LIDAR Enhanced Soil Survey (LESS)

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Background

In the course of mapping soils, the soil scientist uses a combination of science and art to make the soil map. The soil borings and soil pits reveal the soil properties used to classify soils (these decisions are dominated by science, experience, and judgment). The photo tone, landform, and slope breaks provide logical places to delineate soil boundaries (these decisions are dominated by experience, art, and judgment).

Soil line placement is much more subjective because by necessity the soil scientist must project out from the soil borings, interpret the landscape, and sketch the boundary lines. Many of these lines are intended to occur at predetermined slope breaks (0-2%, 2-5%, etc.). Accuracy in delineating lines that separate slope groups has been based on a relatively few readings with a clinometer, stereoscope interpretations, and interpolation based on field experience. In addition, vegetation (trees or crops) can obscure slope readings when trying to create the best line placement. Line placement between soil scientists has also varied with the level of experience and skill in landform interpolation. Because of these limitations, our best efforts at slope break line placement have not always been as accurate as we would like. With the advent of precision farming, highly erodible land determinations, etc., our soils lines are coming under greater scrutiny.

More objective science based slope determinations are becoming possible and affordable, because of advances in technology. In the past a 10 meter DEM (digital elevation model) was used to create raster slope maps. The result was helpful on steep slopes and mapping scales of order 3, but of little value on the nearly level to moderately sloping landforms of an order 2 central Illinois map. The output was not much more than we could glean off the USGS topographic maps. While it provided some idea of the slope in the area, it was not detailed or precise enough to be of much help with most of the soil line placement.

Materials and Methods

In 2007, the Springfield, Illinois, MLRA Soil Survey office obtained LIDAR (Light Detection and Ranging) data with extensive break lines for several townships in Adams County, IL. The county is very progressive in it's use of GIS and purchased approximately 60,000 acres of "high end" LIDAR data along with excellent 6 inch pixel, color orthophotos. We used ArcGIS to create a slope map based on our typical standard slope groups used in Illinois. This slope map was field tested by selecting specific points in the digital data and recording their exact slopes and then using differential GPS to locate those specific points in the field and compare the digital data slopes with actual field determinations (see figure 1).

The slope map showed greater accuracy and consistency than we could obtain with our clinometers. It revealed subtle surface changes that would have likely been overlooked using normal mapping procedures. We believe LIDAR holds exceptional promise for making slope determinations.
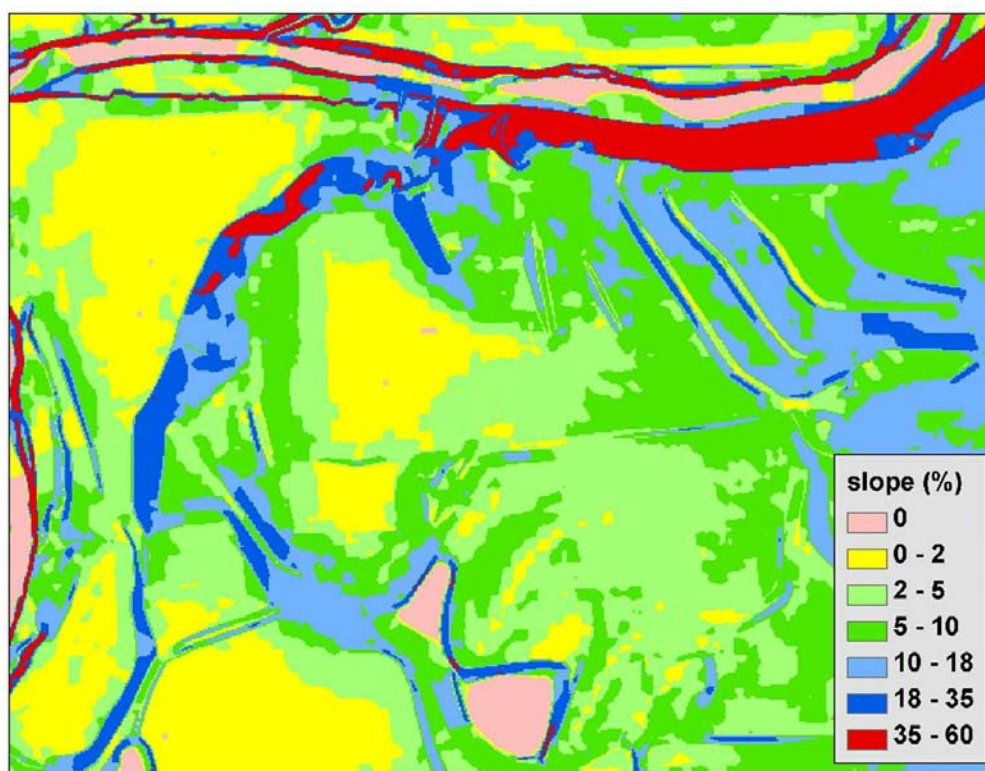
Fig.1. An initial raster slope group map made from LIDAR data taken from Adams Co., IL reveals some slope patterns and excessive detail.

Dale Baumgartner, Resource Analyst at the Springfield, IL MLRA office and Bill Teater soil scientist experimented with onscreen "heads up" digitizing of slope lines using the slope map and orthophotos as a background. While we were pleased with the improved line placement, the process was too slow for production purposes. We then experimented with various ArcGIS generalization commands that produced varying results. We found that in order to maintain better line placement we needed to be working with 1 meter instead of 10 meter pixels. Larger, more averaged pixels created slope lines with less precision in line placement.

We found that merely running the ArcGIS "nibble" command to eliminate all undersized slope units created unintended consequences. For example, small units of adjoining F (18 - 35 %) slopes and G (35 - 60 %) slopes were "nibbled" into the adjacent B (2 - 5 %) slopes unit and lost. Had these F and G units been combined they would have been large enough to meet the minimum size unit and would have been mapped as an F slope unit. We discovered that some commands would be helpful on certain landscapes and less helpful on others. We experimented with many generalizing techniques and prayed for wisdom. We eventually settled on sequential processes that refined the data by eliminating excessive detail while trying to maintain the best position of the final lines. Similar slope areas were selectively and gradually combined using GIS commands until we created units with the least amount of dissimilar slope inclusions that met our desired minimum size. In our case we kept units of one half acre and larger. The minimum size delineation is a variable in the process, so it can be adjusted to fit any desired minimum size. (see figure 2).

We settled on a final process that required a GIS specialist to run more than 80 commands (commands that extract, nibble, and mosaic selected data). This process took several hours to complete a 20,000 acre area. It produced a vectorized slope group map of smoothed polygons for our standard slope groups (see figure 3). We field tested the results, comparing them to the Adams Co. SSURGO soil lines that were manually compiled based on

the standard slope groups, by using light tables, mylar, orthophotos, and USGS topographic maps (see figure 4). We were highly satisfied with the improvement. Our best efforts at updating and recompiling did not compare with the field accuracy of the new slope map.
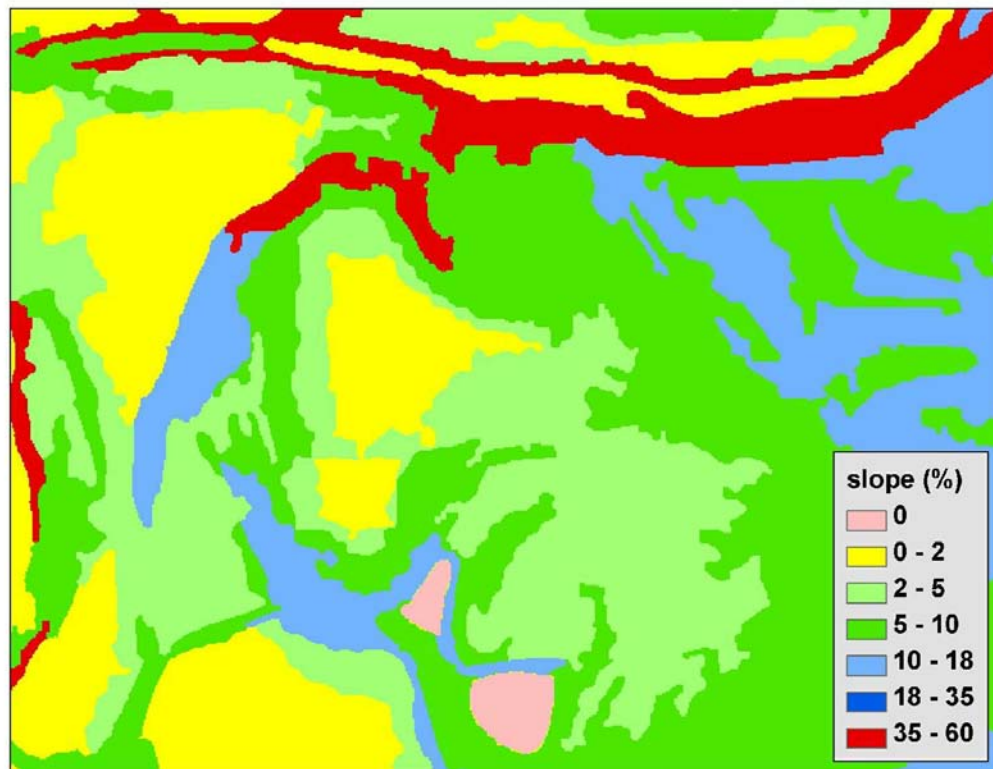

Fig. 2. A final raster slope group map made using a sequence of ArcGIS commands that selectively generalizes LIDAR data in order to reduce dissimilar slope inclusions while retaining good line placement.

Results and Discussion

While the slope map was not all that we wanted, it was a tremendous step forward in improving soil line placement. Areas along stream banks were not improved. The steeply sloping banks sometimes made narrow "spaghetti" units large enough to meet our minimum size. Ditches along roads were also delineated. We have tried to find a way to digitally eliminate these narrow polygons but have yet to come up with a solution.

The Adams County LIDAR data that we used had been "cleaned up" by the vendor and came with extensive slope breaklines. This enabled us to select 0% slope as a slope group producing an instant and extremely accurate water layer. Almost every boundary line was placed within 1 to 2 meters of the shoreline. Errors included a few small areas of level soils and some areas atop buildings with large flat roofs. They were quickly found and converted to an A slope.

Finally, a soil scientist, in this case the Adams County update leader, brought various layers such as 2 foot contour maps, orthophotos, and SSURGO soils into ArcGIS (see figures 3, 4, and 5)
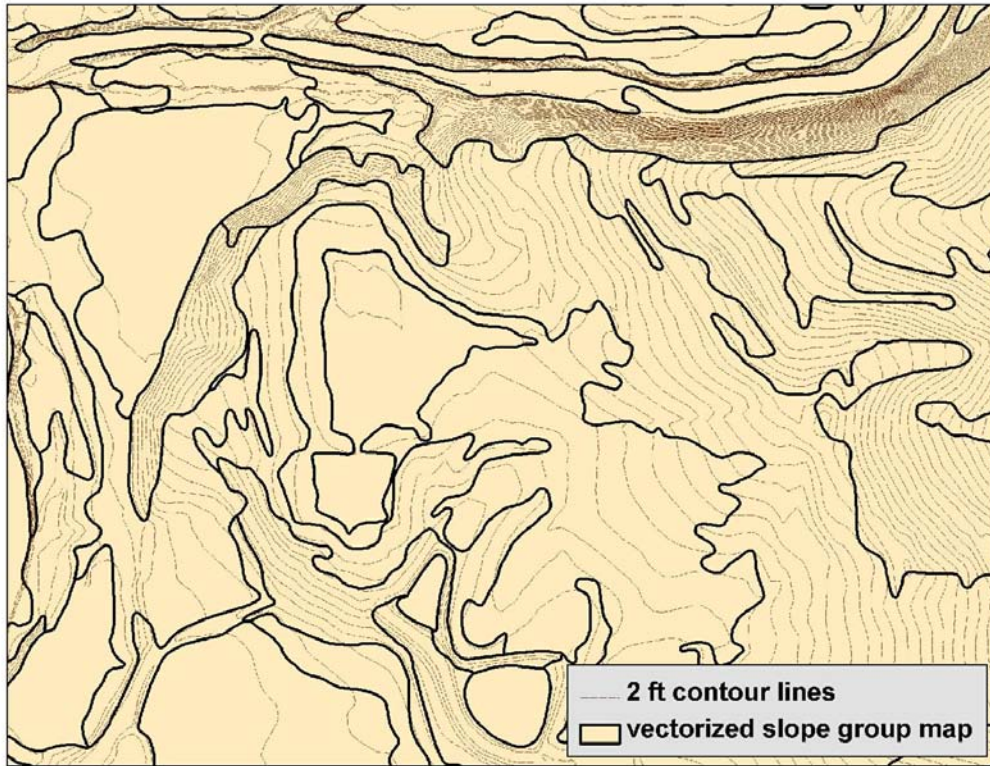
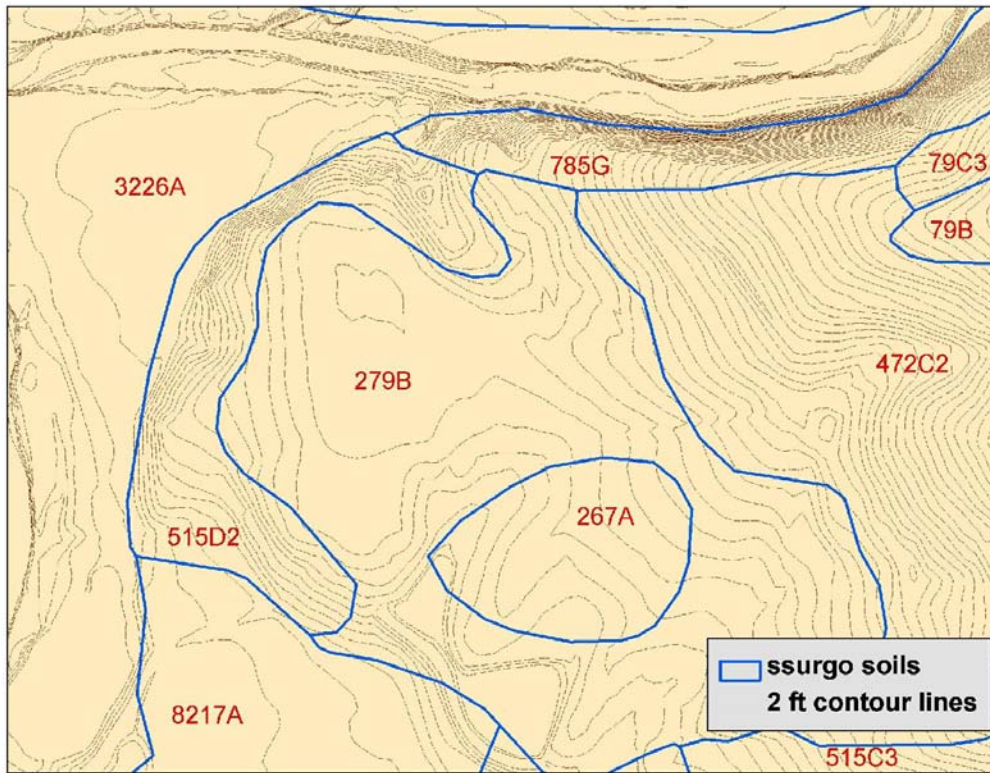**Fig. 3.** A vectorized slope group map with smoothed lines along with a high quality 2 foot contour map.

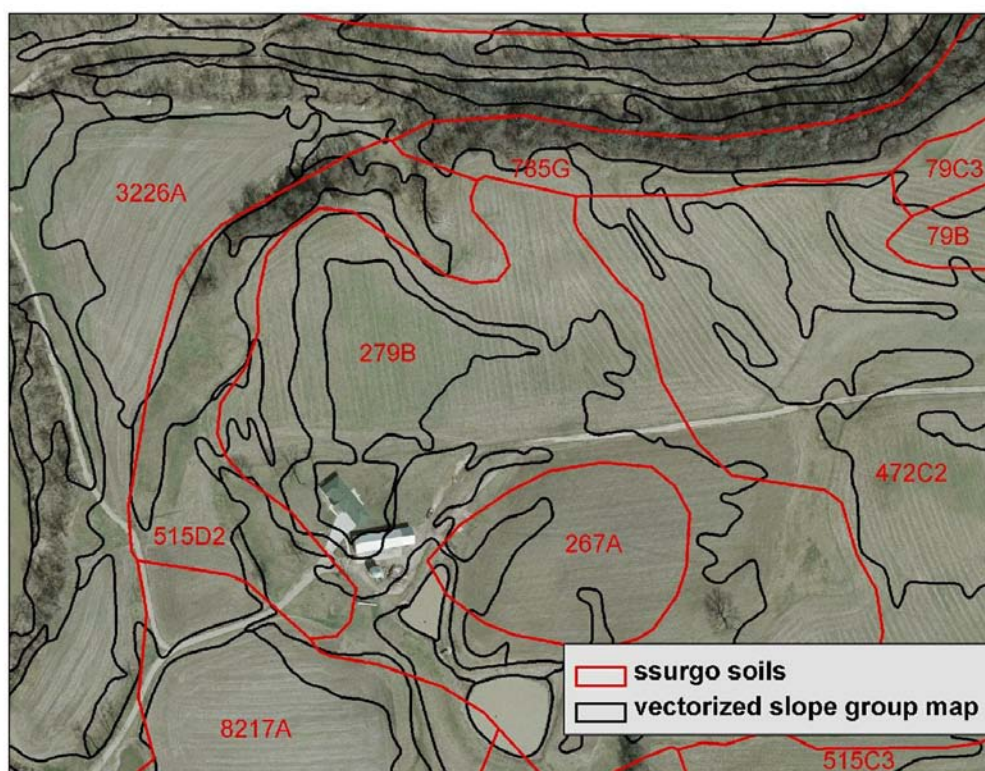**Fig. 4.** The SSURGO soils layer with a high quality 2 foot contour map.

Fig. 5. A comparison of the new vectorized slope group layer and the SSURGO soils layer over a high resolution orthophoto.

He used these layers to edit the slope layer into soil map units and add labels. The final clean up included separating adjacent soils within the same slope group delineation. For example, separating moderately eroded B2 slope units from adjacent uneroded B units on the same landform, or separating different series on the same landform and slope group. In those cases we followed the previous SSURGO soil lines and landform position as much as possible. Most automated lines (70 to 90 percent) did not need to be edited, creating a significant savings of time used to compile lines. In addition the lines were vastly more accurate because of the LIDAR data. The content of our newly drawn polygons reflected the soil series in the SSURGO data, although we sometimes needed to add additional slope mapunits to the legend (no new series were added). Some overly busy areas were generalized to better reflect the SSURGO data and narrow areas of polygons were also addressed. (see figure 6)

With the help of Dwain Daniels, NRCS GIS Specialist, Fort Worth, Texas, we created a GIS model to automate the GIS commands. It requires 2 data inputs (a terrain model and empty geo-database) to run all of the processes. The model can be started at the end of the working day on a selected area of the county and it will work through the different commands overnight. The next day we can examine the new slope map and begin final editing. We have tested the model on various sized areas and have had run times of 20 minutes for 1 section (640 acres of LIDAR data) and 4 hours on a township (23,000 acres of LIDAR data).
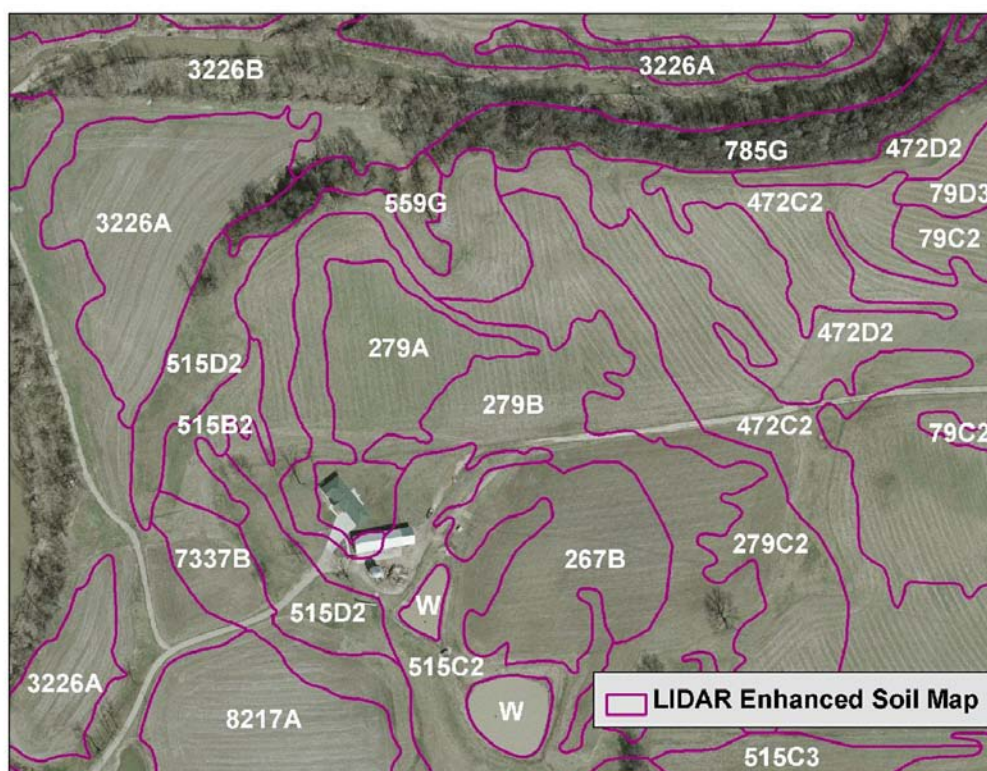
Fig. 6. A LIDAR enhanced soil map with additional slope units more accurately displays the slopes and soils patterns, while increasing the objectivity and science in line placement.

Conclusions

One unexpected revelation from our slope map was that our "nearly level" flood plains were not always nearly level. While the bottomland along the Mississippi River was consistently 0 to 2 percent slope, the smaller tributaries leading down from the uplands were not. In the SSURGO update these areas were typically mapped as 0 to 2 percent (as they have always been), but in many places the slope group would be a better fit at 2 to 5 percent.

Until now, line placement between different sloping units has been mostly a subjective decision. Soil Scientists have done their best to represent the landscape as they saw it and sketched the lines. With LIDAR data as a tool, it is possible to automate most of the soil line placement; with speed and consistency, reducing the amount of dissimilar slope inclusions; and adding more objective science to soil line placement.

The slope map can be tailored to fit the desired mapping scale. The accuracy of LIDAR enables the soil scientist to produce a soil map at a scale of 1:4000 or larger with excellent line placement or at a scale as small as that of a general soil map. The LESS (LIDAR Enhanced Soil Survey) model and slope map that it generates provides an update tool that is ready to use when LIDAR data becomes more readily available.

Our Adams Co. IL project was a trial run. We are trying the LESS model on LIDAR data in several other counties. We will be checking how long it takes to edit/update the SSURGO data, determining what our desired minimum size should be and how fastidious our post GIS model line adjustments should be and experiment with more automated ways of making them.

Individuals desiring to experiment with the GIS model and/or assist us in improving the process of automating soil lines can reach us at bill.teater@il.usda.gov or dale.baumgartner@il.usda.gov.

"..do more with LESS.." -Buckminster Fuller

References and Additional reading:

Aerial LIDAR data layer for Adams Co. IL, for Melrose, Riverside, and Ellington Townships provided by Kucera International Inc., Willoughby, Ohio, Spring 2006

SSURGO soils data layer for Adams Co. IL, provided by USDA, Natural Resources Conservation Service

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