SHORT NOTE

GRID SIZE DEPENDENCY OF PARAMETERS EXTRACTED FROM DIGITAL ELEVATION MODELS

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INTRODUCTION

Automated extraction of drainage features from Digital Elevation Models (DEMs) is an effective alternative to the tedious manual mapping from topographic maps. Several methods to extract drainage features from DEMs are available (Band, 1986; Fairfield and Leymarie, 1991; Jenson and Domingue, 1988; Martz and Garbrecht, 1992; O'Callaghan and Mark, 1984) and have been applied in diverse areas such as hydrology, geomorphology, geology, and biology (Drayton, Wilde, and Harris, 1991; Jenson, 1991; Martz and De Jong, 1991; Moore, Grayson, and Ladson, 1991; Quinn and others, 1991). Studies have investigated the effect of DEM elevation errors on extracted drainage features (Lee, Snyder, and Fisher, 1992), or the combined inherent and operational errors of an integrated GIS application (Walsh, Lightfoot, and Butler, 1987). In this paper the impact of DEM resolution on extracted drainage properties is examined for a study basin using hypothetical drainage network configurations and DEMs of increasing grid size.

METHODOLOGY

The investigation is conducted in the form of a sensitivity analysis. Drainage properties are extracted from DEMs of increasing grid cell size and for several hypothetical network configurations. Two data transformations are necessary to make the various drainage properties and network configurations comparable. First, the drainage properties are expressed in percent difference from a baseline reference. The baseline reference is given by the property value obtained from the highest resolution DEM. Application to an actual watershed has shown that the baseline case given by a 30 × 30 m DEM cell resolution can produce most drainage features within less than 10% of corresponding values measured from USGS 7.5-min topographic quadrangles

(Garbrecht and Martz, 1993). Second, grid size is expressed as a dimensionless grid coefficient defined as the ratio of grid area to network reference area. The network reference area is the mean area draining directly into the channel links of the network. It is calculated as half of the mean channel link length over drainage density, which is equivalent to mean channel link length times overland flow length.

Pertinent drainage features and properties are extracted from DEMs using the Digital Elevation Drainage Network Model DEDNM (Martz and Garbrecht, 1992). This model was selected because the DEM processing is based on flow routing principles similar to those in other leading models, it has been verified using real watershed applications, and because the authors detailed knowledge of the capabilities and limitations of its analytical algorithms. Two categories of algorithms drive model DEDNM: data preparation and data-processing algorithms. Data-preparation algorithms scan the DEM data and resolve indeterminate flow paths in depressions and on flat areas of the landscape. Data-processing algorithms extract parameters such as flow paths, upstream areas, drainage network definition, network topology, channel segment characteristics, channel and subwatershed indexing, and subwatershed areas. The model defines a fully connected drainage network based on two parameters which control the configuration of the extracted network. The parameters are the critical source area (CSA) and the minimum source channel length (MSCL). Parameter CSA is the upstream drainage area below which a source channel is initiated, and parameter MSCL is the shortest accepted length for source channels.

Drainage features are extracted for Bills Creek watershed, an 84 km² drainage area of low relief terrain in southwestern Oklahoma. A DEM of the watershed was custom digitized by NASA from USGS 7.5-min topographic quadrangles. Elevation data are reported in 3-ft (0.91 m) increments on a 30 m grid scale. Additional DEMs of increasing

Table 1. Network configuration parameters for grid size dependency analysis

Critical source area (ha)	Minimum source channel length (m)
16	500
32	1000
64	1500
128	2000
192	2500

grid cell size are generated by successive spatial averaging of the baseline DEM. The linear averaging is reformed on blocks of 2 × 2, 3 × 3, ..., and 20 × 20 cells of the baseline DEM. This provides a series of DEMs with grid cell sizes ranging from 30 to 600 m, incremented in steps of 30 m, and corresponding grid cell areas of 0.09–36 ha.

The various network configurations needed for the sensitivity analysis are extracted from the given series of the DEMs by setting one of the two network parameters, CSA and MSCL, to zero and varying the other. The various network configuration parameters for which the evaluation is performed are shown in Table 1. One additional network configuration having a CSA and MSCL of 8 ha and 135 m, respectively, is extracted from the given series of DEMs. This configuration represents the blueline drainage network shown on the USGS 7.5-min topographic quadrangles of the study watershed. Finally, the extracted drainage properties considered in this analysis are: (1) critical source area; (2) number of channel links; (3) total channel length; (4) mean channel link slope; (5) watershed drainage density; and (6) mean channel link direct drainage area.

RESULTS

Variable critical source area

Results for the five network configurations having MSCL of zero and variable CSA and for the 19
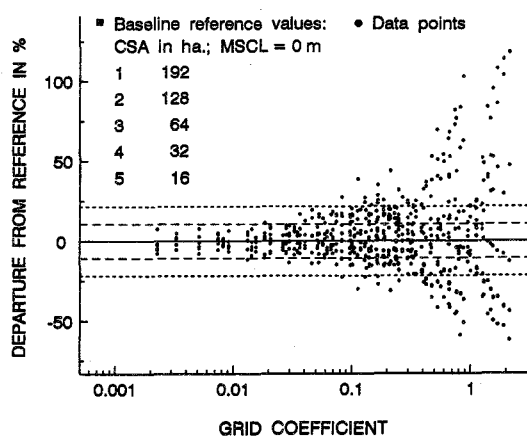

Figure 1. Drainage features versus grid coefficient for zero MSCL and variable CSA.
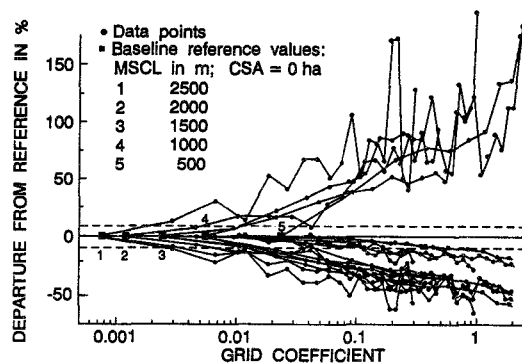

Figure 2. Drainage features versus grid coefficient for zero CSA and variable MSCL.

aggregated DEM grid sizes are shown in Figure 1. For grid coefficients below 0.01 and 0.08 all extracted drainage properties are within 10 and 20%, respectively, of the baseline reference values. The values between grid coefficients 0.01 and 0.04 are mostly within the 10% limit with a few individual values outside the limit. The accuracy of the extracted drainage properties seems to converge to the baseline values with decreasing grid coefficient.

Drainage properties extracted from DEMs with grid coefficients larger than 0.08 increasingly diverge from the baseline values. In particular, number of channel links, total channel length, and drainage density decrease with increasing grid size; mean link drainage area increases with increasing grid size; and, CSA has no trend but increase in variability with increasing grid size. The reasons for these trends are discussed in the following section.

Variable minimum source channel length

Results for the five network configurations having CSA of zero and variable MSCL and for the 19 aggregated DEM grid sites are shown in Figure 2. The data points of each drainage property are connected by solid lines to bring out significant trends with increasing grid size. The immediately diverging trends indicated that parameter MSCL introduces grid dependency. The dependency is the result of (1) the inability of a coarse grid to reproduce consistent channel length values because the amplitude and phase of channel sinuosity are at the order of the grid size, and (2) the channel capturing effect introduced by a coarser digital representation of the terrain. Both these effects lead to shorter channel lengths which result in additional removal of source channels as their length falls below the MSCL value. Therefore, the number of channel links, total channel length, link slope and drainage density decrease with increasing grid size, and mean link drainage area increases with increasing grid size.

Bills Creek drainage network

Results of the network extraction for Bills Creek are shown in Figure 3. The data points are left
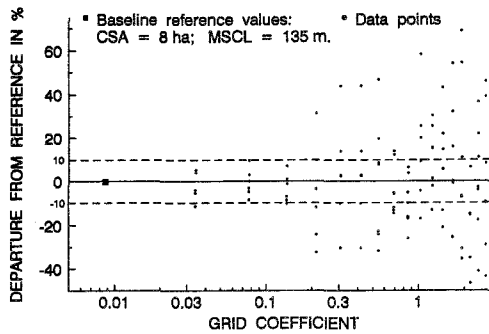
Figure 3. Drainage features versus grid coefficient for Bills Creek network.

unconnected because they predominantly oscillate about the zero departure line and show no significant trend. The extracted drainage properties diverge beyond the 10% limit for grid coefficients above 0.1. It seems that for natural network configurations which are controlled primarily by the CSA parameter the grid dependency establishes itself gradually with increasing grid size as the latter approaches the size of the extracted drainage features. The strong grid dependency for the full range of grid sizes previously observed for parameter MSCL is not a dominant factor here because parameter MSCL does not control the extracted network configuration as in the previous section. However, as the grid size increases to where the cell area approaches the value of CSA, the impact of MSCL may again become noticeable.

CONCLUSIONS

The dependence of extracted drainage properties on DEM resolution is investigated for a 84 km² watershed in southwestern Oklahoma. Grid resolution is decreased by grid cell aggregation of a 30 × 30 m baseline DEM, and drainage properties from various hypothetical network configurations are extracted from each DEM using software DEDNM. Changes in the extracted properties with increasing DEM grid size are examined. The sensitivity analysis suggests that a DEM should have a grid area less than 5% of the network reference area to reproduce important drainage features with an accuracy of about 10%. The study also shows that DEM processing models that rely on a threshold channel length to control network characteristics may be grid size dependent at grid coefficients below 0.05. In general, the grid size dependency is introduced by the inability of a DEM to accurately reproduce drainage features that are at the same scale as the spatial resolution of the DEM. For sinuous channels, this results in shorter channel lengths and for networks with high

drainage density, it leads to channel and drainage area capturing. Channel and drainage area capturing occurs when the DEM grid can no longer resolve the separation between channels or drainage boundaries. In such situations, the number of channel, the size of direct drainage areas, and the network pattern may depart considerably from the initial reference values. If small drainage features are important, the grid size must be selected relative to the size of these features to allow their resolution.

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