CHAPTER 17

Extracting topographic and terrain variables for distributed models

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Summary

Many spatially distributed environmental models such as hydrology, erosion - deposition and water quality models rely on a cellular or grid structure to capture the landscape. Important input and output data requirements result from this approach. GIS represents an adequate framework for pre- and post processing geo-referenced model input variables or output data. In this exercise, the first steps for extracting topographic variables and land surface characteristics from basic GIS data are explained.

Getting started

The data for this case study are stored on the ILWIS 2.1 CD-ROM in the directory d:\appguide\chap16. If you have already installed the data on your hard-disk, you should start up ILWIS and change to the subdirectory where the data files for this chapter are stored, c:\ilwis21\data\appguide\chap16. If you did not install the data for this case study yet, please run the ILWIS installation program (see ILWIS Installation Guide).

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- Double-click the ILWIS program icon in the ILWIS program group.

- Change the working drive and the working directory until you are in the directory c:\ilwis21\data\appguide\chap17.

Now you are ready to start the exercises of this case study.

Outline of methods

In this exercise, the first steps for extracting topographic variables and land surface characteristics from basic GIS data are explained. These variables are then used for hydrologic, erosion and non-point source pollution models. This case study uses a small 16-ha experimental catchment in the Cape Verde islands (Central-east Atlantic). Model input data in a format requested by the AgNPS v5.0 model (Young *et al.*, 1995) are processed. The small size of the watershed permits detailed verification of derived model parameters for user-defined grid resolutions. Larger watersheds (> 200 km^2) can be analyzed using a similar approach (Renschler, 1996; Mannaerts *et al.*, 1995).

The gridding and subsequent processing of topographic and terrain variables from basic GIS data layers such as contour and drainage lines or watershed boundaries require rather advanced GIS routines to be performed. The user should therefore be familiar with vector to raster conversions, map algebra, spatial filtering and neighborhood operators in ILWIS. Although basic principles will apply for most models, most extracting routines are model specific. The AgNPS erosion and runoff water quality model requires a basic cell division of a watershed according to a user-defined grid size. When gridding, border cells with less than 50% of their area within a watershed boundary are excluded (see figure 17.1). Watershed gridcells are numbered proceeding from the northwest corner from west to east in southward direction. This cell numbering presents the essential key index for the input data files and is used to check the runoff routing through the grid system.

In the first four steps, the basic GIS vector files are displayed, rasterized and a grid mask of user-defined size is created with a unique cell numbering (i.e., step 1 to 4). A 20 m cell size was chosen in this example.
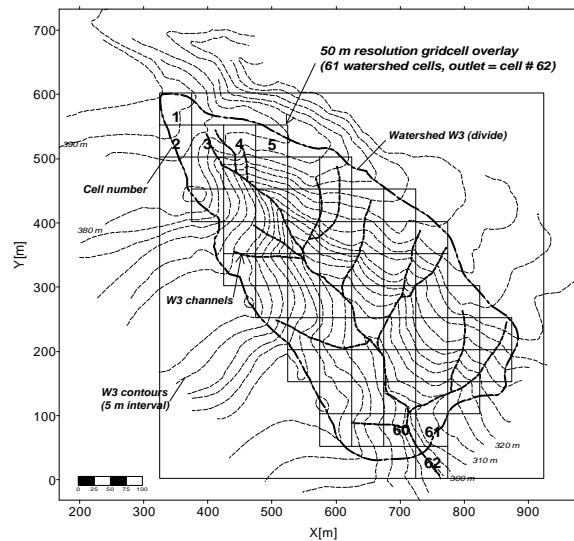

Figure 17.1: Example of a GIS-based gridcell overlay of watershed W3

Step 1: Display input data

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- Display the segment map W3_bnd containing the watershed boundary.

- Display the segment map W3_riv with the analyzed river.

- Display segment map W3_dem with the contour lines, using the Pseudo representation.

Step 2: Polygonize and rasterize input maps

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- Create the map Mask after polygonizing the map W3_bnd using the option Segment to Polygon. Don't select labels!

- Rasterize Mask into Maskr using the option Polygon to Raster (create a georeference called Mask accepting all the defaults).

- Rasterize W3_riv into River using the option Segment to Raster. Use the georeference Mask.

Step 3: Create the Digital Elevation Model of the study area

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- Compute the Digital Elevation Model map Dem from W3_dem using Contour Interpolation and the georeference Mask.

- Display Dem using the representation Pseudo.

Step 4: Grid overlay and unique cell numbering

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- Compute a new map Mask_c20 taking Maskr as the starting map for the option Aggregate. Give a group factor of 20 and select the function Predominant. Accept the default for group. Display Mask_c20.

- Calculate a unique cell map for any cell of Mask_r20 with MapCalc:

> ```
> Temp=ifundef(Mask_c20,0,%C+(%L-1)*28)↵
> ```
>
> creating an identifier domain called `Temp`. Assign 784 as the number of items.
>
> - Create a map `Uniq` using the option Area Numbering (8 connected) creating the new domain `Uniq`. Use the Pseudo representation to display it.

Step 5: Aggregation model inputs

In step 5, the hydrologic flow routing is analyzed, in order to permit continuity of water, sediment and chemical flows through the watershed. A flow direction map is derived using neighborhood operators. The flow direction syntax used by the model (e.g., AgNPS) has to be respected and may not coincide with the GIS neighborhood denominations. This step also illustrates the calculation of two important gridcell attributes i.e., a land slope gradient map and a channel indicator map.

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>
> - Compute a new map `Dem_r20` using Aggregate. Use `Dem` as the input map. Give a group factor of 20, select the function Average. Accept the defaults for group, domain and range. Give a precision 0.1. Display `Dem_r20` using the representation Pseudo.
>
> - Calculate the flow direction matrix map `Dir_flo` with the MapCalc formula:
>
>   ```
>   Dir_flo=10-nbminp(Dem_r20#)↵
>   ```
>
>   Accept all defaults.
>
> - Prepare the neighbor aspect map to be reclassified according to the AgNPS syntax. Calculate first the cell aspect map `Dir_asp` with the following MapCalc formula:
>
>   ```
>   Dir_asp=nbminp(Dem_r20#)↵
>   ```
>
>   Accept the defaults. Reclassify `Dir_asp` using the `Agnps` group domain. Call the result `Cel_asp`.
>
> - Calculate the slope map `Slope`, in percentage, using the dfdx and dfdy filters on `Dem_r20` and then the function Hyp.
>
> - Calculate an aspect map also using the dfdx and dfdy filter. Call the result `Aspect`.
>
> - Compute a channel indicator map called `River_20` using the map `River` and the option Aggregate. Select a group factor of 20 and

the function Predominant. Accept the default for group. Display it.

- Calculate a channel indicator value map Chan_r20 with the MapCalc formula:

    Chan_r20=ifundef(River_20,0,1)↵

    where 1 means included in the river while 0 means outside (domain Boolean).

Step 6: Preparation for model input

All the derived model input variables are linked to a unique watershed cell number. This is obtained by using map crossing and join table column operations for each identified or required topographic or terrain variable.

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- Mask the maps Chan_r20, Dem_r20, Dir_flo, Cel_asp, Slope and Aspect using the map Uniq (when defined) in MapCalc to prepare the maps for the crossing. Call the output maps Chanr20m, Demr20m, Dirflom, Celaspm, Slopem and Aspectm.

- Perform the following map crossings and save the results (a Script is advisable):

    Uniq and Chanr20m and call the output table Un_chn.

    Uniq and Demr20m and call the output table Un_dem.

    Uniq and Dirflom and call the output table Un_flo.

    Uniq and Celaspm and call the output table Un_agn.

    Uniq and Slopem and call the output table Un_slo.

    Uniq and Aspectm and call the output table Un_asp.

- Using the results of the crossings, the Join column option and the column Uniq as the Key, create a table like the following:

	Uniq	Chanr20m	Demr20m	Dirflom	Celaspm	…
1						
2						
…						
784						

! The cell resolution adopted in the aggregation function is 20 m. Repeat the exercise using a 15 and/or 25 grouping factor.

Many more model input variables related to topography, drainage or land surface (e.g., vegetation cover, soil erodibility,...) can be obtained using similar procedures. Extraction routines were used successfully using the ILWIS v.1.41 version (Mannaerts, 1995; Renschler *et al.*, 1997). A small interface program is used to convert ILWIS map files, containing the input parameter data to an input data file acceptable by the AgNPS model. This program, available for two-way or reverse conversions ILWIS 1.41 to and from AgNPS v.5, reads the map values for the respective cells and writes these values to a file in a AgNPS data format. AgNPS output can be converted back to ILWIS files. An ILWIS 2.1 version of these extraction and conversion routines is under study. Model interfaces, able to read the ILWIS 2.1 maps, are also under consideration.

References

Young, R.A., Onstad, C.A., Bosch, D.D. and Anderson, W.P. (1995). *AgNPS version 5.0: Agricultural Non point Source Pollution Model*. USDA-Agricultural Research Service. North Central Soil Conservation Research Laboratory, Morris, Minessota. United States.

Renschler, C.R. (1996). *Soil erosion risk mapping by means of GIS and Hydrologic modelling*. Internal M.Sc. (Diplom) Geo-Ecology thesis. Institute of Geography and Geo-ecology, Technical University Braunschweig, Germany, and International Institute of Aerospace Surveys & Earth Sciences, ITC, Enschede.

Mannaerts, C.M. (1995). *Impact prediction modelling*. ITC Internal Lecture notes. Environmental Systems Analysis & Monitoring ESM.2 M.Sc. Program. International Institute of Aerospace Surveys & Earth Sciences, ITC, Enschede. The Netherlands.

Renschler, C.R., Mannaerts, C.M. and Diekkruger, B. (1997). Spatial and temporal variability in soil erosion risk evaluation. Extended Abstracts (pp.217-220) of *IAHS UNESCO International Conference on Regionalization in Hydrology*, March 10-14 1997, Braunschweig. Germany.