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Google Earth Dissemination of Soil Survey Derived Interpretations for Land Use Planning

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Abstract: The Cooperative Extension Service could help individuals and communities make more informed decisions regarding residential development by providing soil survey-derived land use assessment data through Google Earth, a popular Web-based map viewer. This article describes how existing data sets can be more readily visualized with commercially available Internet software and provides examples of how these maps can be interpreted for land use assessment. Finally, the opportunities and constraints of using Google Earth as a tool for disseminating land use planning information are described.

Introduction

This article describes how Cooperative Extension Service personnel can use Internet-based mapping technologies to help clientele visualize existing land use assessment datasets. Land use is an important part of Extension's mission in community and economic development (USDA, 2008), particularly at the rural-urban interface (Arnold, 2000), in part because of its effect on the environment (Merry, Bettinger, & Hubbard, 2008). Extension can play a vital role in communities by providing land use assessment information through Google Earth, a free and easy-to-use resource for visualizing geographic data.

The Natural Resource Conservation Service (NRCS) provides extensive information through county soil survey reports that is pertinent not only for agriculture but often for other land use suitability assessment. These reports include tables indicating information about soil texture, permeability, water holding capacity, shrink-swell potential, flooding hazard, internal drainage, depth to restrictive features, and plasticity indices. The soils data are used to develop land use interpretations for soil map units or parts of the landscape. Specifically, soils are categorized for common purposes such as the suitability for dwellings with and without basements, small commercial buildings, septic tank absorption, recreation, etc., are provided through the use of tables that are difficult to visualize across the landscape. (Soil Survey Staff, 1993).

In the past, county soil surveys were disseminated in the form of a printed survey. The NRCS added a new distribution method when it introduced the Web Soil Survey. Much of the information found in the printed soil survey reports is now available through the Web Soil Survey, a free Internet-based software application. An advantage of the Web Soil Survey is that it can be used to view map overlays that aid with land use assessment. For example, it can be used to view soil limitations (indicated by semi-transparent colors) overlain on roads and digital imagery for most of the United States.

For users who have the resources and expertise to use a Geographic Information System (GIS), the NRCS also provides the Soil Data Viewer, which can be used to download soil survey data from the Soil Data Mart. The Soil Data Viewer allows land use interpretation information obtained from Soil Data Mart to be mapped within a GIS such as Environmental Systems Research Institute's (ESRI's) ArcGISTM.

Despite free resources being readily available, many land use decisions are often made without giving adequate consideration to natural soil limitations, which can lead to undesirable long-term consequences (Mitchell, 1986). For some, the Web Soil Survey is perceived as inadequate as a tool for comprehensive regional land use planning because data cannot be viewed in the context of other relevant planning information (e.g., environmental, political, infrastructure data sets). Others may consider developing a GIS with soil and other land use planning data; however, the cost of developing and maintaining such an enterprise is often prohibitive.

The use of customizable Internet mapping servers (IMS) is an alternative to the GIS approach for disseminating soils information (Hornbuckle & Christen, 2006; Schmierer, Lynn-Patterson, Langille, &

O'Geen, 2007). An Australian study demonstrated that scanned soil maps, profile descriptions, photos, and physical properties data could be effectively disseminated with Google Earth (Hornbuckle & Christen, 2006). Building on their work, this article focuses on demonstrating the opportunities and constraints of using Google Earth <http://earth.google.com/> as a tool for disseminating soil derived land use assessment information in the United States.

Materials and Methods

The relevant data for the study area, Lexington-Fayette County, Kentucky, were assembled and included NRCS soil survey-derived suitability maps, the comprehensive land use plan designations (Lexington-Fayette Urban County Government, 2007), and Federal Emergency Management Agency (FEMA) 100-year flood data. These datasets were converted to formats that could be viewed in Google Earth using multiple software programs, including Microsoft® Access, ArcGIS, Google Earth, Global Mapper©, Photoshop, and Arc2Earth. (Some readers may choose to jump ahead to the Results and Discussion Section. For those with experience and an interest in GIS, the detailed methods used to obtain and process these data sets are provided below.)

- Soils-derived land use planning data were ordered on-line and downloaded from the Soil Data Mart. The tabular data were in Microsoft Access 2002 format, and the spatial data were in the ESRI® Shapefile format. The tabular data were imported into an empty SSURGO template ("Soil DB_US_2002").

- The soils data were then incorporated into ArcGIS (Version 9.2, Service Pack 4) using the Soil Data Viewer (Version 5.1). The ArcINFO installation was used, but the procedures used in this article could have been completed with the ArcView installation of ArcGIS. Maps were created indicating suitability for dwellings without basements, dwellings with basements, and septic tank adsorption fields because these factors are important considerations for land use assessment for residential development. Legends were obtained from ArcGIS using screen captures. More detailed information about using the Soil Data Viewer is provided by the Soil Survey Staff (2006).

- In order to incorporate these datasets into Google Earth, the geographic data were exported as portable network graphic (PNG) image files at 150, 600, and 1200 dots per inch (dpi), with geographic coordinates, and with the option to export a "world file" enabled from ArcGIS. Because the map scale in ArcGIS was 1:165,000, each pixel represented 92.1, 23.0, and 11.5 feet for the 150, 600, and 1200 dpi images, respectively. Areas in the images with no soil data (i.e., the color representing the areas outside the county boundary) were made transparent with Adobe Photoshop Elements 6.0.

- Next exported images were tiled. This involved slicing up the images into relatively small file (tiles) so that the people who view these images in Google Earth would not have computer system failures. The intent was to make coarse imagery (i.e., 150 dpi images) visible at lower zoom levels and the more detailed imagery (i.e., 600 and 1200 dpi imagery) visible at greater zoom levels. Global Mapper© 9.03 was used to tile each exported ArcGIS image with "export image format" set to "PNG" and "gridding" set to "15 rows by 15 columns." In addition to creating tiles, Global Mapper also created a Keyhole Markup Language (KML) text file. The KML file provided references to and coordinates for the tiled imagery. To turn on and off imagery at different zoom levels, the KML files were edited manually with Microsoft® WordPad, and the Level of Detail (LOD) command was adjusted. The 600 and 1,200 dpi tiles were uploaded to a Macintosh server so that only those specific tiles within the field of view would be downloaded automatically if a user were to zoom in to a high level of detail. WordPad was used to change the KML files so that the high-resolution imagery would be downloaded from the server. The low-resolution (150 dpi) image tiles were not uploaded to the server because they had small file sizes. Instead, they were included in the compressed download (see further explanations in the methods section). KML files were also created with references to legends and titles that had previously been created.

- Google Earth was opened, and three folders were created in the "table of contents," one for each of the three suitability maps (i.e., suitability for dwellings with basements, dwelllings without basements, and septic tank adsorption fields). Next, all KMLs created using the procedures described previously were sequentially opened and added to one of the three appropriate folders. Five KMLs were added to each of the folders, three for the different resolutions images (i.e., 150, 600, 1200 dpi), one for the legend, and one for the label. Each folder was exported from Google Earth as a compressed KMZ file. Any program that opens ZIP files (e.g., WinZip® and PKZip®) can be used to open a KMZ file. In the root directory of each compressed KMZ file, there was a KML file that contained all of the references from that were in the five KML files previously added to each folder. Additionally, compressed 150 dpi image tiles had been added to a subdirectory of the KMZ files. Because the referenced 600 and 1200 dpi images resided on the server as described previously, these tiles were not included in the KMZ file.

- The general procedures described above were used to create maps of the soil map unit boundaries, comprehensive land use plan, and FEMA flood data with miscellaneous modifications such as different image export sizes.

- Soil map symbols were converted to a Google Earth Format in such a way that only a limited number of map symbols were visible at high zoom levels. First, the polygon attribute information in the soil map shapefiles was converted to point data with the "Feature to Point" ArcGIS command (can be found in the "Data Management Tools - Features" Toolbox) with the "inside" option selected. Then the Arc2Earth ArcGIS extension was used to export the shapefile to a Google Earth format with "use regions for this layer" selected, "Export Format" set to "KML File" and "Region Level" set to 16. The exported data files were uploaded to a Macintosh Web server.

Results and Discussion

The datasets assembled for this article can be downloaded from <http://sites.google.com/site/joegepaper/> and opened in Google Earth. Examples of how this information can be used are given below and use soil survey assessments and FEMA flood zones in the context of residential development as an example.

Example Land Use Assessment with Datasets in Google Earth

The study area for this example is Lexington-Fayette County, Kentucky, known for Thoroughbreds and Bluegrass. Part of the 2007 Lexington-Fayette County comprehensive land use plan can be seen in Figure 1. The legend link for this analysis is provided in the figure caption. A substantial portion of the land in this image was being considered for low or medium density development (i.e., areas overlain with yellow and orange strips) at the time the plan was created, although the lower left area was already developed at the time the Google Earth imagery was created in 2004. The green stripes represent areas that are planned for greenspace/openspace, the pink stripes are for mixed uses, and the orange and red stripes (just below the pink area) for civic, cultural, and/or religious uses.

Figure 1.
Semi-Transparent Land Use Plan (legend on-line at <http://sites.google.com/site/joegepaper/Home/land-use-plan---descriptions>)

The analysis presented in Figure 2 depicts the suitability ratings for dwellings without basements for the same tract of land. (The legend can be found on-line at <http://community.ca.uky.edu/LandUse/limitations.png>.) The FEMA 100-year flood map are also overlain (black lines). It is apparent that houses have been built in areas that are very limited for dwellings without basements (i.e., the red areas) according to the soil survey information. Potential problems (e.g., foundation failure) for homeowners could be averted if suitability maps were consulted in the future as potential residential development areas (e.g., yellow and orange striped areas in Figure 1) were considered more extensively during the planning process. Soil survey-derived land use information was intended for course scale (generalized) planning (Soil Survey Staff, 1993). Additional field confirmation is required for detailed planning for a more informed site-sensitive decision-making process.

Figure 2.

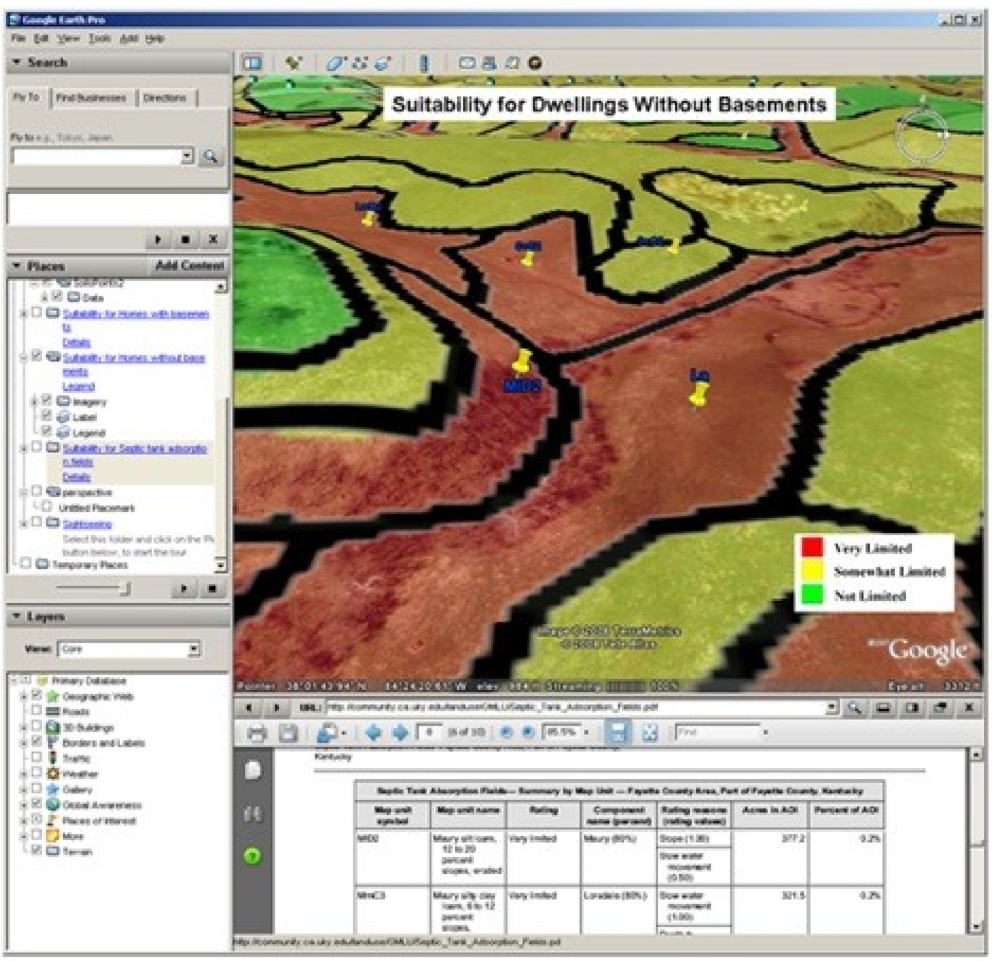
Soil Survey Derived Map of Suitability for Dwellings Without Basements (legend on-line at <http://community.ca.uky.edu/LandUse/limitations.png>) Overlain With FEMA 100-Year Flood Map (Black Lines).

Soil survey information should be considered in the context of other relevant and available spatial data as well. For example, the FEMA 100-year flood zone boundaries are useful to visualize in Google Earth to help identify suitable locations for homes (Figure 2). Site investigations may be particularly important for those areas in a FEMA flood zone where the soil surveys indicated no severe limitations for dwellings without basements. It is important to note that FEMA flood data were also are intended for course scale planning and boundaries often poorly delineate actual flood zones for more detailed assessments. Further, the flood models used to create FEMA flood boundaries did not consider how changes in upland land use (e.g., addition of parking lots) affected down-slope hydrology. However these are often the best in many cases the only legally recognized delineations despite some limitations.

Alternative land uses can be considered when viewing overlays in Google Earth. For example, rather than covering many of the red areas in Figure 2 with impermeable surfaces (e.g., homes, strip malls, parking lots, and roadways), these areas could be zoned as openspaces/greenspaces for parks, playgrounds, wildlife refuges, and natural areas. Greenways could have been used to connect neighborhoods with parks, bicycle paths, and walking trails. Integrating natural and human systems helps create communities that have a higher quality of life (Zoller, 2008).

The Web Soil Survey and Soil Data Viewer describe how soil and landscape factors limit the suitability of soils for specific uses with "fuzzy logic" values (Soil Survey Staff, 2008). Fuzzy logic values are probabilities that describe the degree to which some true value about soil is known because information is inexact. The fuzzy logic values for all properties are equal to 0.00 for areas that are "not limited" for a particular suitability map. Somewhat limited zones (e.g., yellow areas in suitability maps) have at least one factor with a fuzzy logic value > 0.00 but all factors with values < 1.00. Those areas that are very limited (e.g., red areas in suitability maps) have at least one factor with a fuzzy logic value equal to 1.00. The fuzzy logic values for the MlD2 (an eroded Maury silt loam with a 12 to 20% slope) map unit can be seen in the browser window of Google Earth (Figure 3).

Figure 3.
Suitability Map for Dwellings Without Basements Overlain by Soil Map Unit Boundaries (Black Lines) and Map Unit Symbols (Blue Text)



The value of 1.00 for slope indicates that the grade (i.e., 12 to 20 %) is very limiting for dwellings without basements. In contrast, the "La" map unit (i.e., Lanton silty clay loam with a 0 to 2% slope), which is also very limited for dwellings without basements, has fuzzy logic values of 1.0 for flooding and depth to saturated zones (data not shown). This expository information is critical for people involved in the planning process to consider because some limitations are more feasible than others to overcome. For example, it may be feasible to build a house on a 15% grade in some situations, but it is almost always ill advised to construct homes in areas with a high potential for flooding. These differences in relief between the "MlD2" and "La" soil map units are apparent visually in Figure 3 because of the three-dimensional (3-D) rendering capabilities of Google Earth.

Overlaying two semi-transparent limitation maps in Google Earth can highlight areas of multiple constraints. For example, the suitability maps for both houses with and without basements are overlain in Figure 4. The orange color that appears is a result of the combination of the red and yellow colors in the two housing suitability maps. The orange areas can be interpreted as being limited for dwellings without basements and very limited for dwellings with basements. Perhaps homes with slab foundations could be built in these areas, given some site modification. Dwellings with or without basements could be located in the large green areas. Yellow areas will have some limitations for dwellings with and without basements. The red zones are not well suited for residential development according to the soil survey. Instead these areas could become greenway linkages that could connect communities as previously described.

Figure 4.

Suitability for Dwellings With Basements and for Homes Without Basements Overlain by Soil Survey Data*

For the final example, Google Earth allows for the identification of various features such as municipal water supplies (Figure 5). By combining layers of information, land use planners and municipal officials responsible for decision making can make informed decisions when studying suitability maps for septic tank adsorption fields. Failing septic systems are not only costly for homeowners, but also can promote eutrophication and lead to a series of potential public health problems.

Figure 5.
Suitability for Septic Tank Adsorption Fields (legend on-line at <http://community.ca.uky.edu/LandUse/limitations.png> Overlain by Soil Survey Data

Opportunities and Constraints

- Making soil survey data more easily retrievable using Internet applications like Google Earth has the potential to enable professional land use planners as well as citizens (e.g., zoning boards) to make more informed decisions. Some of the opportunities of this approach include the following.

- Suitability data can be viewed within the context of infrastructure information (e.g., roads, schools, businesses, reservoirs) currently available in Google Earth. Other relevant data for land use assessment (e.g., FEMA and comprehensive land use planning maps) can be added as described in this article. High-quality and/or more recently captured imagery can be imported where existing Google Earth imagery is not sufficient or missing. Relatively high-quality imagery can be obtained from GPS Visualizer<http://www.gpsvisualizer.com/> for free. For a fee, higher quality imagery can also be obtained from different sources such as Global Mapper. Software for creating image tiles and regionalized vector data allows Google Earth to efficiently display these datasets.

- The 3-D rendering capabilities of Google Earth allow the various suitability maps to be better visualized across landscapes. The vertical dimension can be exaggerated up to three times in order to enhance the visualization of slope and topography.

- Google Earth software is free and is becoming more widely used. Disseminating land use planning data with Google Earth would potentially expose a wider audience to soil survey information. Only the standard (free) version of Google Earth is required to view these datasets. However, Google Earth Pro has desirable features that allow GIS data to be imported and movies and high-resolution imagery to be exported costs $400 (as of 8/13/2008). However, none of the additional features in the professional edition were required to create the datasets used in this article.

- Google Earth can operate on relatively minimally equipped computer with a Windows, Macintosh, or Linux operating system with moderately fast Internet connectivity (128 Kbs/sec). Only 128 MB (Window or Linux) or 256 MB (Macintosh) of system memory are required. A 500 MHz Intel Pentium 3 processor is the minimum requirement for Windows and Linux platform while a G3 500 MHz processor is required for a Macintosh platform.

- Google Earth allows images of soil data to be partially transparent. The degree opacity of the image can be manually defined in the KML but it can also be changed from within Google Earth. This allows the user to see the land while also seeing the suitability assessment.

- The Google Earth learning curve is not great. Many middle school students have the skill required to download soils data from the Internet for viewing in Google Earth. This could be useful for involving young people in community decision making.

There are also constraints that must be considered in order to make informed decision regarding the adoption of an IMS software application such as Google Earth for visualizing suitability assessment maps.

- Much of the imagery available in Google Earth is not of high quality; however, higher quality imagery can be obtained through other sources as described earlier. The existing imagery is much better for some geographic areas than others.

- Users will be limited to the color selections of those who pre-build the Google Earth datasets because legends must be created outside of Google Earth.

- Land use planners may require specialized geospatial analyses to be applied. In these cases, a full-featured GIS should be considered because Google Earth does not have the capabilities of a dedicated GIS software application.

- A major constraint of the Google Earth approach described here is that a trained individual or institutional support person must use a GIS to process the soil survey information to make it available to users in Google Earth.

- It may be difficult to add new information to Google Earth quickly enough to satisfy a land-planning committee's desire to view different land use planning scenarios. A GIS may be a more appropriate tool in these cases.

- While there are discrete boundaries between soil survey mapping units, these raster datasets have diffuse boundaries. The use of tiling multi-resolution imagery described in this article reduces this problem substantially. For example, the pixel size of the soil suitability was 11.5-ft, which translates into about 349 pixels per acre. This should be acceptable for most situations because transitions between soil mapping units usually are gradual and difficult to define precisely. However, the inherent limitations of original data sources should not be dismissed simply because the data are not digital.

Comments from an Extension Agent

The benefit of this approach is that it can be used by Extension agents in the normal course of work. For example, Greg Henson, a McLean County, KY Extension agent for Agriculture and Natural Resources, indicated the following after viewing these datasets in Google Earth.

> GIS is hard to learn, and most agents just don't have the time or inclination to learn it. But as Agriculture and Natural Resources educators, we're really in the land use education business. With the large amount of geospatial data available, we need better ways to use it. Web based applications like Google Earth and Google Maps give us that opportunity. When combined with high quality local imagery, we can communicate much more effectively with our clientele.

Conclusions

Land use planning is part of the mission of the Cooperative State Research, Education, and Extension Service for community and economic development. By developing innovative ways to help visualize existing land use planning data, Extension could have a great impact on a community's quality of life. Google Earth has great potential to be used as a tool for providing ready access to land use interpretations currently provided by soil surveys without the need for a GIS for everyone.

However, there are opportunities and constraints to a Google Earth approach as described in this article. Therefore, it is not likely that this form of visualization will entirely replace existing resources such as the Web Soil Survey or a full-featured GIS any time soon. However, this approach adds another resource dimension that can be used by the Extension community that is not in a position to utilize a GIS but still needs to serve the larger community. Potentially, Geospatial Extension Specialists could help facilitate the development of these kinds of spatial databases.

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