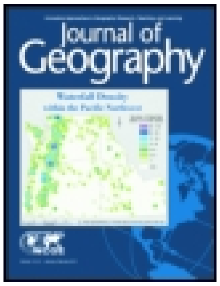

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Making Cropland Data Layer Data Accessible and Actionable in GIS Education

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ABSTRACT

The Cropland Data Layer (CDL) product provides categorized land-cover information encompassing the whole contiguous United States. Using the latest Web and geospatial interoperability technologies, CropScape was built to visualize, query, disseminate, and analyze historical and current CDL data interactively and intuitively over the Internet. CropScape can be utilized as a useful online mapping educational tool and an important source of free geospatial data and geospatial Web services in GIS education. This article introduces the CDL product and functions of CropScape, and presents several specific examples of cropland exploring, thematic map creation, natural disaster assessment, crop planting patterns discovery, geospatial data mashup, and geospatial Web application development to demonstrate CropScape's capabilities.

Key Words: *GIS, geography education, land-cover change, Web-portal*

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INTRODUCTION

Geospatial Web applications offer a timely and accessible way to disseminate and explore various types of geospatial data. Meanwhile, these Web applications can be leveraged by teachers in the classroom as online geospatial data sources and mapping educational tools to improve students' abilities to access, retrieve, and analyze geospatial data and solve real-world problems and complex issues (Sui 2004; Baker 2005; Harris, Rouse, and Bergeron 2010). CropScape[1] is such an application that is of interest to both public and academic users; it disseminates the Cropland Data Layer (CDL) data produced by National Agricultural Statistical Service (NASS) of United States Department of Agriculture (USDA) to public users in an open and interoperable manner, and provides value-added analytical services of data mashup, statistics analysis, change analysis, thematic map creation, and so on (Han, Yang, *et al.* 2012). This article aims to introduce the CDL product and functions of CropScape, and illustrates CropScape's applicability in GIS education using several illustrative examples.

CROPLAND DATA LAYER

In GIS education, utilizing a variety of thematic spatial data in classrooms or laboratories is very helpful to deepen students' understanding of important concepts and to promote their skills in solving real-world problems. The CDL product depicts detailed information on crop and noncrop categories and locations covering the contiguous United States (CONUS) (Boryan *et al.* 2011). This valuable geospatial data offers independent statistical estimates of crop acreage throughout the growing season, and serves as an important input in the official statistical reporting process (Johnson and Mueller 2010). And it has been extensively used by policy and decision makers, scientists, educators, and farm producers on the issues of food security (Hartz *et al.* 2012), land-cover change (Wright and Wimberly 2013), pesticide control (Belden *et al.* 2012), agricultural sustainability (Kutz *et al.* 2012), bioenergy crop inventory (Wang *et al.* 2011), and hazards assessment (Breazeale 2012). This georeferenced raster data can be used as an important geospatial data source for teachers and students exploring land-cover and land-use change or agricultural geoinformation of the CONUS in the GIS-related courses.

CROPSCAPE

In the past decade geospatial Web applications have become the major channels of geospatial data dissemination and publication. These applications offer basic map operations and advanced functions of data customization, visualization, and analysis. Users can utilize them at any time from any place using Internet-connected computers (Di and Deng 2010). Many easy-to-use online mapping tools like Google Earth (Todd 2007), Global Visualization Viewer (GloVis) (Campbell 2007), and DEM Explorer (Han, Di, *et al.* 2012) have been recommended for classroom use.

The latest Web technologies and open geospatial standards make it more feasible to build powerful Web geospatial applications. Using Asynchronous JavaScript and XML (AJAX), Rich Internet Application (RIA), Simple Object Access Protocol (SOAP), Web Services Description Language (WSDL), and Open Geospatial Consortium's (OGC) geospatial standards of Web Map Service (WMS), Web Feature Service (WFS), Web Coverage Service (WCS), and Geography Markup Language (GML), CropScape was developed to provide users with useful functions of online visualization, geospatial navigation and querying, reformatting and transformation, delineation of area of interest (AOI), on-the-fly data analysis, on-demand data processing and dissemination, thematic map creation, etc., in a service-oriented architecture (SOA) environment (Han, Yang, *et al.* 2012). Besides popular OGC, WCS, WFS, and WMS serving the CDL data and other geospatial data, CropScape also provides Web geoprocessing services to disseminate, visualize, retrieve, and analyze the CDL data for any AOI in the CONUS. For example, the GetCDLPDF service creates the on-demand CDL thematic maps with customized settings, and it has been proven very useful in NASS operation and been utilized by CropScape's users; there exists no online geospatial applications having such a functional service available. Educators and students can consume these services in their applications or scientific workflows to accomplish the specialized tasks. Technical methods of these geoprocessing services design and implementation can be adopted to disseminate and analyze other geospatial data.

Teachers and students can access CropScape through common Web browsers, like Internet Explorer or Firefox, on any Internet-connected computer. They can explore the CDL data within the state of interest simply by entering CropScape link plus state abbreviation (e.g., *http://nassgeodata.gmu.edu/CropScape/VA*). It is a very useful online learning portal to teach GIS concepts and skills in the K–12 classrooms, especially where desktop GIS software is not available. The detailed functionalities and geospatial Web services of CropScape can be referred from the published article (see Han. Yang, *et al.* 2012). CropScape can help educators and students access, visualize, retrieve, and analyze on-demand CDL data at any geographic level in the CONUS through its intuitive graphical user interface (GUI), as seen Figure 1. The functions of each GUI component are described briefly as follows.

Map View

CropScape opens to display the latest CDL data (NASS normally releases the CDL data for the previous year at the end of January of each year), the CONUS state and county boundaries, and other geospatial data in the map view. These vector and raster data layers are combined together to generate useful and helpful maps. The map view provides students with a rich visual context to view the nationwide land-cover features, find out and interpret information contained in these layers, and tell stories about cropland lands and resources. The geographic coordinates of the current cursor location in the projection of USA Contiguous Albers Equal Area Conic (USGS version) are given on the toolbar. This location information tells where the pixel attached with the land-cover feature is.

Map Layers

The map layer list includes not only the CDL layers from 1997 to 2012 but also the background layer (global land cover), the crop-mask layer, the boundary layers of states, agricultural statistics districts (ASDs), counties in the CONUS, the water layers (rivers and lakes), and the road layers (national freeway system and regional major highways). These reference layers help students navigate geographical context and define their AOIs. In addition, students can add other geospatial data of their interest as the auxiliary layers into the map view to offer additional information by uploading the raster file in GeoTIFF format or the vector file in GML or ESRI shapefile format. They can learn how to choose helpful layers and integrate them with other existing layers to make the map view more informative from a geographic perspective.

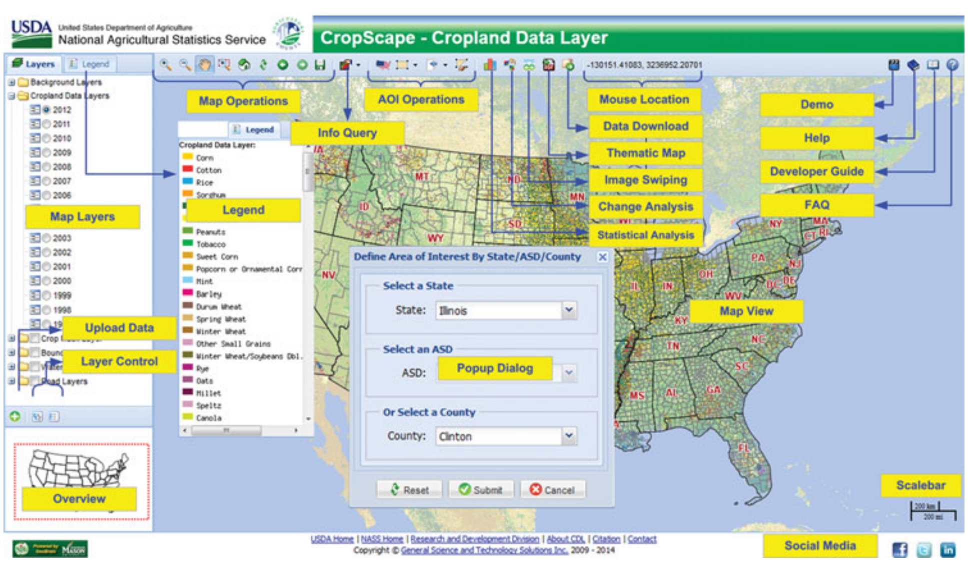

Figure 1. CropScape user interface in the browser window, showing the function of each component. (Color figure available online.)

Map Operations

The map operation buttons on the upper toolbar provide shortcuts to navigate the map extent and view crop fields clearly, including Zoom In/Out, Pan, Drag-Box Zoom, Full Extent, Refresh, Previous/Next View, and Saving Current Map Extent. Students can be guided to use these basic operations to change the scale and location of the map view or center their AOIs in the map view.

Information Query

The information query tools help query the land-cover category information and the county level crop acreages that are obtained from the 2007 Census of Agriculture to answer spatial questions. Category Name, Value, and Color are displayed in the popup box when querying land-cover information at the specified location, or County Name, State Name, FIPS Code, Total Cropland Acreage, and Total Irrigated Cropland information when querying the 2007 county cropland statistical information of the selected county. Based on their geography knowledge of specified area, students can learn how to interpret these land-cover features and related statistics information.

AOI Operations

The AOI operation buttons offer the shortcuts to define, import, export, and erase AOI. CropScape provides three options of AOI definition. The complete list of the CONUS states, ASDs, and counties is loaded in the popup dialog for selection. The AOI in the shape of rectangle, circle, and polygon can be dragged and drawn in the map view. In addition, students can upload the polygon vector file in GML or ESRI shapefile format. After the AOI is defined, the map view will be zoomed to appropriate extent and centered on the location of interest. Students can leverage this function to define an AOI, like one community of their choice, in a familiar geographic context, so they can discover more information and answer questions about this area by starting with their familiar district and moving outward.

Geospatial Analysis

Statistical analysis offers acreage estimates of land-cover categories within the AOI for a specified crop year. Students can use the output maps, charts, and tables to gather and report land-cover information and explore crop-distribution patterns both regionally and locally. They can also extract cropland information from multiyear CDL data and discover cropland changes or planting patterns over years. The CDL image swiping helps students view the differences between images of two crop years interactively. Change analysis helps students investigate the detailed land-cover changes between two selected years. The detailed functional description will be demonstrated in the subsequent sections. These analytical functions are very helpful for developing students' skills to analyze questions about land cover of AOI and utilize geographic knowledge in finding the solutions to these problems.

Data Retrieval

Students can retrieve the CDL data within a given AOI for the available crop years in the preferred projection in a compressed or uncompressed form. The image of the output CDL file can be viewed in the output window or be exported in a KML (Keyhole Markup Language) file for visualization in Google Earth or Google Maps. For students who are interested in the hardcopy map, the CDL data within a defined AOI can be outputted as a thematic map with presentable quality in PDF format for print.

Help Resources

The Demo, Help, Developer Guide, and FAQ buttons on the right of the toolbar allow students to access the demonstration video and user guide of CropScape application, developer guide of using CDL Web data and processing services, and frequently anticipated questions on the CDL data and CropScape.

Social Media

The Facebook, Twitter, and LinkedIn links of the CropScape group are put at the lower right corner for learning the latest updates or important news from these popular social media sites.

CropScape makes a nationwide archive of cropland information freely available for the use in a variety of GIS curricula, and supports land-use/land-cover exploration and applications in classrooms at different grade levels. Easy-to-use and intuitive, CropScape is an ideal Web mapping tool to help students gain experience of applying GIS technology and methods towards solving real-world problems such as natural resource and environmental management, and expand their knowledge of using GIS in problem-based learning activities.

The following illustrative examples, which can be used in simple individual or group projects of college-level GIS courses, are given in the subsequent sections:

1. Explore agricultural characteristics within an AOI that is defined by the uploaded vector file.
2. Present the CDL data and other geospatial data in a thematic map.
3. Upload and display geospatial data to designate natural disaster area and evaluate cropland damages.
4. Extract the CDL data of interest for several continuous years and discover crop planting patterns.
5. Mashup CDL data with other online geospatial data to build a comprehensive map.
6. Build a Web mapping application using CropScape's Web geospatial services.

EXAMPLE 1: CROPLAND EXPLORING

With CropScape, students can explore the CDL data within any AOI across the CONUS to answer questions having local, regional, state, or national implications. The specific AOI can be a state, ASD, or county of interest, or be defined by the uploaded vector file. The online

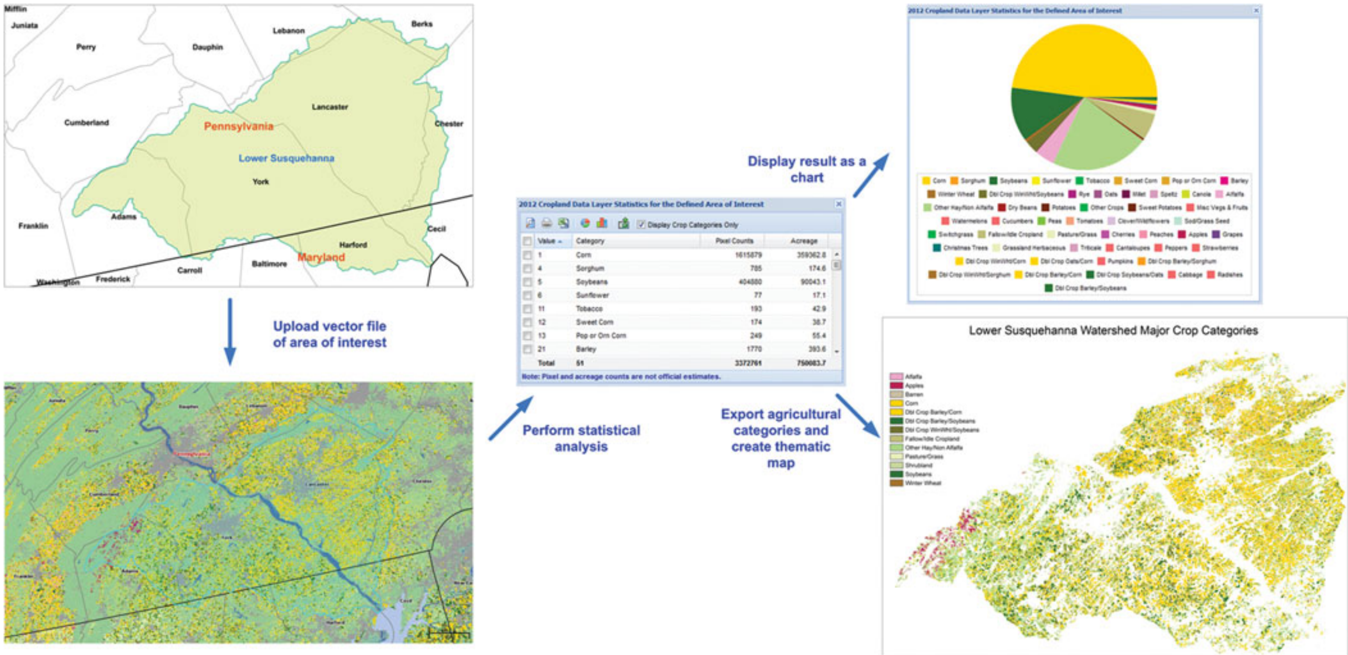

Figure 2. Statistical analysis of and thematic map creation of the Cropland Data Layer data within the area of interest, taking Lower Susquehanna Watershed as an example. (Color figure available online.)

functions of statistical analysis and change analysis can be performed on the CDL data within the highlighted AOI to generate tabular and graphical summaries of land-cover categories and tabular and imagery data of land-cover changes respectively.

The preloaded list of the CONUS states, ASDs, and counties from the user interface of CropScape helps students select any administrative or statistical district of interest. However, a hydrologic unit defined by U.S. Geological Survey (USGS) (Seaber, Kapanos, and Knapp 1987) is often used as the study area in land cover and change, agricultural drought, agricultural irrigation, conservation tillage, precision farming, etc., which are related to landscape information. Here, Lower Susquehanna Watershed (USGS Cataloging Unit 02050306), located mainly in southeastern Pennsylvania with a small portion in Maryland, is selected as the study area (Fig. 2). The study showed that one of key factors affecting water quality in this watershed area was agricultural activity (U.S. Geological Survey 1998). The boundary file of this hydrological unit is extracted from the 1:250,000-scale hydrological units of the United States (U.S. Geological Survey 1994), and uploaded to CropScape in a compressed file to define the AOI. The 2012 CDL data within this watershed is counted using statistical analysis, and the result is displayed in the form of table and bar chart. The statistical summaries in the table can be saved in a CSV (comma-separated values) file, and the selected land-cover categories (crop categories only) from the list can be exported in a GeoTIFF file for mapping to display major crops distribution. These land-cover summaries provide useful information to understand the agricultural facts and land-use/land-cover characteristics in watershed assessment and other study fields.

Example 2: Thematic Map Creation

Utilizing cartographic principles to create a thematic map with basic map elements is one of the important goals of GIS courses. Discovering the appropriate geospatial datasets for use in a GIS course project, understanding their types, sources, and metadata information, and processing these data by georeferencing, clipping, and reformatting can be also covered in this technical topic. CropScape offers data downloading of the CDL file in GeoTiff format along with its attribute table, including category value; name; red, green, blue color values; and opacity value for generating elements related the CDL data in a thematic map.

Here, creating a thematic map of the 2011 Iowa CDL data and ethanol plant locations is given to demonstrate how to integrate data from different sources and convey spatial relationship to audiences. The state of Iowa is the top corn-producing state in the United States and has the most corn-based biorefineries in the country (Renewable Fuels Association 2013). It will be very meaningful to display spatial patterns of corn, biorefinery locations, and railroads in a thematic map. The 2011 Iowa CDL data as well as its attribute table is obtained directly from CropScape. The Web site of Iowa Corn provides the detailed information on ethanol plants and their locations in the state in Google Map (Iowa Corn Promotion Board/Iowa Corn Growers Association 2012), which can be exported as a KML file and

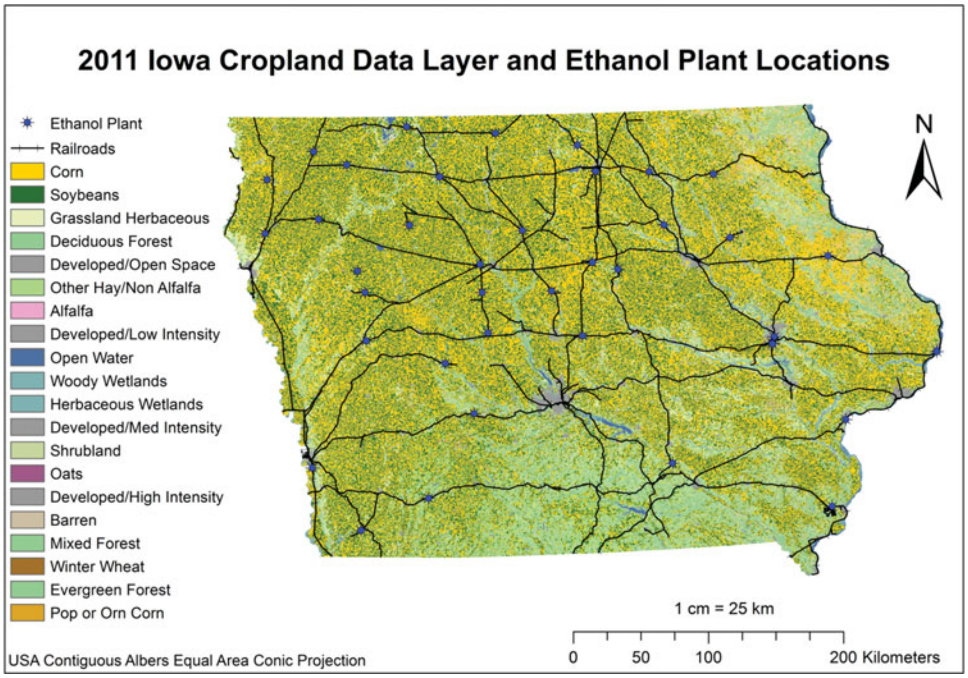

Figure 3. The 2011 Iowa Cropland Data Layer data and ethanol plant locations. (Color figure available online.)

be converted to an ESRI shapefile file using GIS software. The Iowa rail lines in ESRI shapefile format can be obtained freely from the Iowa Department of Transportation (Iowa Department of Transportation 2002). These data can be overlaid and combined with title, north, legend, scale, and projection information in ArcGIS software to create the thematic map (Fig. 3), which shows that all ethanol refineries are located in the corn-planted areas and on or near the railway lines for convenient production and transportation.

Example 3: Natural Disaster Assessment

Applying GIS analysis functions in natural resource management, agriculture, and biology is very helpful for developing students' problem-solving skills. Students can upload their raster or vector data of the selected topic or the project area to CropScape and analyze the CDL data within the study area. A real-world scenario of crop damage assessment of the 2011 Mississippi River floods is presented below according to the technical report of Food and Agricultural Policy Research Institute, University of Missouri (Brown, Gerlt, and Wilcox 2011).

The LandSat TM data for the study area (part of Mississippi County, Missouri) are downloaded from the USGS Web site, then clipped and reprojected to generate the raster file in GeoTIFF format. Figure 4 shows the May 7, 2010, image that depicts no flooding and the May 10, 2011, image that illustrates flood inundation after the levee was breached. At first, the raster files are uploaded to the server side of CropScape and added as the auxiliary layers. Next, the inundated area is identified and drawn roughly according to the differences between these two layers. Then, the above-mentioned statistical analysis is performed on the AOI CDL data available for the previous years (here, using the crop years of 2006–2010), the acreage of primary crops (i.e., corn, cotton, rice, sorghum, soybeans, double-crop winter wheat, and soybean) planted in this area are extracted from the results, and averaged to estimate the possible damages of croplands caused by the flood in 2011, as shown in Table 1. In this scenario, if the flood areas can be recognized more accurately and be exported to an ESRI shapefile in remote sensing software, the AOI can be defined in CropScape in the same way as in Example 1.

Table 1. Crop damage estimation (unit: acre).

Crop	2010	2009	2008	2007	2006	Average
Corn	20,254.1	20,142.5	17,946.4	32,442.9	20,758.6	22,308.9
Cotton	456.4	492.9	462.6	23,28.6	3,274	1,402.9
Rice	4,554	3,258.5	3,758.4	4,080	6,395.4	4,409.3
Sorghum	501.7	1091.9	3,530.5	1,532	1,580.8	1,647.4
Soybeans	116,330.4	10,1323.3	92,745.7	84,845.4	93,692.7	97,787.5
Double Crop: Winter Wheat/Soybeans	7541	20,308.4	24,164.4	17,063.8	19,483.1	17,712.14

Example 4: Crop-Planting Patterns Discovery

Gaining practical and research experiences in the applications of GIS and understanding of how GIS operates in public sectors are important objectives of GIS courses. The CDL data from CropScape provides a useful online mapping resource to engage students in research activities related to agricultural problems and promote their research practices through both individual and group projects.

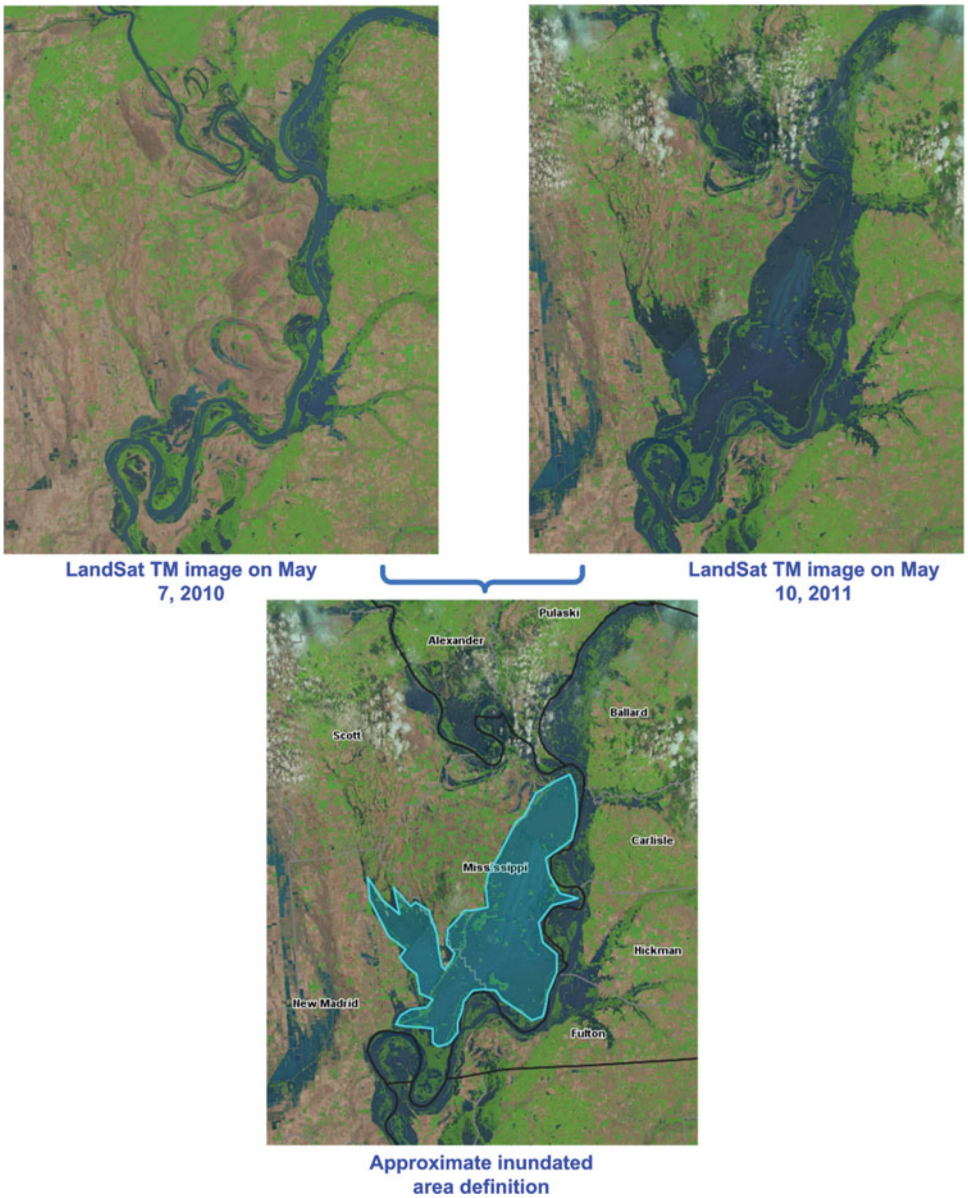

Figure 4. Define one inundated area of the 2011 Mississippi River flood by comparison of LandSat TM images. (Color figure available online.)

Students can analyze the CDL data to discover information and knowledge of cropland-cover change and crop-spatial pattern and density (Boryan, Craig, and Willis 2009). The following gives an example of exploring single crop planting intensity during the crop years of 2006–2011 in Delaware County, Iowa.

The 2006–2011 CDL data for this county can be customized and easily downloaded in a compressed file from CropScape. After obtaining these data, a workflow is built using ArcGIS ModelBuilder (Fig. 5). In the ModelBuilder, these CDL data serve as the input data variables of the workflow, and the crop value of corn is used as the value variable. The *Equal To* and the *Raster Calculator* tools of Spatial Analyst in ArcGIS are added as model tools. The output data parameter is the raster file with values (0–6) to represent the corn-planting intensity of this county during 2006–2011. Here, 6 means six years in a row planted to corn, 5 means five out of six years planted to corn, and so on. The continuous corn-cropping areas are easily identified from the image. Students can overlay the raster file of planting intensity with other geospatial data like digital elevation model (DEM) data, average annual precipitation, water resource points, soil classification, land capability classification to discover more useful information and knowledge from spatial relationships between them.

Example 5: Geospatial Data Mashup

Geospatial data mashup that integrates online geospatial data from a variety of sources intuitively helps students access Web mapping programs for their visualization needs, develop their familiarity with these online data sources, inspire their curiosity of spatial patterns, and enhance their spatial thinking abilities (Batty *et al.* 2010). CropScape provides standard OGC WCS and WMS services along with the KML output of the CDL data for use in Google Earth, Google Maps, ArcGIS Explore, Bing Maps, and other software with WCS, WMS, and KML support. An example of geospatial data mashup using Google Earth as a platform is given as follows.

The 2006–2011 CDL data of Colby County, Kansas, is clipped and exported as a KML file in CropScape. U.S. Drought Monitor provides the datasets of weekly drought condition in multiple formats across the United States and Puerto Rico (Svoboda *et al.* 2002). Polygons that contain the spatial information and the drought intensity (including five levels, abnormally dry, moderate drought, severe drought, extreme drought, and exceptional drought) can be downloaded in the KMZ files by week from U.S. Drought Monitor Web site. To display the 2012 Midwest drought

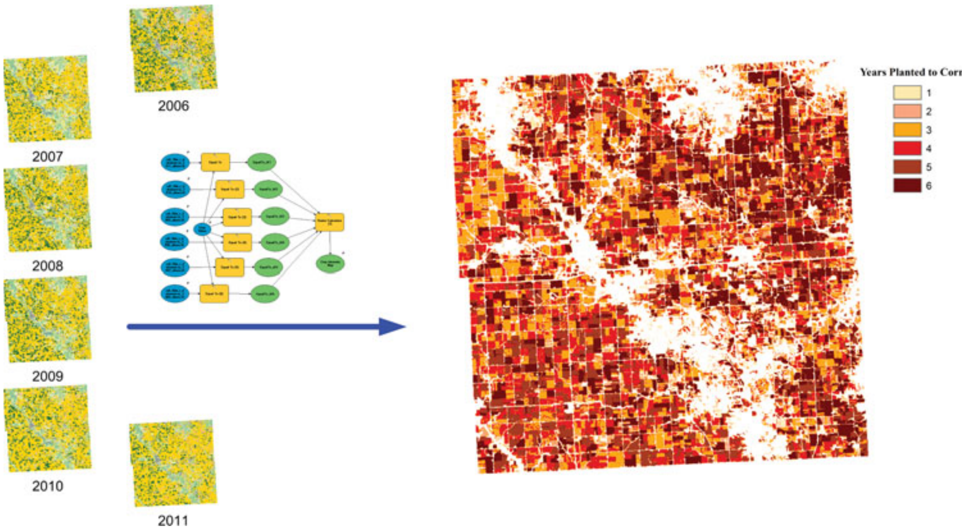

Figure 5. Corn planting intensity for the crop years of 2006–2011, Delaware County, Iowa. (Color figure available online.)

impact in this county, the KMZ file for August 21, 2012, is downloaded. The KMZ file of the U.S. General Soil Map, which contains locations and names of the soils, can be downloaded from the Google Earth Library Web site (Google Earth Library 2010). The KML and KMZ files are loaded flexibly and operated intuitively in Google Earth to explore drought impacts on crops planted on different soils and convey useful information for further analysis (Fig. 6). This kind of data mashup not only enhances the value of these data sources effectively, but also potentially inspires students' research interests and creative thinking.

Example 6: Geospatial Web Application Development

The geospatial Web services enable users to leverage distributed geospatial data and computing resources over the Web, and to automate geospatial data integration and analysis (Zhao and Di 2010). Building a GIS application using open-standard-compliant geospatial services and open-source packages promotes students' skills in programming and develops their experiences with presentation and production of a GIS project. CropScape offers free and standard geospatial data and processing services and detailed developer guide[2] to support machine-to-machine interactions with the CDL data and other geospatial data and spatial analysis functions. The following example presents how to construct a Web mapping application that loads geospatial data services provided by CropScape.

Open-source packages, including OpenLayers, ExtJS, and GeoExt, are utilized to build this Web application. OpenLayers is the most popular open-source mapping library that can consume layers from free OGC WMS and WFS servers, Google Maps, Bing Maps, Yahoo Maps, OpenStreetMap, and ArcGIS Servers, and interact with these layers through a suite of map controls. ExtJS is a free cross-browser JavaScript framework for building responsive Web applications using its GUI components. GeoExt is an open-source JavaScript library that connects OpenLayers and ExtJS by loading OpenLayers map object in the ExtJS panel and linking OpenLayers objects in ExtJS data components. It is easy to build a Web geospatial application utilizing the components and objects defined in these packages (Appendix). At first, an OpenLayers Map object is constructed in the Web page. Then, the required WMS layers of the 2008–2012 CDL data and the boundary files

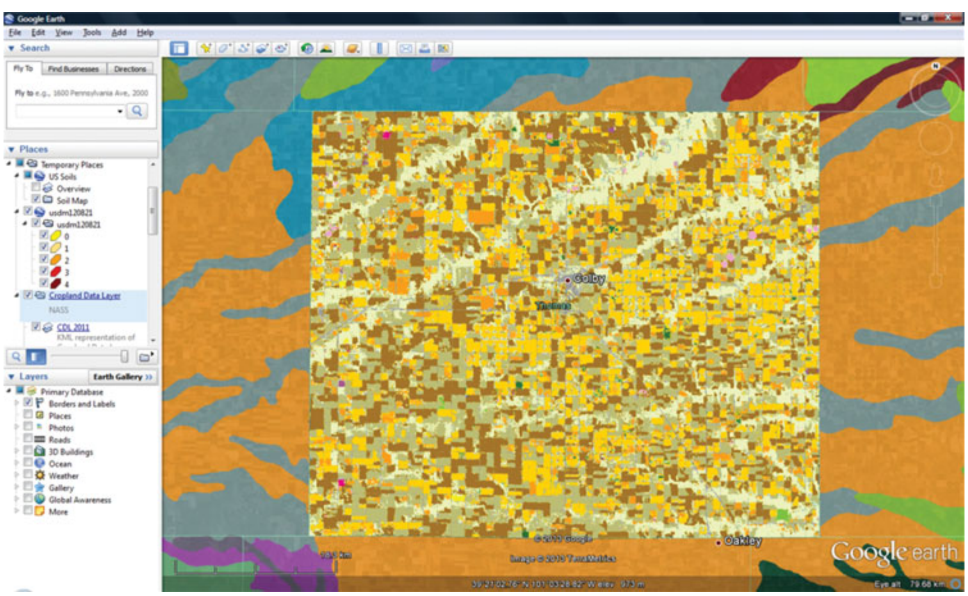

Figure 6. Multisource geospatial data mashup. (Color figure available online.)

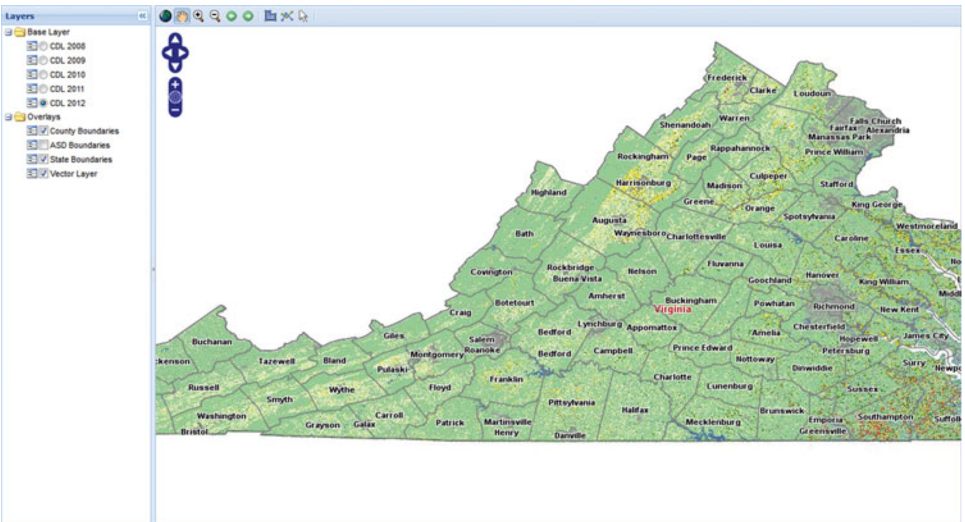

Figure 7. Simple Web application example integrating the Web Map Service layers of the 2008–2012 Cropland Data Layer (CDL) data and the boundary files of Virginia. ASD = agricultural statistics district. (Color figure available online.)

(including state, ASDs, and counties) of Virginia are created and added in the above map. Next, a toolbar containing the created shortcut buttons of map navigation and geometry drawing is constructed, and a map panel is created to load the toolbar and display the map at the specified scale and location. Finally, a layer tree is created to control the display of these layers, and a view port is constructed to combine the layer tree and the map panel together. This simple Web application can be opened in the Web browser, as displayed in Figure 7. For students with advanced programming skills, they can try to add Google Maps layers or Bing Maps layers in this Web application through OpenLayers API and integrate CropScape's Web geoprocessing services using ExtJS GUI components and AJAX requests.

Conclusions

CropScape provides the GIS education community with online informative tools to visualize, query, download, and analyze the landscape information across the CONUS. It is running in a cluster environment of four high-performance servers to ensure its reliability and responsiveness, and we conducted the load test of 250 concurrent users successfully before official release in January 2011. CropScape has been used as one of the federal geospatial data sources in GIS courses by educators at institutions such as University of Alabama in Huntsville (UAH), Eastern Illinois University, University of Hawaii, and George Mason University. For instance, in the course Introduction to Remote Sensing (Atmospheric Science Department in UAH)[3], students use CropScape to answer questions related to crop categories, such as these: What were the dominant crop categories in Madison County Alabama in 2008? What was the dominant land cover for the specified drainage basin in 2011? What can you infer about the land-cover changes in the specified drainage basin between 2008 and 2011?

Moreover, CropScape has been identified as a recommended geospatial data resource by the libraries of several universities, including Cornell University, the University of Wisconsin–Madison, and the University of Maryland.

The examples presented in this article are for illustrative purposes only; more practical cases will be created by experienced educators with CropScape's applications in GIS courses. In sum, CropScape is an ideal tool for use as a contextual mapping backdrop in GIS education at different levels to help increase students' GIS technical skills, develop new information and knowledge for the study area with the CDL data, and support a wide variety of land use and land-cover-related GIS course projects.

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Notes

1. CropScape: *http://nassgeodata.gmu.edu/CropScape/* (accessed July 21, 2012).
2. CropScape Developer Guide: *http://nassgeodata.gmu.edu/CropScape/devhelp/help.html* (accessed July 21, 2012).
3. GIS in APES Learning Materials: *http://nsstc.uah.edu/~anderse/docs/GIS-in-APES_Lab2-3_GPS_water.doc* (accessed July 14, 2013).

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APPENDIX: AN EXAMPLE CODE OF CONSUMING CROPSCAPE WEB SERVICES

```
<html xmlns="http://www.w3.org/1999/xhtml">
  <head>
    <title>Virginia Cropland Data Layer</title>
    <link rel="stylesheet" type="text/css" href="css/ext-all.css"/>
    <script type="text/javascript" src="ext/ext-base.js"></script>
    <script type="text/javascript" src="ext/ext-all.js"></script>
    <script type="text/javascript" src="OpenLayers.js"></script>
    <script type="text/javascript" src="GeoExt.js"></script>
  </head>
  <body>
    <script type="text/javascript">
          Ext.onReady(function() {
              //Step 1: Construct an OpenLayers Map Object
              var map = new OpenLayers.Map({allOverlays: false});
              //Step 2: Construct OpenLayers WMS Layer Objects
              var cdl2012 = new OpenLayers.Layer.WMS("CDL 2012",
                        "http://129.174.131.7/cgi/wms_cdl_va.cgi", {
                            layers: "cdl_2012_va"
                        }, {
                            buffer: 0,
                            visibility : false
                        });
              map.addLayers([cdl2012]);
             //Step 3: Create toolbar and map panel
              var toolbarItems = [];
              var action = new GeoExt.Action({
                      control:  new  OpenLayers.Control.ZoomToMaxExtent(),
                      map: map,
                      icon: 'images/mapfull.gif',
                      tooltip: "zoom to max extent"
                  });
              toolbarItems.push(action);
              var mapPanel = new GeoExt.MapPanel({
                        border: true,
                        region: "center",
                        tbar: toolbarItems,
                        map: map,
                        center: [-79.50, 37.75],
                        zoom: 8
                  });
              //Step 4: Construct layer tree panel and viewport
              var layerTree = new Ext.tree.TreePanel({
                        region: "west",
                        title: "Layers",
                        …
                });
              var viewPort = new Ext.Viewport({
                        layout: "fit",
                        hideBorders: true,
                        items: {
                            layout: "border",
                            deferredRender: false,
                            items: [mapPanel, layerTree]
                        }
                });
          });
    </script>
  </body>
</html>
```

(Color figure available online.)