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A novel approach to mapping land conversion using Google Earth with an application to East Africa

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A B S T R A C T

Effective conservation planning relies on the accurate identification of anthropogenic land cover. However, accessing localized information can be difficult or impossible in developing countries. Additionally, global medium-resolution land use land cover datasets may be insufficient for conservation planning purposes at the scale of a country or smaller. We thus introduce a new tool, GE Grids, to bridge this gap. This tool creates an interactive user-specified binary grid laid over Google Earth's high-resolution imagery. Using GE Grids, we manually identified anthropogenic land conversion across East Africa and compared this against available land cover datasets. Nearly 30% of East Africa is converted to anthropogenic land cover. The two highest-resolution comparative datasets have the greatest agreement with our own at the regional extent, despite having as low as 44% agreement at the country level. We achieved 83% consistency among users. GE Grids is intended to complement existing remote sensing datasets at local scales.

Software availability

GE: Grids is a web application written in Javascript using the Google Earth application programming interface (API), which is freely available from Google. The program requires a web browser, the Google Earth plug-in and internet connectivity. The codebase is maintained and can be downloaded as a zip file from http://andrewstanish.com/files/GERasterCreator.zip. The zip file contains a.html file, accessory files, and a ReadMe file. Use the ReadMe file for suggestions on program instruction and notes on Google's Terms of Service. GE Grids is free, regulated under the GNU General Public License v3 (http://www.gnu.org/copyleft/gpl.html) and intended for further open-source development. The developer is Andrew Stanish (andybp85@gmail.com).

1. Introduction

Land use land cover (LULC) datasets describe how humans use land (land use) as well as the physical features that cover the earth's surface (land cover). These datasets aid in the identification of the location, intensity, and extent of human activities which is essential to conservation planning (Hansen et al., 2000). In LULC datasets, anthropogenic land cover is typically classified as either cropland or urban extent. However, identification of these land uses is challenging and varies greatly across datasets (Vancutsem et al., 2012; Potere and Schneider, 2007; Fritz et al., 2011). Traditional remote sensing classification approaches require grouping spectral signatures and subsequent accurate discrimination between groups i.e. land cover types (Pfeifer et al., 2012). However, emerging remote sensing techniques, such as object-based classification reduce this

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reliance on unique spectral properties by allowing probabilistic class descriptions (Blaschke, 2010). Classification may be relatively easy where vegetated landscapes are homogenous and extensive e.g. some croplands. However, in heterogeneous landscapes with small, patchy agricultural fields, discriminating cropland from natural land cover using classification algorithms can be difficult (Tchuenté et al., 2011; Vancutsem et al., 2012).

Furthermore, while the financial burdens of obtaining satellite image data are decreasing, generating remote sensing classification products still require specialized, and often expensive, training and software (Stensgaard et al., 2009; Pettorelli et al., 2014). Access to these resources may present particular hurdles to research and conservation programs, particularly those in developing countries. Error in selecting, downloading, processing, and analyzing remote sensing datasets may additionally result in inappropriate recommendations and conclusions (Watson et al., 2015), particularly for ecological applications (Kerr and Ostrovsky, 2003). Inappropriate analyses may result in missed opportunities, or squandered resources (Wilson et al., 2005). There is thus a need for easily created, inexpensive, locally-accurate datasets that can confidently be used in conservation planning (Watson et al., 2015).

One possible solution to problems associated with the cost and difficulty of conducting remote sensing classification analyses and the accuracy of LULC datasets is to use free, easy to access, high-resolution image data (pixel resolution of 10 m or better; moderate resolution data is between 10 and 250 m (Pfeifer et al., 2012)) like that available through Google Earth. Google Earth is a free, easy-to-use program owned by Google Inc. that allows access to sub-meter pixel resolution data for over a quarter of the world's landmass and three-quarters of the global population (Google, 2014).

Google Earth's high-resolution data are useful as a platform for validating datasets (Fritz et al., 2011) used previously with urban extent (Schneider et al., 2009) and land cover (Defourny et al., 2008). While Google Earth has the potential for wider use in scientific literature, particularly in LULC analyses (Potere, 2008), one prominent challenge is that native analysis functions in Google Earth are minimal (Yu and Gong, 2012), limited to drawing points, lines, and polygons. We previously used the polygon drawing feature to identify anthropogenic land use conversion in West Africa (Riggio et al., 2013) and Mozambique (Jacobson et al., 2013). The results were a significant improvement over existing datasets and aided in determining potential habitat. Although the time-consuming nature of these analyses limited further application, the success of the method spurred the creation of a new tool, "GE Grids", to speed land cover class identification. GE Grids is the first free, customizable creator of raster datasets for use with Google Earth. GE Grids creates a user-defined, interactive grid (raster) overlaid on Google Earth image data. This tool circumvents expensive, specialized programs and knowledge, and enables easy use of Google Earth's high-resolution data to create localized datasets. We use GE Grids to document anthropogenic land conversion in East Africa, a region of significant conservation importance (Ray et al., 2005; Myers et al., 2000; Jenkins et al., 2013) experiencing rapid human population growth (UN, 2013).

2. Methodology

2.1. GE grids program design and workflow

GE Grids is a browser-based application that provides a customized interface to map land cover using satellite and aerial data available in Google Earth. The application relies on the free Google Earth plug-in (GEP) and Google's public application programming interface (API) as well as a plugin called "filesaver.js" written by Eli Grey and available on GitHub. The program is written in JavaScript and tested in the Google Chrome and Mozilla Firefox web browsers.

The GE Grids program consists of two main objects: "dataset" and "filesys". "dataset" has two functions: to store internal data displayed on the GEP, and to handle the functionalities related to creating, rendering, and updating the ASCII data. "filesys" controls the download and upload of data. The download functionality makes use of filesaver.js for cross-browser compatibility. The upload function handles data uploading and rendering ASCII raster files. It sets the GEP grid parameters to what it reads from the file, triggers the GEP to draw the grid, and creates an array with the IDs of each grid cell lined up in the same order as on the grid. The upload method then reads through the file, value by value, and triggers the dataset object to change the color of the grid cell and change the value stored for the ASCII output, until it reaches the end of the file.

GE Grids calls a series of four functions. These four functions, in the order they are called, are "initGrid," "genPolygons," "makePolygon," and "clickInit." "initGrid" sets the GEP camera view, calls "genPolygons" to draw the grid in the GEP, triggers the dataset object to create the internal copy and render the ASCII, and finally calls "clickInit" to set up the user interface. "genPolygons" draws and positions the grid using the values specified by the user in the html input. The "makePolygon" subroutine creates the actual grid cell in the GEP. Finally, "clickInit" sets up the user interface for interacting with and changing grid cells.

In summary, program execution begins with page load, and the program initiates the GEP. The user can then change the default grid options and Google Earth preferences via the user interface. When the user clicks the "Draw" button, the grid parameters are read into an object, and "initGrid" is called. Once the GEP grid and ASCII raster are set up, the user can click on a grid cell. When this happens, the dataset "object" changes the color of the grid cell, updates its internal store of the values, and re-renders the values in the ASCII output. There is no internal save functionality, but the user can download a copy of the ASCII raster and re-upload it to continue.

The user interface of GE Grids is a combination of generic controls provided by Google Earth and input parameters for creating a grid. Controls allow the user to navigate around the Google Earth imagery and to enter the information necessary to specify or "draw" a grid (Fig. 1). Options include: the latitude and longitude of the upper right-hand corner coordinates of the grid, the size of each cell (in Degrees – a function of Google Earth's use of the WGS 1984 lat/long coordinate system), and the number of cells on each axis. Each cell can be visually divided into 9 minor grids (3×3) using the "Grid Guides" function to ease the classification of heterogeneous cells. Although the study was done using square grids, the program supports any number of cells per side.

The overall workflow is summarized in Fig. 2. Once the user creates a grid using the "Draw" feature, they can interact with the grid by clicking on the grid edges to change their color from white to red. This corresponds with a data value change from 0 to 1; or if the No Data function is clicked on, to −999 (or any other value chosen by the user). The result can be downloaded as a text file in ASCII raster format for import into GIS software or as a KML file to upload into Google Earth. The ASCII file can also be re-uploaded into GE Grids for editing and error checking.

This tool meets the legal requirements of the Google Earth API Terms of Service. GE Grids is free to all users, does not alter or blur imagery from Google Earth, and allows attribution of the image data to remain visible. In using this tool, users are also agreeing to abide by Google's Terms of Service. Importantly, the image data itself and the output from GE Grids should not be used for