GIS APPLICATIONS IN SOIL SURVEY UPDATES

ABSTRACT

Recent computer hardware and GIS software developments provide new methods that can be used to update existing digital soil surveys. Multi-perspective visualization of soil/landscape relationships in ArcScene concurrent with a Planimetric edit session in ArcMap will provide the soil mapper an effective set of tools for survey maintenance. Also, intersection of slope information derived from DEMs with existing soil data will provide a quantitative analysis of slope inclusions within map units.

BACKGROUND

The United States Department of Agriculture - Natural Resources Conservation Service is changing its way of conducting geospatial business activities. Personnel are starting to work with digital technology throughout all levels of the agency. Digital elevation data has been evaluated and found to be effective for some soil survey applications (Klingebiel, 1988). One of the challenges to be overcome when applying geospatial tools that are now available to business applications occurs when new tasks can now be performed with the advent of GIS. Incorporation of "new" geospatial data into business activities is also a challenge for employees who are new to the technology. There are many new geospatial tools available in a variety of software packages. A major improvement in the soil survey update or maintenance process is converting the older soil survey from an analog/hard-copy to a digital format. This can be a tedious process of recompiling the spatial features to a rectified image base. This paper examines the application of geospatial technology to two tasks of an update or maintenance of digital existing soil surveys, visualization of a 3D perspective while editing and identification, location, and quantification of slope gradient inclusions in a digital soil survey prior to update or maintenance initiation.

SOIL SURVEY UPDATES

Soil surveys have been produced by NRCS in cooperation with local, state, and federal entities as part of the National Cooperative Soil Survey for over 50 years. Over the past 10 years more than 1000 digital soil surveys have been produced in ESRI coverage and shapefile formats. Published soil surveys typically consist of a bound document containing a narrative text, tables, and maps. The narrative text section consists of a description of the soil survey area, the general and detailed soil map unit descriptions. The tables contain physical and chemical soil properties for each map unit and interpretations of the soil map units limitations for specific uses. The maps section consisted of a general soil map, the detailed soil map (scale ranges from 1:12,000 to 1:31,580) on fold-out sheets, and a location map for the user to quickly locate which map panel or atlas sheet displays the area of interest. Detailed soil maps have soil map unit delineations drafted onto an aerial photo base. Each soil map unit has a slope gradient range that in many cases is part of the map unit name, e.g., Dubbs silt loam, 1 to 3 percent slope. Each individual map unit delineation is labeled with a map unit symbol that is the identifying link to the tabular attribute and descriptions in the manuscript part of the soil survey document. Typically, additional spatial information is considered important and drafted onto the image base with the soil delineations. These other spatial layers may include, the hydrology, transportation, township and range public land units, and cultural features.

Based on factors such as changes occurring over time, including development/land use changes, concepts in soil classification, etc. a soil survey is considered to be out of date and in need of update or maintenance. In most cases the tabular attribute data for the mapunits pertaining to a soil survey are updated over time and are available to users as requested. Also, in many cases it is determined the map unit delineations adequately represent the soil occurrence on the landscape and only the aerial photo base needs to be updated. Less commonly it is determined that modification of the spatial features, the map unit delineations, of a published soil survey is required. The amount of modification to the spatial features may be the result of a variety of factors related to changing mapping and classification concepts. The required level of detail (designated as orders 1-5) of a survey area may have changed because of landuse changes (Soil Survey Staff, 1993). The very shape of the landscape may have changed over time due to natural or cultural occurrences. For example, in intensive agricultural areas thousands of acres have been smoothed or leveled to provide a uniform distribution of irrigation water or reduce crop loss due to wet conditions. These kinds of landform changes are easily detected with current digital elevation data. Slope information such as aspect, gradient, complexity, and shape can be derived from a DEM.

Fig. 1. Example of drastic cultural landform modification, cut and fill land leveled area on the right.

APPLICATION OF GEOSPATIAL TOOLS

Use of ArcScene for 3D visualization.

Surface creation from elevation data can be accomplished using different data formats such as grids (raster) or triangulated irregular network (TIN). Grid data are widely accessible but are limited in use for terrain analysis because ridge and peaks positions cannot be located beyond the accuracy of the grid cell resolution. TIN data that more accurately reflect the land surface are not as available and require more processing to produce. Production of a surface for visualization of the soil map unit/ landscape relationship can be accomplished with elevation data at a 30-meter resolution.

Soil map unit boundaries are not always coincident with landform changes observable on a DEM surface. However, where they are coincident, then observation of soil map unit boundary line placement on a digital terrain model of the landscape provides the soil scientist with the capability to view from any perspective the soil/landform relationship. This allows for the identification of areas where the soil map unit line may need to be adjusted to more appropriately fit the landform as depicted on the terrain surface model. Non-digital methods used to perform this function in the past required stereoscopic interpretation with hard copy stereo pair aerial photos. The quality of the soil map unit boundary placement lay entirely in the interpretation skills of the soil scientist (King, 2001). One of the software tools available for 3D visualization is ArcScene. There are other software packages that can perform this functionality and this should not be considered an endorsement for any particular software. There is software that will allow the user to edit the line placement in the 3D perspective view with or without the use of digital stereoscopic interpretation. Using ArcGIS the user will be able to view the map unit line placement in the 3D perspective view in an ArcScene window and then any modification will be performed in an ArcMap session running concurrently.

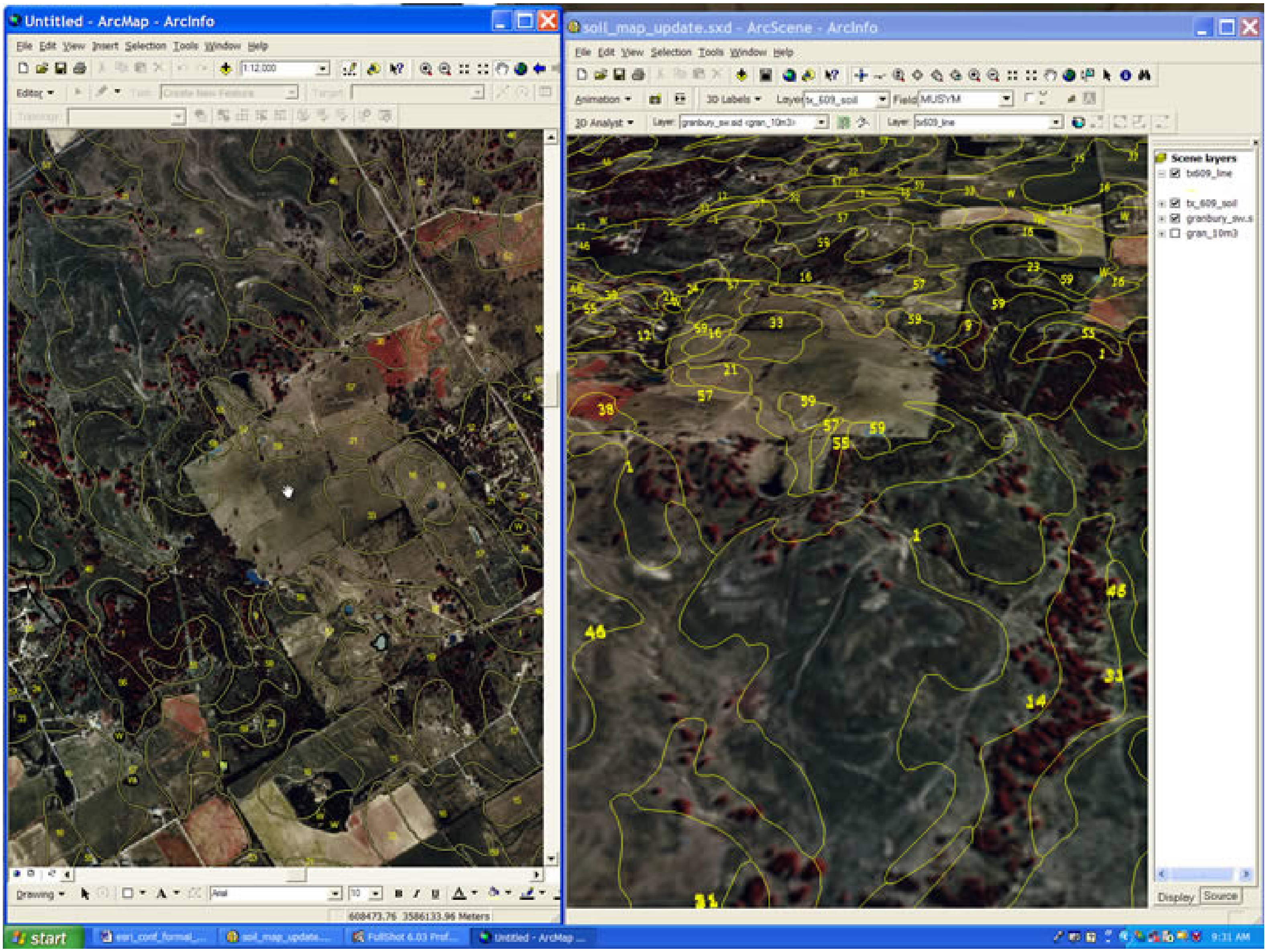


Fig. 3. Example of an ArcMap and ArcScene session running concurrently. The perspective view in ArcScene is rotated about 170 degrees from the planimetric view in ArcMap.

Use of Spatial Analyst to derive slope gradient information.

Slope gradient, as defined for soil survey purposes, is the angle of the ground surface (in percent) in the direction that overland water would flow (Soil Survey Staff, 2002). The slope function in Spatial Analyst is used to obtain this percent rate of change. It calculates the maximum rate of change between each cell and its neighbors; for example, the steepest downhill descent for the cell (the maximum change in elevation over distance between the cell and its eight neighbors). Every cell in the output raster has a value. It is the first derivative of the elevation data. The increase in quality and availability of DEM data will allow for analyses that had previously not been easily performed over a large area. For example, the production of slope information derived from the DEM when integrated with soil map units can be used to quickly identify areas that have changed since the soil survey was completed. The quantity of areas within individual map units that are outside of the described slope range of the map unit can be determined. The location of these areas can be symbolized and coordinates obtained for navigation to these areas for on-site verification.

The process for creating a slope layer.

Obtain the Elevation data. Depending on the type of terrain will determine the quality of DEM data needed for the soil map unit/slope analysis. If the area has a lot of relief and small areas with less than 5% slope, then elevation data with a least a 10 meter resolution is considered the largest acceptable resolution. If the area of interest consists of low relief with slopes less than 5%, then finer higher quality resolution elevation data, e.g., LIDAR or IFSAR, should be acquired if possible.

Convert DEM to GRID. If not obtained in an ESRI Grid format, the elevation data will need to be converted. The data may also need to be modified by projection to the coordinate system of the soils data for analysis.

Convert z values to feet. To achieve the percent slope map unit delineations necessary for the analysis with the soil map units, the elevation values will need to be converted from meters to feet. The equation for conversion used is:

Meters * 3.28 = Feet.

Attempt to reduce the rice paddy effect. Elevation data obtained from USGS in most cases is produced by interpolation of contour lines. This process results in a pattern of cells with similar values in the location of the contour line. The residual effect of the contour line on the surface will have an undesirable effect on the slope gradient values obtained.

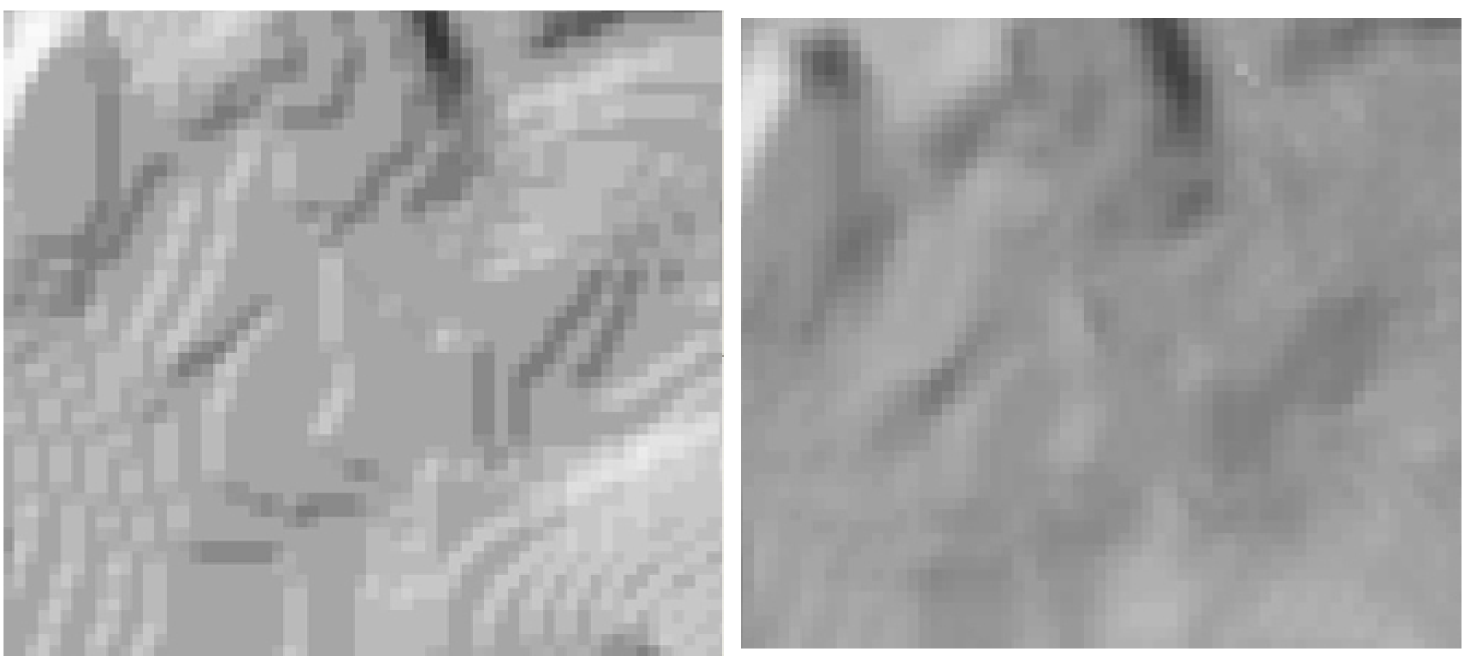


Fig. 4. Example of rice paddy effect and generalization result.

Contour line residual effect. **After generalization.**

Generalize the elevation data. To overcome the residual effect of the contour line location, a generalization of the elevation values is applied. A mean neighborhood function is performed in a circular area with a radius of 3 cells. This will create a grid that can be used for slope calculation.

Create slope. The percent slope grid is created. If the coordinate system projection for the **x** and **y** units are in meters, then a **z** factor (0.304) will need to be entered. The software assumes the z units are consistent with the **x** and **y** units.

Generalize the slope grid. To further overcome the residual effect of the contour line location and reduce the number of small polygon features a generalization of the original slope grid is applied. Again, a mean neighborhood function is performed in a circular area with a radius of 3 cells. This will create a grid that can be reclassified for to produce the slope map unit layer.

Convert floating point to integer. Prior to reclassifying the slope grid, the cell values need to be changed from floating point to integer. This arithmetical calculation is completed in the raster calculator dialog window. The equation entered in the raster calculator is:

Int(([generalized slope grid] + 0.5)).

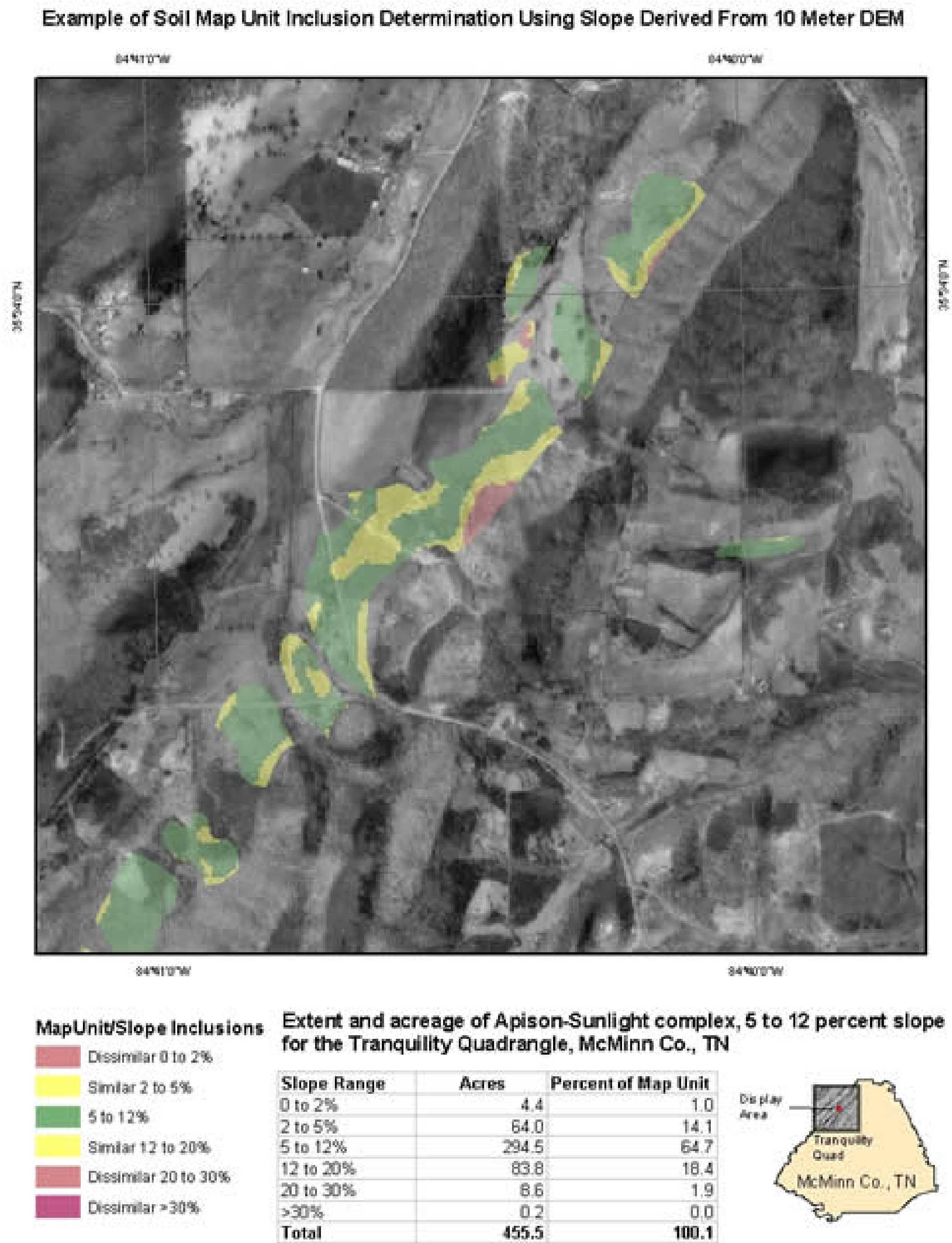
The addition of 0.5 is applied to the cell values in order to round off the cell values to the nearest foot.

Classify the slope breaks. The integer values in the resulting grid cells can then be classed into groups that the soil scientist wants to use in the analysis with the soil map units. This may be identical to the original soil map unit slope ranges or there may be a reason to evaluate how the existing map unit delineations will match a different range of slope values.

Reclassify. The integer slope grid can then be reclassified to create a grid with cells that have the same value for each of the various slope classes.

Convert to vector format. The reclassified grid is converted to a polygon shapefile. It is recommended to not generalize the lines in the conversion process. The result of the conversion will be a polygon shapefile with polygons that delineate areas of the slope ranges as designated by the reclassified grid. These slope range map units can be symbolized using the single attribute labeled GRIDCODE.

Analysis with soil map units. The slope map shapefile can be intersected with the soil map units for analysis. Individual soil map units can be examined to detect the presence of large inclusions that are outside of the named slope range. These areas can be symbolized and the location determined for on-site evaluation.



Slope Range	Acres	Percent of Map Unit
0 to 2%	4.4	1.0
2 to 5%	64.0	14.1
5 to 12%	294.5	64.7
12 to 20%	83.8	18.4
20 to 30%	8.6	1.9
>30%	0.2	0.0
Total	**455.5**	**100.1**

Fig. 5. Example of soil map unit analysis using slope classes derived from 10 meter DEM.

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