59	7.05	5.42	5.70	4.78	4.70	4.70
225	8.98	9.72	10.74	9.14	10.31	8.35	8.20	8.20
Mean	8.01	8.99	10.12	8.29	9.20	7.57	7.49	7.49
STD	1.58	1.41	1.78	1.63	2.04	1.58	1.58	1.58
	Area Category = 2 and Fractal Category = 2							
2	9.63	10.88	11.67	8.83	11.17	9.24	9.15	9.16
5	14.68	15.82	18.88	15.04	18.39	14.68	14.71	14.71
37	7.84	10.29	12.87	10.45	9.24	7.13	7.05	7.05
44	8.74	10.17	11.94	10.18	10.58	8.54	8.54	8.54
45	8.85	10.12	10.93	8.34	9.90	8.42	8.34	8.34
46	8.52	9.00	11.07	7.81	9.48	8.16	8.10	8.10
48	12.10	12.28	12.78	9.41	15.34	11.97	11.96	11.96
60	11.99	14.19	17.08	11.69	15.39	11.71	11.69	11.68
78	9.63	10.51	9.98	9.09	11.40	8.93	8.74	8.74
81	7.93	9.18	9.49	7.78	9.18	7.42	7.31	7.31
82	7.08	8.14	9.17	8.30	8.31	6.72	6.67	6.66
90	9.40	12.24	14.22	12.52	11.32	8.81	8.68	8.68

Appendix G. Standard Deviation of Slope Values of the Polygon for the Different Slope Methods

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 2 (continued)							
98	8.41	9.17	9.73	7.46	11.04	8.22	8.20	8.20
102	11.54	12.66	14.29	11.63	13.47	10.51	10.20	10.20
104	9.33	10.55	13.33	9.73	11.15	8.91	8.82	8.82
112	9.10	10.03	12.85	9.61	11.86	8.98	8.99	8.99
124	12.59	13.52	13.68	11.49	13.79	11.91	11.74	11.74
125	14.05	14.73	16.66	13.36	17.12	13.44	13.26	13.26
148	8.04	8.54	10.66	7.22	9.00	7.45	7.31	7.31
150	6.42	8.26	7.95	7.35	6.90	5.68	5.56	5.56
161	17.82	19.18	22.59	17.17	22.70	17.88	17.92	17.92
162	6.89	7.68	9.29	6.63	8.86	6.61	6.62	6.62
177	5.86	7.11	7.32	5.80	5.78	5.20	5.06	5.06
178	9.92	11.61	13.66	9.62	11.92	9.51	9.43	9.43
180	12.50	12.82	15.03	11.61	14.97	12.15	12.05	12.05
187	8.23	8.96	10.64	7.68	10.57	7.94	7.92	7.92
188	8.75	10.70	12.22	10.03	9.75	8.16	8.03	8.03
214	6.94	8.04	8.52	6.91	7.48	6.10	5.94	5.94
218	10.71	12.07	13.64	9.98	11.55	10.05	9.88	9.88
220	11.78	13.50	18.85	12.00	13.30	11.31	11.19	11.19
Mean	9.84	11.06	12.70	9.82	11.70	9.39	9.30	9.30
STD	2.70	2.71	3.51	2.57	3.59	2.80	2.81	2.81
	Area Category = 2 and Fractal Category = 3							
12	10.38	11.55	14.29	10.12	12.53	10.12	10.04	10.03
43	8.54	8.48	11.23	7.58	10.28	8.20	8.13	8.13
49	13.71	15.64	19.34	14.27	16.23	13.26	13.14	13.14
51	12.92	13.97	15.42	11.82	16.73	12.81	12.78	12.78
59	15.84	16.23	15.28	13.17	17.92	15.58	15.52	15.52
86	7.00	7.41	8.46	6.56	9.14	6.82	6.82	6.82
103	8.75	8.86	11.68	8.27	11.23	8.67	8.69	8.69
109	8.25	9.53	10.63	7.84	9.44	7.74	7.64	7.64
115	15.75	14.95	20.54	14.68	18.25	15.60	15.54	15.54
128	12.43	12.58	14.73	11.60	15.46	12.26	12.22	12.22

Appendix G. Standard Deviation of Slope Values of the Polygon for the Different Slope Methods

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 3 (continued)							
134	9.85	15.45	19.74	18.34	11.74	8.86	8.69	8.69
140	13.63	14.93	18.59	15.03	16.18	13.31	13.27	13.26
182	6.91	8.17	8.61	6.48	8.68	6.54	6.46	6.47
189	10.16	10.98	13.38	10.06	11.25	9.90	9.85	9.85
205	11.94	14.79	17.55	15.95	14.36	11.51	11.44	11.44
216	10.95	12.03	11.81	9.48	12.70	10.43	10.32	10.32
Mean	11.06	12.22	14.45	11.33	13.26	10.73	10.66	10.66
STD	2.83	3.02	3.90	3.62	3.21	2.88	2.88	2.88
	Area Category = 2 and Fractal Category = 4							
17	10.54	11.04	13.33	9.63	12.03	9.95	9.79	9.79
27	8.72	9.24	12.18	10.11	9.90	8.34	8.25	8.25
32	14.74	16.06	20.32	15.48	17.23	13.69	13.40	13.40
33	8.70	11.01	11.41	11.21	9.57	7.82	7.64	7.64
39	12.36	11.91	10.95	9.38	15.30	12.50	12.62	12.62
42	12.62	13.34	14.98	10.54	14.70	12.62	12.70	12.70
88	9.72	10.85	11.43	8.74	11.71	9.15	9.04	9.03
110	12.47	12.79	15.63	11.98	14.91	12.09	11.99	11.99
123	12.23	13.94	18.71	12.55	15.75	12.14	12.15	12.15
136	8.46	9.46	9.40	8.13	8.98	7.79	7.66	7.66
149	11.29	11.47	13.85	10.83	13.09	10.94	10.86	10.86
156	13.44	14.20	18.75	15.36	14.49	12.72	12.54	12.54
168	9.01	9.23	10.23	8.02	9.79	8.65	8.55	8.55
192	14.53	14.60	16.47	14.25	16.88	14.17	14.05	14.05
206	11.90	12.26	14.46	10.70	12.54	11.50	11.41	11.41
222	8.26	10.29	12.48	8.99	9.59	7.77	7.67	7.68
Mean	11.19	11.98	14.03	10.99	12.90	10.74	10.64	10.64
STD	2.18	2.04	3.25	2.38	2.79	2.23	2.25	2.25
	Area Category = 2 and Fractal Category = 5							
11	10.90	11.90	14.14	10.80	12.77	10.58	10.48	10.48
16	7.12	7.81	8.29	6.04	8.72	6.79	6.74	6.74
18	8.15	8.59	8.79	6.84	9.56	7.57	7.43	7.43

Appendix G. Standard Deviation of Slope Values of the Polygon for the Different Slope Methods

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 5 (continued)							
28	10.04	13.06	14.52	15.47	10.08	8.63	8.36	8.36
66	8.96	9.88	11.84	9.05	10.12	8.57	8.49	8.50
107	10.67	10.60	13.23	10.04	12.02	10.39	10.34	10.35
119	8.55	9.38	12.04	8.42	10.29	8.32	8.29	8.29
Mean	9.20	10.17	11.83	9.52	10.51	8.69	8.59	8.59
STD	1.40	1.84	2.46	3.11	1.41	1.38	1.39	1.39
	Area Category = 2 and Fractal Category = 6							
21	12.37	15.36	18.37	16.62	13.06	11.16	10.87	10.87
41	12.71	13.71	16.52	11.99	15.17	12.36	12.27	12.27
166	12.85	12.85	18.64	13.01	14.32	12.62	12.56	12.57
Mean	12.64	13.97	17.84	13.87	14.18	12.05	11.90	11.90
STD	0.25	1.28	1.15	2.43	1.06	0.78	0.90	0.91
	Area Category = 3 and Fractal Category = 2							
54	7.38	8.55	10.03	7.55	7.86	6.80	6.68	6.68
63	7.13	8.32	9.06	7.15	8.80	6.50	6.37	6.37
152	7.28	8.46	10.26	7.43	9.16	6.92	6.88	6.88
183	7.76	8.65	8.73	7.85	8.52	7.10	6.96	6.96
Mean	7.39	8.50	9.52	7.50	8.59	6.83	6.72	6.72
STD	0.27	0.14	0.74	0.29	0.55	0.25	0.26	0.26
	Area Category = 3 and Fractal Category = 3							
6	14.74	15.80	19.08	14.30	17.76	14.22	14.09	14.09
9	9.35	10.32	12.22	8.65	9.99	8.71	8.53	8.53
93	13.14	13.16	16.51	11.95	15.87	12.86	12.79	12.79
96	9.90	10.67	12.01	9.86	11.46	9.57	9.48	9.48
100	9.60	9.94	11.52	9.46	11.51	9.07	8.93	8.92
108	10.45	10.73	12.75	10.78	12.26	9.90	9.77	9.77
114	12.84	14.23	15.91	13.78	14.78	12.12	11.92	11.92
130	9.06	10.16	10.89	8.88	10.43	8.38	8.22	8.22
132	12.99	13.45	16.19	12.23	14.67	12.42	12.27	12.27
141	15.42	15.74	20.85	15.32	20.04	15.13	15.06	15.06
143	11.18	11.81	12.36	10.53	13.27	10.65	10.51	10.51

Appendix G. Standard Deviation of Slope Values of the Polygon for the Different Slope Methods

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 3 and Fractal Category = 3 (continued)							
153	14.11	15.56	20.95	13.83	16.16	13.99	13.98	13.98
154	15.99	15.60	19.92	14.70	19.16	15.67	15.59	15.59
172	7.90	9.03	10.45	7.81	9.37	7.50	7.42	7.43
173	11.67	11.91	13.74	10.88	13.89	11.38	11.32	11.32
184	10.19	11.38	12.48	10.71	11.91	9.67	9.53	9.54
203	12.31	13.08	15.37	12.10	14.81	12.13	12.10	12.10
213	13.52	13.85	17.26	13.32	15.65	13.19	13.12	13.12
Mean	11.91	12.58	15.03	11.62	14.05	11.48	11.37	11.37
STD	2.35	2.22	3.49	2.24	3.07	2.43	2.45	2.45
	Area Category = 3 and Fractal Category = 4							
7	8.78	9.03	10.02	7.79	10.29	8.47	8.40	8.40
36	12.71	13.45	16.10	12.04	15.11	12.56	12.56	12.56
67	13.33	13.45	16.47	12.21	15.30	13.00	12.93	12.93
127	12.13	12.67	15.03	12.17	14.51	11.91	11.87	11.87
129	21.49	22.03	29.89	21.90	26.30	21.17	21.08	21.08
131	15.98	15.81	19.55	14.72	18.63	15.87	15.86	15.86
151	8.79	9.40	10.11	8.14	10.07	8.22	8.11	8.10
230	12.47	13.44	15.30	12.26	14.84	12.09	12.02	12.02
Mean	13.21	13.66	16.56	12.65	15.63	12.91	12.85	12.85
STD	4.10	4.06	6.27	4.39	5.14	4.15	4.16	4.16
	Area Category = 3 and Fractal Category = 5							
1	13.95	15.17	17.01	13.42	16.77	13.39	13.25	13.25
3	14.47	15.04	20.16	14.72	16.13	13.79	13.57	13.57
24	12.91	16.01	21.23	20.24	14.19	11.62	11.34	11.34
26	13.40	17.05	22.12	20.66	15.07	12.23	11.97	11.97
74	14.70	15.49	20.73	15.41	18.20	14.39	14.31	14.31
120	8.29	9.04	10.79	8.16	10.44	7.99	7.95	7.95
158	18.75	20.14	27.09	19.96	22.28	18.29	18.17	18.17
186	16.56	17.35	23.33	18.18	19.56	16.06	15.94	15.94
Mean	14.13	15.66	20.31	16.34	16.58	13.47	13.31	13.31
STD	3.02	3.15	4.80	4.30	3.58	3.07	3.07	3.07

Appendix G. Standard Deviation of Slope Values of the Polygon for the Different Slope Methods

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 3 and Fractal Category = 6							
71	16.31	17.45	19.25	15.04	19.79	16.34	16.35	16.35
105	8.82	9.98	11.44	8.52	10.44	8.49	8.42	8.42
Mean	12.57	13.71	15.35	11.78	15.12	12.41	12.39	12.39
STD	5.30	5.28	5.52	4.61	6.62	5.55	5.60	5.61
	Area Category = 4 and Fractal Category = 2							
190	11.42	11.79	14.52	11.20	13.42	11.33	11.31	11.31
	Area Category = 4 and Fractal Category = 5							
139	11.71	12.43	14.81	12.14	13.40	11.34	11.25	11.25
	Area Category = 4 and Fractal Category = 6							
10	14.34	15.16	18.49	13.66	17.63	14.87	14.03	14.03
137	11.65	12.24	15.47	11.81	13.04	11.05	10.86	10.86
Mean	13.00	13.70	16.98	12.73	15.33	12.96	12.44	12.44
STD	1.90	2.06	2.13	1.31	3.25	2.70	2.25	2.25
	Area Category = 5 and Fractal Category = 2							
35	11.77	12.24	14.41	11.07	14.68	11.51	11.46	11.46

APPENDIX H

TRIM MEAN OF THE POLYGON FOR THE DIFFERENT SLOPE METHODS

Appendix H. Trim Mean of the Polygon for the Different Slope Methods

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 1							
34	45.37	45.31	65.81	52.84	53.58	44.48	44.18	44.18
65	25.91	26.92	39.66	30.24	30.31	25.78	25.75	25.75
72	30.61	31.40	43.27	36.66	37.00	30.02	29.84	29.84
75	29.58	29.08	42.20	34.84	36.99	29.24	29.15	29.15
80	25.04	26.09	38.09	31.40	30.07	24.38	24.18	24.18
85	31.36	31.42	45.06	37.51	37.64	30.46	30.19	30.19
92	37.10	36.23	50.04	41.56	45.07	36.45	36.25	36.25
95	34.99	34.76	48.39	40.76	41.17	34.13	33.87	33.87
126	38.25	37.17	56.51	42.40	47.07	38.19	38.17	38.16
163	45.26	45.88	66.78	51.33	52.68	44.96	44.90	44.91
164	44.50	44.67	68.54	52.87	50.64	43.88	43.70	43.71
196	16.31	18.71	27.46	23.65	19.70	15.97	15.91	15.91
241	36.69	37.37	49.68	42.59	43.20	36.46	36.40	36.40
Mean	33.92	34.23	49.35	39.90	40.39	33.42	33.27	33.27
STD	8.65	8.13	12.25	8.92	9.88	8.61	8.59	8.59
	Area Category = 1 and Fractal Category = 2							
4	46.97	47.48	74.12	54.40	54.69	46.41	46.24	46.24
55	22.09	24.34	31.05	28.45	26.88	21.39	21.20	21.20
56	23.50	24.95	32.33	27.67	28.48	23.31	23.27	23.27
58	25.50	27.71	40.18	34.14	30.32	24.49	24.19	24.19
61	38.03	38.89	53.49	45.63	43.17	37.57	37.42	37.42
70	31.22	30.79	42.94	37.65	37.89	30.51	30.30	30.30
73	27.15	28.92	40.81	32.61	32.38	26.62	26.46	26.46
77	39.78	41.41	57.44	45.63	46.70	39.36	39.23	39.23
83	26.83	27.91	39.56	33.10	31.55	25.99	25.75	25.75
84	32.55	34.06	45.19	39.78	39.45	31.32	30.94	30.94
89	31.79	33.78	44.32	36.51	38.80	31.27	31.10	31.11
101	23.45	20.82	37.08	29.41	27.19	22.44	22.16	22.15
111	33.26	34.86	49.06	40.28	40.12	32.41	32.14	32.14
113	28.18	29.44	41.29	34.52	34.64	27.89	27.80	27.79
117	35.50	35.91	51.84	41.80	45.38	35.34	35.31	35.31

Appendix H. Trim Mean of the Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 2 (continued)							
121	19.76	20.45	31.84	25.18	23.63	19.43	19.35	19.35
135	19.25	20.55	31.18	25.77	22.24	18.67	18.53	18.52
142	31.81	32.51	50.09	41.19	38.17	30.78	30.48	30.48
144	26.34	28.08	42.47	35.14	31.38	25.42	25.13	25.12
145	17.05	19.04	29.48	24.27	20.48	16.54	16.42	16.42
147	25.96	27.06	39.97	31.71	30.23	25.57	25.46	25.46
165	22.39	24.03	34.05	30.69	26.40	21.76	21.60	21.60
174	38.05	38.02	58.35	46.46	47.54	37.60	37.53	37.53
185	33.73	35.95	50.14	44.11	38.90	32.00	31.47	31.47
193	15.02	17.00	24.47	21.83	17.93	14.30	14.14	14.14
195	16.72	18.56	28.19	24.67	20.04	15.85	15.63	15.64
198	34.73	36.29	47.85	42.30	40.93	33.99	33.77	33.76
199	38.39	40.68	54.79	45.54	44.36	38.05	37.96	37.96
202	31.30	31.35	48.17	36.43	38.83	31.20	31.20	31.20
204	16.10	18.30	27.29	22.60	18.98	15.59	15.49	15.48
210	17.60	19.56	28.57	26.23	20.39	16.26	15.93	15.93
217	17.28	20.00	29.94	25.50	20.77	16.35	16.11	16.11
219	31.12	30.43	45.74	35.62	39.75	31.05	31.04	31.03
232	36.22	38.91	53.73	43.30	43.88	35.63	35.46	35.45
Mean	28.08	29.35	42.27	35.00	33.60	27.42	27.24	27.24
STD	8.10	7.94	11.12	8.28	9.75	8.17	8.18	8.18
	Area Category = 1 and Fractal Category = 3							
15	23.54	25.95	38.67	31.33	27.93	22.39	22.08	22.08
29	25.99	27.87	38.53	33.07	30.26	24.83	24.46	24.46
40	32.13	33.37	44.13	38.23	38.67	31.66	31.52	31.52
50	27.00	31.90	50.22	34.75	30.64	26.38	26.24	26.24
52	25.88	27.45	40.16	31.34	30.27	25.48	25.37	25.36
64	41.64	42.73	65.21	50.31	49.42	40.39	39.97	39.97
76	18.48	21.26	31.20	26.98	21.65	17.26	16.92	16.92
94	23.82	24.80	35.88	29.20	28.48	23.18	22.98	22.98
97	33.86	34.86	47.36	37.90	42.04	33.56	33.48	33.48

Appendix H. Trim Mean of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 3 (continued)							
146	28.85	30.01	46.45	37.60	34.71	27.75	27.41	27.41
155	22.58	24.05	35.77	30.10	27.22	22.30	22.26	22.26
157	24.81	26.94	38.69	33.54	28.86	23.77	23.47	23.46
159	23.03	25.34	36.67	32.51	26.22	21.97	21.66	21.67
167	24.89	26.73	37.83	32.78	29.12	23.77	23.46	23.46
170	29.04	30.80	44.01	37.73	33.69	28.12	27.85	27.85
179	44.00	40.44	70.59	55.14	53.96	44.32	44.46	44.46
191	18.98	21.62	32.59	26.76	22.32	18.08	17.86	17.87
201	21.94	24.36	36.18	31.91	25.21	21.01	20.76	20.76
208	18.72	21.52	31.55	26.99	22.05	17.71	17.46	17.46
226	42.98	43.76	65.63	51.64	52.14	42.40	42.24	42.24
227	22.41	25.56	37.02	32.82	25.61	20.43	19.84	19.83
231	35.78	38.46	49.14	44.00	44.20	35.49	35.43	35.43
233	27.01	29.39	39.78	34.96	30.55	25.89	25.58	25.58
240	42.01	41.39	62.52	50.03	51.68	41.78	41.72	41.72
243	30.26	31.53	44.11	38.50	36.38	29.73	29.59	29.59
Mean	28.38	30.08	44.00	36.40	33.73	27.59	27.36	27.36
STD	7.71	6.79	11.09	7.99	9.85	7.97	8.05	8.05
	Area Category = 1 and Fractal Category = 4							
8	30.11	30.72	44.25	35.54	34.29	29.44	29.24	29.24
19	26.71	29.52	39.44	35.34	30.82	25.41	25.04	25.04
20	18.24	20.93	31.31	26.52	21.50	17.23	16.94	16.94
38	26.75	28.35	40.00	33.58	32.07	26.33	26.20	26.20
68	22.81	25.24	38.24	31.53	26.30	22.10	21.91	21.91
69	20.68	22.63	34.53	28.41	24.39	19.66	19.38	19.38
79	23.28	25.07	34.66	29.36	27.42	22.45	22.22	22.22
91	20.32	18.99	30.62	24.46	24.73	19.66	19.47	19.48
106	8.06	10.52	28.10	16.33	14.13	10.29	11.10	11.10
122	35.09	35.35	43.92	40.65	38.44	34.28	34.02	34.02
138	31.90	33.83	49.93	38.77	36.83	31.30	31.11	31.11
160	28.56	30.34	40.87	34.15	34.72	28.13	27.99	27.99

Appendix H. Trim Mean of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 4 (continued)							
169	25.01	27.34	42.76	32.52	27.83	23.83	23.48	23.48
176	32.87	34.93	47.97	41.03	38.64	32.41	32.30	32.30
194	43.56	43.57	63.65	47.59	55.29	43.15	43.02	43.02
200	42.43	42.81	60.70	50.05	50.22	41.62	41.35	41.35
207	17.95	21.83	31.79	26.88	21.92	17.20	17.09	17.09
209	25.79	28.59	41.78	33.83	29.32	24.38	23.96	23.96
211	32.15	33.23	47.72	38.83	36.90	31.43	31.21	31.21
212	27.42	27.48	41.17	32.23	34.62	27.09	27.01	27.01
221	27.82	31.72	45.83	40.60	32.58	26.14	25.64	25.65
223	25.21	28.66	38.20	33.29	29.94	24.61	24.46	24.46
228	39.33	39.54	58.55	46.10	46.36	38.72	38.56	38.56
229	34.08	37.97	51.87	44.22	40.79	33.27	33.04	33.04
238	41.61	44.17	62.57	48.76	46.61	40.89	40.66	40.66
Mean	28.31	30.13	43.62	35.62	33.47	27.64	27.46	27.46
STD	8.39	8.05	9.99	8.18	9.57	8.19	8.12	8.12
	Area Category = 1 and Fractal Category = 5							
13	13.75	17.66	25.75	22.22	16.26	12.87	12.65	12.66
22	20.75	24.79	36.67	29.57	24.21	20.01	19.82	19.82
23	22.16	23.43	36.33	31.20	26.55	21.28	21.03	21.03
25	13.33	14.64	24.57	21.09	16.01	12.60	12.43	12.43
30	17.18	19.04	28.93	23.97	20.27	16.57	16.42	16.42
31	20.75	23.35	34.66	28.84	24.11	19.70	19.43	19.43
47	21.60	23.61	33.84	29.80	25.12	20.65	20.41	20.41
133	36.63	38.24	49.71	44.14	43.50	35.49	35.14	35.15
171	28.66	31.14	46.55	37.07	32.48	27.71	27.44	27.44
175	26.60	28.41	40.06	34.40	31.15	25.12	24.68	24.68
215	36.14	36.19	53.39	42.43	40.44	35.31	35.03	35.03
235	36.42	37.50	48.78	43.72	40.09	35.45	35.18	35.18
236	48.70	50.09	66.55	54.75	61.59	48.37	48.27	48.27
Mean	26.36	28.31	40.45	34.09	30.90	25.47	25.22	25.23
STD	10.50	9.99	12.08	9.94	12.82	10.54	10.54	10.54

Appendix H. Trim Mean of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 6							
14	17.54	20.29	30.59	26.48	20.23	16.24	15.89	15.90
53	24.89	23.94	39.36	30.76	28.23	24.36	24.23	24.22
57	31.45	39.02	57.62	40.96	36.87	30.91	30.80	30.81
87	18.41	19.00	30.76	24.46	21.32	18.03	17.92	17.92
116	24.51	28.20	38.02	33.25	26.77	22.27	21.58	21.58
234	63.29	63.33	97.15	73.03	76.11	62.43	62.18	62.18
239	20.67	25.24	38.06	30.80	22.55	18.63	18.09	18.09
242	47.34	49.37	66.76	53.49	57.77	47.25	47.25	47.25
Mean	31.01	33.55	49.79	39.15	36.23	30.02	29.74	29.74
STD	16.19	15.79	23.02	16.51	20.26	16.49	16.58	16.58
	Area Category = 2 and Fractal Category = 1							
62	19.57	21.40	30.87	25.67	23.73	18.98	18.84	18.84
118	33.89	34.78	47.76	39.34	40.13	33.32	33.15	33.15
181	16.64	18.73	27.46	24.12	19.86	16.05	15.95	15.95
197	17.60	19.23	27.24	23.30	20.81	17.06	16.92	16.92
225	25.79	27.41	35.29	32.71	29.99	25.20	25.05	25.05
Mean	22.70	24.31	33.72	29.03	26.90	22.12	21.98	21.98
STD	7.20	6.79	8.50	6.86	8.39	7.20	7.18	7.18
	Area Category = 2 and Fractal Category = 2							
2	27.03	28.02	40.46	34.45	31.65	26.07	25.79	25.80
5	43.35	42.79	67.62	49.41	51.73	42.81	42.65	42.65
37	24.41	25.62	37.05	31.02	29.56	23.76	23.58	23.57
44	20.56	22.51	32.46	28.02	24.63	19.75	19.54	19.54
45	20.70	23.17	35.74	29.68	23.71	19.22	18.78	18.78
46	23.26	25.26	35.60	30.25	27.54	22.61	22.43	22.43
48	32.42	35.86	50.80	41.72	37.97	31.67	31.46	31.46
60	58.41	58.07	82.51	65.43	69.65	57.90	57.74	57.75
78	27.36	27.87	38.89	33.74	32.21	26.45	26.18	26.18
81	21.51	23.08	33.26	27.73	25.67	20.70	20.46	20.46
82	21.09	21.75	33.93	26.91	25.13	20.62	20.49	20.49
90	26.45	26.75	39.60	33.27	31.82	25.85	25.68	25.68

Appendix H. Trim Mean of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 2 (continued)							
98	35.29	36.18	52.23	39.98	42.57	34.81	34.66	34.66
102	28.26	29.63	41.24	35.20	34.15	27.83	27.72	27.72
104	40.94	41.28	56.79	45.23	48.07	40.80	40.75	40.75
112	34.58	36.20	52.55	40.49	41.54	34.25	34.17	34.16
124	35.04	37.25	50.36	44.00	40.81	33.62	33.20	33.19
125	36.43	37.57	52.07	44.27	44.28	35.79	35.60	35.59
148	28.27	29.20	43.89	33.39	33.25	27.90	27.80	27.80
150	16.25	18.60	27.58	23.37	19.34	15.36	15.15	15.15
161	45.62	45.49	65.34	53.48	55.99	45.35	45.26	45.26
162	33.51	34.37	50.46	38.52	40.85	32.92	32.77	32.78
177	16.34	18.68	27.62	23.63	19.00	15.73	15.61	15.61
178	32.32	33.30	47.30	39.77	38.61	31.64	31.44	31.44
180	30.14	31.82	44.33	37.67	36.10	29.50	29.33	29.33
187	30.70	31.62	47.17	36.19	37.97	30.36	30.27	30.27
188	18.01	20.14	29.67	24.76	21.10	17.32	17.14	17.15
214	19.76	21.83	30.59	26.92	23.51	19.12	18.95	18.95
218	27.83	30.51	46.22	35.92	31.67	26.79	26.50	26.50
220	20.75	24.08	34.06	28.85	24.51	20.03	19.85	19.85
Mean	29.22	30.62	44.25	36.11	34.82	28.55	28.36	28.36
STD	9.51	8.91	12.65	9.41	11.54	9.62	9.64	9.64
	Area Category = 2 and Fractal Category = 3							
12	24.06	27.39	38.07	31.35	28.90	23.23	23.01	23.01
43	25.58	26.80	39.14	31.88	30.99	25.09	24.94	24.94
49	21.21	24.40	35.31	29.49	25.38	20.28	20.06	20.06
51	34.67	36.38	49.39	42.67	40.87	34.25	34.13	34.13
59	38.05	40.28	53.58	47.28	44.55	37.33	37.12	37.12
86	34.29	35.32	48.69	38.59	41.58	33.86	33.72	33.73
103	35.47	36.37	53.66	40.10	42.78	34.86	34.67	34.67
109	28.71	30.02	43.03	35.30	33.44	28.12	27.95	27.95
115	27.12	28.32	45.16	35.34	31.60	26.29	26.07	26.07
128	29.44	30.21	42.66	36.65	35.22	28.98	28.87	28.87

Appendix H. Trim Mean of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 3 (continued)							
134	21.31	22.22	34.70	27.85	25.25	20.94	20.88	20.88
140	40.50	41.67	58.39	48.59	47.83	39.74	39.51	39.51
182	32.46	33.06	47.63	37.17	41.14	32.17	32.08	32.08
189	23.18	24.85	34.66	30.69	26.99	22.14	21.85	21.85
205	25.30	25.91	38.96	32.11	30.98	24.70	24.55	24.55
216	29.29	32.52	45.11	39.35	33.95	28.33	28.04	28.05
Mean	29.41	30.98	44.26	36.53	35.09	28.77	28.59	28.59
STD	5.96	5.81	7.28	6.08	7.16	6.02	6.02	6.02
	Area Category = 2 and Fractal Category = 4							
17	23.08	25.51	37.10	31.28	26.80	21.68	21.26	21.26
27	15.56	17.47	26.59	22.46	18.48	14.89	14.73	14.73
32	28.66	31.45	45.19	36.53	33.33	27.05	26.57	26.57
33	24.72	25.31	36.81	31.80	29.41	23.98	23.77	23.77
39	37.78	39.57	61.14	45.73	43.46	35.93	35.31	35.31
42	37.51	38.64	58.14	45.29	43.37	35.95	35.44	35.44
88	29.64	31.10	44.15	37.47	35.14	28.41	28.04	28.03
110	25.53	27.74	38.49	33.24	31.05	24.80	24.59	24.59
123	42.70	44.35	63.33	49.13	51.51	42.33	42.22	42.22
136	34.73	36.07	47.98	41.06	41.38	34.10	33.90	33.90
149	26.48	27.62	39.70	33.53	31.23	25.49	25.21	25.21
156	41.52	42.22	56.16	47.66	46.27	40.97	40.80	40.80
168	23.57	26.01	36.04	31.09	27.49	22.75	22.55	22.55
192	32.22	33.60	46.48	40.85	37.37	31.16	30.86	30.87
206	26.51	29.11	42.30	34.79	30.40	25.66	25.42	25.42
222	22.75	25.28	35.09	29.99	26.39	22.08	21.89	21.89
Mean	29.56	31.32	44.67	36.99	34.57	28.58	28.28	28.28
STD	7.57	7.28	10.42	7.41	8.72	7.55	7.53	7.53
	Area Category = 2 and Fractal Category = 5							
11	23.35	25.25	36.20	31.23	27.00	22.24	21.93	21.93
16	19.16	20.91	29.70	25.44	23.16	18.60	18.45	18.45
18	20.54	22.78	33.06	27.86	23.92	19.28	18.93	18.93

Appendix H. Trim Mean of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 5 (continued)							
28	23.00	24.01	36.21	30.70	27.29	22.14	21.89	21.89
66	19.14	20.19	31.70	26.02	22.42	18.26	18.06	18.06
107	22.39	24.38	36.74	30.78	26.14	21.30	21.01	21.01
119	32.13	32.84	45.56	37.58	39.08	31.46	31.27	31.26
Mean	22.81	24.34	35.59	29.94	27.00	21.90	21.65	21.65
STD	4.46	4.18	5.13	4.11	5.66	4.53	4.54	4.54
	Area Category = 2 and Fractal Category = 6							
21	17.81	19.72	32.34	26.86	21.13	16.96	16.76	16.76
41	48.07	48.44	69.87	54.93	57.34	47.33	47.11	47.11
166	22.72	24.29	37.82	31.31	26.40	21.99	21.79	21.79
Mean	29.53	30.82	46.68	37.70	34.96	28.76	28.55	28.55
STD	16.24	15.43	20.27	15.09	19.56	16.28	16.27	16.27
	Area Category = 3 and Fractal Category = 2							
54	21.70	23.08	32.67	27.67	25.51	21.21	21.08	21.08
63	27.93	29.05	39.63	33.39	33.71	27.43	27.29	27.29
152	31.08	31.90	46.94	36.21	37.17	30.57	30.43	30.43
183	17.41	19.86	28.93	25.33	20.63	16.64	16.45	16.45
Mean	24.53	25.97	37.04	30.65	29.25	23.96	23.81	23.81
STD	6.14	5.49	7.95	5.02	7.55	6.24	6.26	6.26
	Area Category = 3 and Fractal Category = 3							
6	29.86	33.26	48.78	38.08	35.55	28.71	28.37	28.37
9	21.83	24.66	36.76	29.61	25.34	21.07	20.90	20.90
93	32.05	33.21	46.23	39.22	38.03	31.31	31.09	31.09
96	22.85	24.88	37.22	29.92	26.56	22.12	21.92	21.91
100	24.77	26.31	36.91	30.41	29.42	24.36	24.25	24.25
108	23.39	25.25	36.80	29.93	27.87	22.95	22.84	22.84
114	27.45	29.49	41.88	34.72	32.85	26.87	26.71	26.71
130	26.39	27.83	40.14	33.46	31.17	25.73	25.54	25.54
132	41.93	43.03	57.65	49.87	48.90	41.55	41.44	41.44
141	46.16	47.25	63.88	52.43	57.29	45.82	45.73	45.73
143	28.04	28.92	41.40	34.88	33.24	27.20	26.96	26.95

Appendix H. Trim Mean of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 3 and Fractal Category = 3 (continued)							
153	35.46	37.45	53.53	41.82	42.18	35.13	35.04	35.04
154	40.77	42.35	56.49	49.50	48.85	40.00	39.79	39.79
172	29.94	31.11	44.74	35.83	36.00	29.51	29.39	29.39
173	26.22	28.28	40.02	34.61	30.99	25.31	25.05	25.05
184	29.26	30.80	42.91	36.17	34.72	28.60	28.41	28.41
203	30.65	32.49	45.98	38.37	36.56	29.96	29.77	29.77
213	35.12	36.97	52.39	42.98	41.29	34.45	34.27	34.27
Mean	30.67	32.42	45.76	37.88	36.49	30.04	29.86	29.86
STD	6.86	6.63	8.11	7.03	8.51	6.93	6.95	6.95
	Area Category = 3 and Fractal Category = 4							
7	22.01	24.35	35.37	29.55	25.97	20.97	20.67	20.67
36	30.49	32.35	47.11	38.11	35.79	29.61	29.37	29.37
67	36.36	38.09	53.46	44.49	42.71	35.58	35.34	35.34
127	26.53	27.83	40.78	33.29	31.51	26.03	25.90	25.90
129	48.08	48.14	69.69	54.99	57.83	47.77	47.69	47.69
131	34.67	36.77	49.78	42.72	39.89	33.71	33.43	33.43
151	27.90	29.55	40.43	34.46	32.71	27.08	26.84	26.84
230	33.19	34.74	48.81	41.50	38.89	32.10	31.78	31.78
Mean	32.40	33.98	48.18	39.89	38.16	31.61	31.38	31.38
STD	7.87	7.36	10.51	7.95	9.56	8.02	8.07	8.07
	Area Category = 3 and Fractal Category = 5							
1	39.32	41.68	61.95	47.15	47.01	38.15	37.78	37.78
3	28.14	30.49	47.60	35.61	33.41	27.54	27.40	27.40
24	11.83	12.17	21.69	18.14	14.25	11.32	11.20	11.21
26	7.12	7.73	14.20	11.05	9.07	7.01	7.00	7.01
74	53.86	54.45	77.99	59.12	64.24	53.68	53.63	53.63
120	32.90	34.11	48.46	37.87	39.65	32.51	32.40	32.40
158	72.29	72.22	97.43	80.01	85.55	71.71	71.53	71.53
186	54.08	54.71	75.51	61.09	63.99	53.56	53.40	53.40
Mean	37.44	38.45	55.61	43.75	44.65	36.93	36.79	36.79
STD	22.19	22.00	28.45	22.96	26.12	22.13	22.09	22.09

Appendix H. Trim Mean of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 3 and Fractal Category = 6							
71	43.16	42.07	63.94	50.20	50.95	42.37	42.12	42.12
105	21.03	21.88	33.80	27.73	24.92	20.21	19.99	19.99
Mean	32.10	31.97	48.87	38.97	37.93	31.29	31.06	31.05
STD	15.64	14.27	21.32	15.89	18.41	15.67	15.65	15.65
	Area Category = 4 and Fractal Category = 2							
190	26.28	27.83	39.01	32.85	30.97	25.68	25.53	25.53
	Area Category = 4 and Fractal Category = 5							
139	24.74	26.80	38.36	32.21	29.19	24.05	23.85	23.85
	Area Category = 4 and Fractal Category = 6							
10	41.50	42.59	62.27	48.92	49.11	39.27	40.49	40.49
137	19.06	21.38	32.71	27.03	22.29	18.01	17.75	17.75
Mean	30.28	31.98	47.49	37.98	35.70	28.64	29.12	29.12
STD	15.87	15.00	20.90	15.48	18.97	15.03	16.08	16.08
	Area Category = 5 and Fractal Category = 2							
35	28.00	29.70	42.09	35.02	33.62	27.38	27.20	27.20

APPENDIX I

SLOPE MODE VALUE OF THE POLYGON FOR THE DIFFERENT SLOPE METHODS

Appendix I. Slope Mode Value of the Polygon for the Different Slope Methods

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 1							
34	- -	49.60	66.60	52.60	54.40	- -	- -	- -
65	26.00	26.80	40.00	- -	32.80	25.40	- -	- -
72	30.00	- -	- -	33.40	36.80	- -	25.60	29.00
75	- -	- -	40.00	37.20	42.40	28.40	29.40	- -
80	34.40	26.80	36.60	30.80	40.40	- -	- -	- -
85	- -	33.40	50.00	40.20	42.40	- -	33.40	33.40
92	38.40	40.20	- -	43.40	- -	- -	- -	- -
95	34.40	30.80	46.60	44.80	- -	33.60	- -	- -
126	- -	43.40	60.00	- -	56.00	48.40	- -	38.80
163	43.40	46.40	60.00	46.40	- -	43.00	- -	- -
164	40.40	46.40	66.60	52.00	- -	- -	40.40	40.40
196	- -	23.60	- -	23.60	23.20	- -	19.20	20.00
241	- -	30.80	43.40	38.00	36.00	36.00	- -	30.40
Mean	35.29	36.20	50.98	40.22	40.49	35.80	29.60	32.00
STD	6.02	9.26	11.43	8.87	10.21	8.70	7.99	7.41
	Area Category = 1 and Fractal Category = 2							
4	- -	- -	86.60	62.00	- -	44.20	51.40	51.40
55	- -	26.80	26.60	29.80	21.20	- -	23.40	- -
56	25.40	26.80	30.00	25.40	- -	22.20	- -	22.20
58	28.40	- -	40.00	28.60	- -	22.40	- -	24.00
61	- -	26.80	26.60	26.80	48.20	- -	51.20	51.20
70	- -	43.40	43.40	34.40	40.80	23.80	- -	- -
73	- -	33.40	46.60	- -	38.60	- -	- -	- -
77	39.00	33.40	53.40	- -	44.40	39.20	- -	38.40
83	29.20	30.80	40.00	35.40	- -	26.60	- -	- -
84	26.80	- -	- -	38.00	42.40	31.40	- -	- -
89	- -	33.40	43.40	- -	36.60	- -	- -	- -
101	- -	- -	40.00	- -	- -	- -	15.00	15.00
111	- -	33.40	43.40	38.00	42.40	- -	- -	- -
113	16.60	16.60	36.60	28.60	- -	- -	- -	22.20
117	- -	33.40	43.40	33.40	- -	- -	- -	- -

Appendix I. Slope Mode Value of the Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 2 (continued)							
121	23.60	- -	33.40	21.40	26.00	17.60	- -	- -
135	- -	21.00	- -	26.00	- -	18.00	17.20	17.20
142	- -	37.20	53.40	41.80	42.40	- -	23.60	- -
144	- -	33.40	- -	33.40	29.20	21.20	33.20	31.60
145	18.00	16.60	30.00	26.00	- -	17.20	17.20	14.00
147	- -	- -	43.40	30.80	- -	24.80	24.40	24.40
165	22.40	21.00	26.60	26.00	23.20	23.00	20.40	- -
174	45.40	44.80	30.00	- -	- -	58.60	- -	- -
185	- -	40.20	- -	53.80	- -	- -	20.00	- -
193	15.00	16.60	26.60	21.40	17.40	15.00	15.60	- -
195	15.40	16.60	23.40	- -	19.80	12.60	- -	17.40
198	- -	40.20	53.40	45.40	53.00	38.40	36.60	41.80
199	49.00	- -	60.00	- -	- -	- -	- -	- -
202	- -	- -	40.00	30.80	- -	26.00	- -	26.00
204	- -	16.60	30.00	21.40	23.20	12.40	18.00	- -
210	20.00	23.60	26.60	- -	- -	- -	11.20	11.20
217	10.60	- -	26.60	- -	- -	- -	- -	- -
219	- -	31.40	43.40	39.00	- -	- -	23.20	23.20
232	28.40	40.20	40.00	40.20	- -	- -	49.20	25.20
Mean	25.83	29.50	39.56	33.51	34.30	26.03	26.52	26.85
STD	10.88	9.04	13.16	9.89	11.30	11.82	13.08	12.20
	Area Category = 1 and Fractal Category = 3							
15	28.40	26.80	36.60	- -	- -	24.80	- -	28.60
29	28.40	30.80	36.60	30.80	32.80	28.40	22.80	22.80
40	29.20	- -	43.40	31.40	32.80	- -	- -	- -
50	13.40	26.80	40.00	- -	30.60	21.80	16.20	- -
52	23.40	- -	33.40	- -	- -	22.00	- -	21.60
64	- -	40.20	53.40	40.20	46.40	- -	40.60	- -
76	18.00	13.80	40.00	26.80	- -	- -	- -	10.20
94	- -	- -	26.60	- -	27.20	- -	20.60	20.60
97	33.40	34.00	50.00	41.80	41.60	32.60	32.80	31.20

Appendix I. Slope Mode Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 3 (continued)							
146	34.40	33.40	43.40	40.60	- -	- -	- -	- -
155	23.60	23.60	26.60	26.00	21.20	- -	- -	- -
157	28.40	23.60	36.60	30.80	32.80	17.20	23.20	26.00
159	- -	23.60	33.40	- -	17.80	23.00	15.60	- -
167	- -	18.00	23.40	- -	46.40	15.80	32.80	- -
170	40.60	38.00	43.40	43.40	46.20	- -	26.80	35.80
179	41.20	43.40	53.40	- -	48.20	38.00	- -	- -
191	23.60	23.60	30.00	26.80	- -	10.20	- -	17.00
201	- -	- -	33.40	- -	- -	- -	23.60	23.60
208	- -	13.80	26.60	26.00	- -	- -	- -	- -
226	38.40	39.00	56.60	40.20	49.80	- -	- -	33.80
227	15.00	- -	33.40	- -	- -	27.40	23.00	- -
231	38.40	37.20	56.60	40.20	46.40	36.60	- -	- -
233	15.00	26.80	30.00	- -	- -	- -	15.20	- -
240	- -	40.20	66.60	- -	- -	38.00	- -	45.20
243	- -	33.40	36.60	30.80	- -	- -	- -	37.80
Mean	27.81	29.50	39.60	33.99	37.16	25.83	24.43	27.25
STD	9.12	8.83	11.15	6.66	10.63	8.79	7.74	9.46
	Area Category = 1 and Fractal Category = 4							
8	31.80	33.40	53.40	34.40	37.40	32.60	- -	- -
19	- -	38.00	- -	40.20	25.20	- -	- -	- -
20	15.00	- -	43.40	- -	- -	- -	16.20	16.20
38	28.40	28.40	33.40	30.80	- -	21.80	- -	21.60
68	23.80	16.60	33.40	28.60	- -	- -	22.20	21.80
69	10.60	13.80	46.60	21.40	17.40	- -	- -	21.60
79	25.40	- -	30.00	35.40	- -	25.40	19.40	- -
91	13.40	13.80	30.00	- -	- -	21.80	15.20	- -
106	- -	- -	26.60	- -	- -	- -	- -	- -
122	- -	26.80	33.40	- -	- -	27.60	32.40	32.20
138	32.00	40.20	50.00	- -	- -	29.60	35.00	35.00
160	32.00	33.40	50.00	35.40	37.60	32.40	- -	30.40

Appendix I. Slope Mode Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 4 (continued)							
169	18.00	24.00	40.00	29.80	- -	- -	- -	- -
176	- -	- -	46.60	25.40	- -	- -	- -	- -
194	39.80	40.60	- -	48.00	- -	39.80	- -	- -
200	38.00	- -	56.60	44.80	- -	- -	- -	- -
207	6.00	10.60	43.40	26.80	18.00	22.20	13.40	13.40
209	33.00	- -	43.40	38.00	38.40	33.00	33.00	33.00
211	29.20	38.00	40.00	53.80	- -	- -	30.80	- -
212	- -	30.80	43.40	30.80	- -	- -	- -	24.20
221	18.40	- -	43.40	49.60	- -	- -	- -	17.20
223	- -	23.60	30.00	- -	- -	24.00	- -	22.80
228	48.40	30.80	70.00	- -	55.80	59.00	- -	- -
229	- -	33.40	63.40	- -	- -	- -	- -	- -
238	- -	- -	83.40	- -	58.80	36.60	- -	- -
Mean	26.07	28.01	44.95	35.83	36.08	31.22	24.18	24.12
STD	11.32	9.63	13.78	9.33	15.62	10.17	8.61	7.05
	Area Category = 1 and Fractal Category = 5							
13	8.40	- -	26.60	- -	18.40	- -	10.60	- -
22	15.00	18.00	33.40	26.00	- -	- -	15.00	15.00
23	- -	16.60	33.40	24.00	28.00	21.80	15.00	15.00
25	0.00	0.00	23.40	0.00	0.00	0.00	0.00	0.00
30	- -	7.40	36.60	- -	- -	- -	11.20	11.20
31	18.00	23.60	36.60	26.00	- -	- -	- -	- -
47	15.00	16.60	23.40	- -	- -	- -	21.80	- -
133	50.00	43.40	36.60	- -	21.20	42.40	52.80	- -
171	- -	38.80	- -	38.80	- -	27.20	34.20	34.20
175	28.40	- -	46.60	19.40	36.20	29.20	- -	39.00
215	- -	37.20	63.40	41.80	33.60	39.80	36.40	- -
235	36.60	- -	56.60	- -	- -	38.60	41.40	41.40
236	- -	- -	73.40	53.80	- -	- -	- -	- -
Mean	21.43	22.40	40.83	28.73	22.90	28.43	23.84	22.26
STD	16.12	14.76	16.03	16.26	13.15	14.62	16.59	15.88

Appendix I. Slope Mode Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 1 and Fractal Category = 6							
14	- -	16.60	33.40	30.80	23.20	10.80	11.20	11.20
53	25.40	12.00	33.40	33.40	- -	- -	20.00	20.00
57	16.60	56.60	66.60	- -	18.40	- -	- -	- -
87	- -	- -	36.60	26.00	- -	15.40	24.40	- -
116	11.80	- -	- -	34.40	36.60	- -	- -	- -
234	- -	64.00	113.40	74.00	87.80	- -	69.20	- -
239	- -	10.60	33.40	- -	- -	- -	14.40	- -
242	38.40	- -	- -	58.20	53.80	- -	50.80	50.80
Mean	23.05	31.96	52.80	42.80	43.96	13.10	31.67	27.33
STD	11.68	26.10	32.42	18.95	28.09	3.25	23.16	20.79
	Area Category = 2 and Fractal Category = 1							
62	13.40	16.60	20.00	21.40	- -	27.20	11.80	- -
118	- -	30.80	50.00	43.40	- -	34.20	- -	- -
181	- -	7.40	20.00	26.00	- -	13.80	- -	- -
197	18.60	19.40	23.40	22.40	21.20	15.00	15.00	15.00
225	22.40	31.40	26.60	31.40	30.80	30.00	28.80	- -
Mean	18.13	21.12	28.00	28.92	26.00	24.04	18.53	15.00
STD	4.52	10.14	12.60	8.99	6.79	9.16	9.03	0.00
	Area Category = 2 and Fractal Category = 2							
2	29.20	30.80	40.00	30.80	23.20	20.60	23.60	23.60
5	46.00	44.80	73.40	54.20	- -	47.20	47.60	50.20
37	26.40	26.80	30.00	26.80	- -	- -	- -	- -
44	10.60	- -	23.40	26.80	- -	21.40	- -	20.00
45	15.00	26.80	- -	28.60	26.00	14.20	14.20	14.20
46	- -	23.60	33.40	26.80	25.20	23.00	24.00	24.00
48	26.00	37.20	50.00	- -	23.20	- -	- -	24.80
60	50.00	50.80	83.40	80.60	- -	- -	68.40	- -
78	- -	31.60	36.60	38.00	- -	30.60	- -	- -
81	19.00	16.60	33.40	24.00	22.20	- -	20.40	- -
82	19.00	21.40	33.40	26.00	24.00	18.80	19.20	19.20
90	19.00	16.60	33.40	26.00	25.20	21.20	21.60	21.60

Appendix I. Slope Mode Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 2 (continued)							
98	41.20	40.20	50.00	44.80	47.20	41.20	36.20	36.00
102	25.00	26.80	36.60	- -	28.00	25.40	27.80	27.80
104	39.00	40.20	53.40	40.20	51.80	- -	38.80	38.80
112	- -	35.40	56.60	43.40	- -	28.60	38.20	- -
124	29.20	43.40	43.40	58.20	28.00	25.00	24.40	- -
125	46.40	43.40	- -	- -	- -	49.20	41.20	- -
148	34.20	33.40	50.00	35.40	40.40	34.80	32.60	30.60
150	13.40	16.60	- -	- -	20.60	15.40	16.60	16.60
161	58.40	- -	46.60	49.60	51.20	57.80	39.60	- -
162	36.60	40.20	53.40	40.20	47.20	35.80	35.80	35.80
177	- -	16.60	26.60	26.00	18.40	- -	15.80	15.80
178	- -	33.40	43.40	38.00	49.20	37.20	- -	- -
180	30.00	- -	30.00	26.80	- -	- -	- -	18.60
187	34.40	30.80	46.60	31.40	- -	34.80	31.20	27.80
188	- -	- -	- -	23.60	17.40	15.40	16.20	16.80
214	20.00	21.00	26.60	30.80	26.00	21.80	- -	20.00
218	36.60	- -	- -	40.20	- -	28.80	- -	- -
220	17.40	24.20	26.60	- -	21.20	16.60	16.20	16.20
Mean	30.08	30.90	42.41	36.69	30.78	28.90	29.53	24.92
STD	12.54	9.98	14.59	13.30	11.95	11.78	13.14	9.36
	Area Category = 2 and Fractal Category = 3							
12	23.80	26.80	36.60	26.80	30.00	28.80	25.00	25.00
43	26.80	26.80	36.60	30.80	34.80	27.20	27.20	22.80
49	- -	- -	- -	26.80	- -	- -	21.20	21.20
51	31.80	26.80	- -	37.20	29.20	24.80	24.40	- -
59	- -	33.40	60.00	33.40	36.80	20.80	60.40	- -
86	36.60	33.40	50.00	40.20	45.20	35.40	36.60	36.60
103	- -	40.20	50.00	44.80	- -	30.20	35.40	35.40
109	26.00	26.80	40.00	26.80	- -	24.80	25.00	25.00
115	8.40	16.60	26.60	- -	- -	- -	- -	- -
128	33.40	- -	36.60	40.20	42.40	- -	31.20	- -

Appendix I. Slope Mode Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 3 (continued)							
134	23.60	- -	33.40	26.00	23.20	21.80	19.60	- -
140	23.20	40.20	50.00	44.80	- -	33.80	- -	33.60
182	34.40	33.40	53.40	- -	42.40	- -	- -	36.60
189	- -	23.60	33.40	21.40	23.20	27.20	25.80	- -
205	- -	26.80	36.60	28.40	23.20	26.80	26.20	- -
216	29.60	33.40	53.40	- -	- -	- -	- -	25.00
Mean	27.05	29.86	42.61	32.89	33.04	27.42	29.83	29.02
STD	7.75	6.62	9.91	7.77	8.53	4.51	10.89	6.37
	Area Category = 2 and Fractal Category = 4							
17	13.40	- -	30.00	38.00	- -	12.60	17.40	17.40
27	15.00	16.60	- -	21.40	9.00	7.20	11.20	11.20
32	- -	16.60	- -	26.00	26.00	15.00	- -	- -
33	26.80	26.80	36.60	26.80	- -	- -	25.60	26.80
39	- -	40.20	63.40	44.80	- -	47.80	46.80	46.80
42	38.00	44.80	50.00	40.60	55.80	- -	- -	34.40
88	34.40	33.40	50.00	36.00	43.40	- -	- -	- -
110	- -	16.60	36.60	- -	- -	27.20	- -	- -
123	- -	44.80	56.60	44.80	51.00	- -	51.60	39.80
136	32.00	- -	43.40	35.40	44.40	- -	35.80	- -
149	30.00	33.40	43.40	33.40	- -	- -	31.20	- -
156	38.00	40.20	50.00	- -	53.00	- -	35.60	- -
168	25.40	26.80	- -	26.80	23.20	28.20	21.20	21.20
192	48.40	43.40	46.60	44.80	- -	32.60	- -	- -
206	18.60	19.40	- -	40.20	23.20	33.00	- -	15.20
222	23.60	26.80	33.40	28.60	29.20	24.60	23.40	23.20
Mean	28.63	30.70	45.00	34.83	35.82	25.36	29.98	26.22
STD	10.31	10.83	9.80	7.85	15.75	12.38	12.77	11.91
	Area Category = 2 and Fractal Category = 5							
11	26.00	20.20	30.00	- -	28.00	- -	19.60	19.60
16	- -	23.60	33.40	26.80	20.40	- -	25.00	25.00
18	15.00	24.20	30.00	26.80	21.20	- -	20.60	20.60

Appendix I. Slope Mode Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 2 and Fractal Category = 5 (continued)							
28	20.00	23.60	36.60	28.60	25.20	- -	- -	20.00
66	- -	13.80	23.40	- -	- -	- -	- -	- -
107	- -	23.60	36.60	28.60	28.00	- -	- -	- -
119	36.60	33.40	40.00	40.20	- -	28.40	- -	28.40
Mean	24.40	23.20	32.86	30.20	24.56	28.40	21.73	22.72
STD	9.29	5.81	5.55	5.66	3.63	0.00	2.87	3.84
	Area Category = 2 and Fractal Category = 6							
21	0.00	0.00	36.60	0.00	0.00	0.00	0.00	0.00
41	60.60	- -	86.60	61.20	- -	58.40	49.40	49.40
166	22.40	7.40	33.40	30.80	12.60	28.40	- -	20.00
Mean	27.67	3.70	52.20	30.67	6.30	28.93	24.70	23.13
STD	30.64	5.23	29.83	30.60	8.91	29.20	34.93	24.85
	Area Category = 3 and Fractal Category = 2							
54	25.40	24.00	30.00	26.80	25.20	18.00	21.20	19.80
63	28.40	26.80	40.00	30.80	- -	25.40	- -	27.80
152	26.00	30.80	46.60	35.40	40.40	- -	30.60	- -
183	13.40	16.60	30.00	21.40	18.40	18.40	17.20	17.40
Mean	23.30	24.55	36.65	28.60	28.00	20.60	23.00	21.67
STD	6.73	5.99	8.14	5.95	11.26	4.16	6.88	5.45
	Area Category = 3 and Fractal Category = 3							
6	15.00	30.80	40.00	- -	- -	17.80	22.40	- -
9	15.00	16.60	- -	26.00	- -	- -	14.20	- -
93	36.60	33.40	40.00	40.20	32.80	40.00	- -	- -
96	23.60	26.00	33.40	26.00	26.00	- -	21.80	21.60
100	20.00	- -	33.40	28.60	- -	20.00	22.20	22.20
108	- -	26.00	33.40	26.00	28.00	20.60	21.20	21.20
114	26.00	15.00	30.00	26.00	20.40	19.00	24.80	- -
130	28.40	- -	36.60	30.80	40.40	25.60	27.20	- -
132	36.60	- -	56.60	53.80	- -	43.00	- -	- -
141	28.40	- -	50.00	53.80	66.40	- -	- -	- -
143	- -	33.40	36.60	- -	32.80	24.80	- -	- -

Appendix I. Slope Mode Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 3 and Fractal Category = 3 (continued)							
153	28.40	35.40	40.00	35.40	- -	27.20	- -	25.60
154	33.40	26.80	46.60	56.80	68.40	53.00	29.80	29.80
172	28.40	30.80	50.00	30.80	42.40	27.20	28.60	28.60
173	13.40	26.80	33.40	- -	- -	- -	34.20	15.40
184	31.80	30.80	43.40	30.80	32.80	25.40	27.60	24.80
203	38.00	30.80	43.40	43.40	27.20	17.20	33.00	33.00
213	34.40	33.40	53.40	- -	- -	- -	43.20	35.80
Mean	27.34	28.29	41.19	36.31	37.96	27.75	26.94	25.80
STD	8.02	6.09	7.89	11.35	15.83	10.95	7.27	6.12
	Area Category = 3 and Fractal Category = 4							
7	26.00	16.60	36.60	26.00	32.80	22.60	27.20	23.60
36	28.40	30.80	33.40	30.80	30.80	22.60	27.80	- -
67	46.40	35.40	50.00	35.40	- -	33.00	- -	- -
127	23.60	21.40	30.00	30.80	26.00	20.60	20.40	18.20
129	28.40	43.40	46.60	- -	- -	39.60	28.40	- -
131	13.40	23.60	30.00	26.00	21.20	21.20	- -	22.80
151	28.40	30.80	36.60	30.80	- -	- -	- -	26.60
230	34.40	44.80	50.00	44.80	- -	24.80	23.20	23.20
Mean	28.63	30.85	39.15	32.09	27.70	26.34	25.40	22.88
STD	9.36	10.13	8.49	6.48	5.19	7.19	3.46	3.02
	Area Category = 3 and Fractal Category = 5							
1	44.80	40.20	60.00	44.80	48.20	42.40	41.20	43.20
3	10.60	30.80	40.00	40.20	- -	30.60	35.40	- -
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	48.40	44.80	70.00	- -	56.80	- -	45.60	- -
120	36.60	33.40	46.60	35.40	42.40	- -	29.80	- -
158	- -	77.80	90.00	80.20	79.00	72.20	- -	- -
186	- -	43.40	70.00	49.60	58.80	48.40	- -	48.00
Mean	23.40	33.80	47.08	35.74	40.74	32.27	25.33	22.80
STD	22.43	25.31	32.83	28.36	30.07	28.43	20.33	26.40

Appendix I. Slope Mode Value of a Polygon for the Different Slope Methods (continued)

Polygon	Slope Method 1	Slope Method 2	Slope Method 3	Slope Method 4	Slope Method 5	Slope Method 6	Slope Method 7	Slope Method 9
	Area Category = 3 and Fractal Category = 6							
71	57.00	15.00	76.60	61.20	53.80	- -	48.00	55.00
105	14.20	16.60	33.40	28.60	28.00	- -	- -	- -
Mean	35.60	15.80	55.00	44.90	40.90	- -	48.00	55.00
STD	30.26	1.13	30.55	23.05	18.24	- -	0.00	0.00
	Area Category = 4 and Fractal Category = 2							
190	28.40	30.80	33.40	- -	- -	- -	28.40	28.40
	Area Category = 4 and Fractal Category = 5							
139	16.60	23.60	30.00	26.00	21.20	17.20	17.20	17.40
	Area Category = 4 and Fractal Category = 6							
10	48.60	- -	66.60	45.40	50.20	45.40	45.80	45.60
137	3.80	7.40	33.40	30.80	10.60	7.20	5.20	2.80
Mean	26.20	7.40	50.00	38.10	30.40	26.30	25.50	24.20
STD	31.68	0.00	23.48	10.32	28.00	27.01	28.71	30.26
	Area Category = 5 and Fractal Category = 2							
35	28.40	30.80	40.00	30.80	32.80	28.40	22.40	22.00

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The author was born on November 22, 1954, in Baltimore, Maryland. After moving to Winsted, Connecticut, at age 10, he graduated from the Gilbert School and then Northwestern Connecticut Community College. There he attained an Associate of Science degree in Park Management and Design in 1977. The author then moved to Flagstaff, Arizona, to attend Northern Arizona University, where he met and married Marilyn Fossum in 1981. Upon graduating, cum laude, from Northern Arizona University in 1982 with a degree in Forestry, he went to work for the Dixie National Forest in Utah as a Forest Technician. The next year the author went to the University of Minnesota to pursue a Masters degree in Forestry, with an emphasis in remote sensing. His Masters thesis was entitled "Application of 35mm Aerial Photography to Evaluate Post-Harvest Aspen Regeneration." Upon graduation from the University of Minnesota in 1984, he worked for both the Tonto and Dixie National Forests. In 1985, the author became a Project Research Analyst for the Coconino County Highway Department in Flagstaff, Arizona. His main responsibility there was developing a county road information system. In 1987, he moved to Blacksburg, Virginia to pursue a PhD in Forestry specializing in Geographic Information Systems and Spatial Data Analysis. During the summer of 1990, the author was asked to be part of a team that designed a national forest land use and management planning system for Indonesia. At that time he worked in Jakarta, Indonesia for the Food and Agriculture Organization of the United Nations.

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