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Reported Uses of CropScape and the National Cropland Data Layer Program

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ABSTRACT

This paper will highlight the unique cropland area monitoring program which was developed within the United States Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS). The report will also focus on the remote sensing based land cover products which are delivered via an interactive web portal known as CropScape. CropScape provides open accessibility, visualization, and geospatial analytics to the user community. CropScape also supports the ethos of data democracy, providing free and open access to digital geospatial data layers. CropScape utilizes open web standards, thereby supporting transparent and collaborative government initiatives. This paper discusses documented uses and applications of NASS' Cropland Data Layer (CDL) products, and how CropScape, a web-based program, delivered across the internet to connect USDA researchers with a previously unreachable audience. CropScape users can now interact, visualize, and query CDL products to determine planted agricultural cropland area at the field level for any given year across the landscape of our nation.

Keywords: Cropland Data Layer, CropScape, land cover, geospatial

1. Background

Since 1997, NASS has produced an annual crop-specific land cover product called the Cropland Data Layer (CDL). The CDL depicts more than 100 unique crop categories across the United States, and is delivered at 30 meters, or .09 hectare pixel resolution. Today, a national CDL product is available for the years 2008 through 2012, with the entire historical CDL dataset disseminated via CropScape at http://nassgeodata.gmu.edu/CropScape. The CDL is a national land cover product delivered just a few months after the growing season concludes. Combined, the CDL and

CropScape, are unique land cover products and dissemination methods that are not duplicated anywhere in the world on a national scale and are performed annually.

The CDL is derived using a supervised land cover classification approach. It combines the satellite imagery collected during the growing season from such sensors as Landsat, Resourcesat, and the Disaster Monitoring Constellation. It also combines agricultural-specific ground truth data from USDA's Farm Service Agency (FSA) program known as the Common Land Unit (CLU). And, it combines ancillary, non-agricultural ground truth data through the United States Geological Survey's (USGS) National Land Cover Dataset (NLCD). The process integration of these satellite resources with highly accurate and abundant ground truth provides for this one-of-a-kind, annual national land cover data product.

In January 2011, NASS, in cooperation with George Mason University's Center for Spatial Information Science and Systems (CSISS), released CropScape, a new data visualization portal, thus enabling open access to NASS's CDL geospatial data. CropScape was designed to provide users with free and open access to interactively visualize, query, and disseminate the CDL by using a standard browser interface to extract cropland area statistics, derive charts and graphs, and perform change analysis between years. Additionally, CropScape delivers online geoprocessing services such as dynamic, mashable, on-demand data delivery which effectively links directly to other geospatial applications such as Google Earth.

2. Methods

The CDL program relies on synergistic partnerships with the USDA's FSA who provides updated reported field level data on an annual basis from the CLU data set. This effectuates a robust ground truthing set of the agricultural domain. USDA's Foreign Agricultural Service (FAS) provides subscription-based access to their Satellite Image Archive, thus providing independent collections of satellite-based data (i.e., Resourcesat or Disaster Monitoring Constellation). The USGS, which produces the NLCD (Xian 2009), was utilized to derive the CDL's non-agricultural domain, along with the Percent Tree Canopy, Percent Imperviousness and National Elevation Dataset products. The USGS's Earth Resources Observation Systems (EROS) Data Center has been providing free access to Landsat imagery since 2008, and is also used as an image input. The CDL program and process to derive the CDL were described in detail (Boryan et al. 2011 and Johnson and Mueller 2010), utilizing a supervised decision tree classification approach with the aforementioned data streams.

The CDL was initially disseminated via CD-ROM and DVD media in the early 2000's, and subsequently select states became available for download via File Transfer Protocol (FTP) from the NASS website (NASS 2013). In the mid-2000's, USDA's National Resources Conservation Service (NRCS) began serving the entire inventory of CDL products through their Geospatial Data Gateway (NRCS 2013). It became apparent that better dissemination methods were needed to meet the growing end-users' need to interact and query this content-rich dataset.

Hence, a new interactive web-based CDL visualization method was developed to provide access like never before to users via web mapping services, while also offering open, geospatial protocols for data sharing. CropScape's primary function (Han 2012) was to offer an interactive, visual, and analytical experience that would enable users to download crop area statistics, examine quantitative changes on maps between crop years, perform a visual swipe function between years, and print map products. This could all be accomplished on a national level, within a state, an agricultural statistics district, or even within a county. One could also draw their own ad-hoc areas. Since CropScape was launched in January 2011, more than 81,000 users have interacted with the site, leveraging its comprehensive capabilities with continued demand for enhanced functionality or system improvement. CropScape facilitates a dynamic user experience in an open framework for decision support, while also upholding numerous agricultural-specific research projects. The remainder of this paper focuses on published uses of CDL datasets from peer-reviewed journals and documented websites that have ingested CDL data via CropScape mash-ups.

3. Uses of CDL

The CDL product has matured since its creation in 1997, with methods (Boryan et al. 2011), ground truth data, and accuracies of cropland identification making vast improvements, while the CropScape portal expanded product usage from mostly power Geographic Information Systems (GIS) users to those who had little or no GIS-related experience, but had extensive agricultural industry knowledge. CropScape has empowered the masses to perform area change and rotational crop analysis with a queryable, interactive interface. CDL end-users are now documenting their uses in peer-reviewed literature, with uses of the CDL product ranging from research on agricultural sustainability studies, to environmental issues, land conversion assessments, crop rotations, decision support, disasters, farmer surveys, carbon, bioenergy, ecology, and biodiversity. However, there is a segment of our user community who is using it for agribusiness decision support, as well as for insurance and financial purposes. These users cannot be quantified and will not publish their uses of the CDL dataset, as their uses are considered confidential or trade secrets. Additionally, other web portals are developing protocols that either host the CDL data or deliver it as part of web mapping services.

The research communities documented uses of CDL range from local food studies in Greenbrier Valley, West Virginia, where they are identifying agricultural production areas (Hartz et al. 2011), to Montana's Tongue River Basin, where scientists are studying water resources and availability to provide a detailed picture of land use versus agricultural statistics (Fitzgerald and Zimmerman 2013). And, users at the University of Idaho Extension (Painter et al. 2013) are leveraging CropScape to design an oilseed survey that will help producers and processors who were interested in trying oilseed production. In another study, the CDL was utilized to identify wheat area, mask wheat fields, and then derive an empirical regression yield model for Kansas, which was then scaled to a wheat-producing region in the Ukraine (Becker-Reshef et al. 2010). Finally, the CDL was utilized to characterize crop distributions and changes in crop rotations across the Great Lakes Basin (Lunetta et al. 2010).

The following studies focused on land conversions and transitions, where wetlands were transitioning to row crops (Johnston 2013), and where western corn belt grassland was being converted to corn/soybean production (Wright and Wimberly 2013). Users access the CDL to screen results with an agricultural mask and examine the agricultural rotational patterns and fallow land for wetland change monitoring in the Northern California marshlands (Potter 2013). Users in Illinois and Indiana accessed the CDL to study county level rates of conversion from farmland to evaluate developed farmland preservation policies (Thompson and Prokopy 2009). And, researchers examining the Northern Great Plains grassland conversions noted the need for additional statistical research of such large datasets, and cited CDL accuracy assessments as a critical means for deriving parameter estimates in empirical land-use models (Rashford et al. 2013).

The following studies focused on crop rotations, crop area expansion, tilled and cultivation studies, and statistical sampling. A study (Plourde et al. 2013) focused on crop rotational patterns, with trends moving towards monoculture cropping practices, and examined rotation sequences, which reflected the increasing intensification of corn production. The CDL served as a regression tree training model for agricultural production trends and crop rotation practices in the Great Platte

River Basin (Howard et al. 2012). Research on Iowa crop rotation patterns indicated corn expansion into land not under recent cultivation, which impacted the amount of soil carbon sequestration (Stern et al. 2012). Four years of CDL data were assimilated to create a consistent national level annual tilled cropland dataset, and another approach derived a cultivated rule-based dataset modeling (Boryan et al. 2012). And, yet another study used the CDL to characterize statistical sampling units into strata, to classify land into different types at the field level, and then as a proxy to estimate variances for crops of interest (Zimmer 2012).

The following chemical/environmental studies have used the CDL for project input: sampling site selection for pesticide contaminants in High Plains wetlands (Belden et al. 2012); estimating total pesticide usage and intensity in the Chincoteague Bay subbasin; characterizing agricultural, environmental, and other scientific parameters (Kutz et al. 2010); estimating the watershed scale environmental impacts of corn stover removal using the Soil Water Assessment Tool (SWAT) for determining that stover removal was sensitive to watershed characteristics and management inputs, including slope and fertilization applications (Cibin et al. 2012), and estimating field level nitrogen losses in another study that merged SWAT predictions with CDL data, thereby tying the changes in corn and soybean prices based on the US ethanol mandate to the expansion of the hypoxic zone in the Gulf of Mexico (Hendricks et al. 2013).

The CDL has also demonstrated uses in the carbon, bioenergy, ecology, and disaster domains. It has been utilized to derive net annual soil carbon changes, calculate the fossil fuel emissions from crop production, compute the cropland net primary production, which is used for estimating and spatial distributions, and to provide improved estimates of crop carbon dynamics in a spatially explicit manner (West et al. 2009). Another study used the CDL to evaluate the potential of marginal lands for biomass production and mitigation efforts on greenhouse gas emissions (Gelfand et al. 2012), and a bioenergy production study (Muth et al. 2013) of comprehensive spatial assessments of residue removal across the United States. A unique application was used in a North Dakota sunflower field study, which focused on (Schaaf et al. 2009) the foraging use of fall migrating non-blackbirds. Finally, scientists utilized CropScape to analyze the crop damage and loss following the devastating tornadoes that devoured sections of Alabama in April 2011. Using CropScape with tornado swath, along with National Aeronautics Space Administration resources, scientists were able to accurately describe crop damage and loss (Herdy 2012).

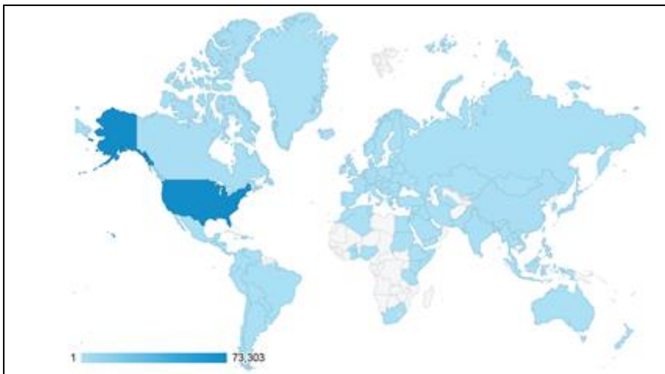
CropScape provides for a dynamic user experience with wide-ranging capabilities in an open, geospatial context, and facilitates the delivery and analysis of geospatial cropland information to the user community. Currently no other entity provides an annual national crop specific land cover product in an interactive, accessible manner, via a visually immersive experience. CropScape's Open Geospatial Consortium compliant architecture and web mapping services have created opportunities from within the geospatial community to develop data sharing through the wire, encapsulating one website's geospatial data within another, using a technique called mash-up (Han et al. 2012).

Many sites utilize web-based tools for the United States cropland, bioenergy, and soils data exploration, including the demonstration of linking CDL spatial functionality to detailed crop rotation management for agroecosystem modeling (Kipka et. al 2013) using web service requests. The Billion Ton Study (US Dept. of Energy 2011) hosts a mashable site called the Knowledge Discovery Framework at https://bioenergykdf.net/ where varying scales of data i.e., national, regional, and local can be queried, analyzed, uploaded, and visualized for decision-support with regard to economic and environmental impacts of development options for biomass feedstock production and biorefinery infrastructure. Another site where the CDL can be queried against bioenergy datasets for acreage planted information (Yang et al. 2011) was developed in another application called integrated Agricultural Information and Management System (iAIMS), and it delivers dynamic and interactive climate, soil, CDLs, and road infrastructure databases at https://beaumont.tamu.edu/CroplandData/.

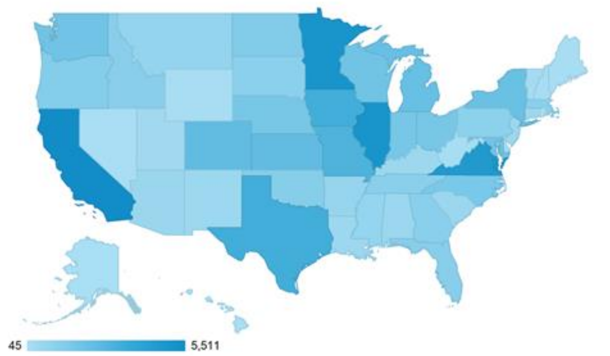
4. Discussion

In preparation for this paper, Google Analytics were run against CropScape's user base, and the following information was tabulated. Figure 1a depicts CropScape's global user base, with the majority of users coming from the United States. However, the reach of CropScape was global with users reporting from every continent except Antarctica. Table 1 shows the number of top ten country unique visitors in descending order using CropScape with the United States, Canada, China, Germany, United Kingdom, Argentina, France, Brazil, Spain, and Mexico. Figure 1b shows the United States locations of CropScape users; California, Illinois, Minnesota, Virginia, and Iowa were the top five reported state users, in descending order. Note that both the CSISS and NASS Spatial Analysis Research Section were located in the state of Virginia, which could account for higher than expected numbers. The total number of unique reported visitors was 81,650 as of June 2013. Figure 2 shows the reported number of CropScape visitors since CropScape became operational in January 2011. Note the sharp user access increase during both January 2012 and 2013, when the newest CDL products were released. However, there was an intense user spike for unforeseen reasons during the end of June 2011, when users visited CropScape coincident with the release of the NASS June Acreage Report. It is believed that the public thought that the CDL was going to be updated and released coincident with the June Acreage Report. However, it is impossible to release a completed, final CDL product at this time, as it is necessary to wait until the growing season has completed, all crops have emerged, matured, and senesced. Once that is complete, the metadata is finalized, and all products are checked for quality assurance and quality control.

Figure 3a shows the CropScape website and interface at http://nassgeodata.gmu.edu/CropScape. CropScape provides additional ancillary data layers for purposes of navigation and dissemination, including a crop mask to shade-out all non-agricultural areas, and political, water, and road boundary layers to facilitate orientation purposes. Figure 3b shows an enlarged depiction of Craighead County, Arkansas in 2012, with the crop legend appearing on the left side of the graphic. Note there was much discussion and many decisions to be made to properly represent each crop category cartographically. When making these decisions, we considered each crop category color and its geographic distance to similar crop colors. Mapping the more than 100 crop categories was extremely challenging (Ebinger 2012).



1a. *Global CropScape users.*



1b. *US CropScape users.*

Figure 1a: The darker blue color indicates higher incidence of reported CropScape users globally.
Figure 1b: The darker blue color indicates higher incidence of reported CropScape users in the US.

Country	Unique Visitors

US	73,303
Canada	1,100
China	913
Germany	502
United Kingdom	441
Argentina	393
France	388
Brasil	362
Spain	300
Mexico	291

Table 1: List of the top ten unique national country visitors to CropScape, note n = 81,650.

Figure 2: Lists the unique number of unique visits since January 2011 when CropScape became operational.

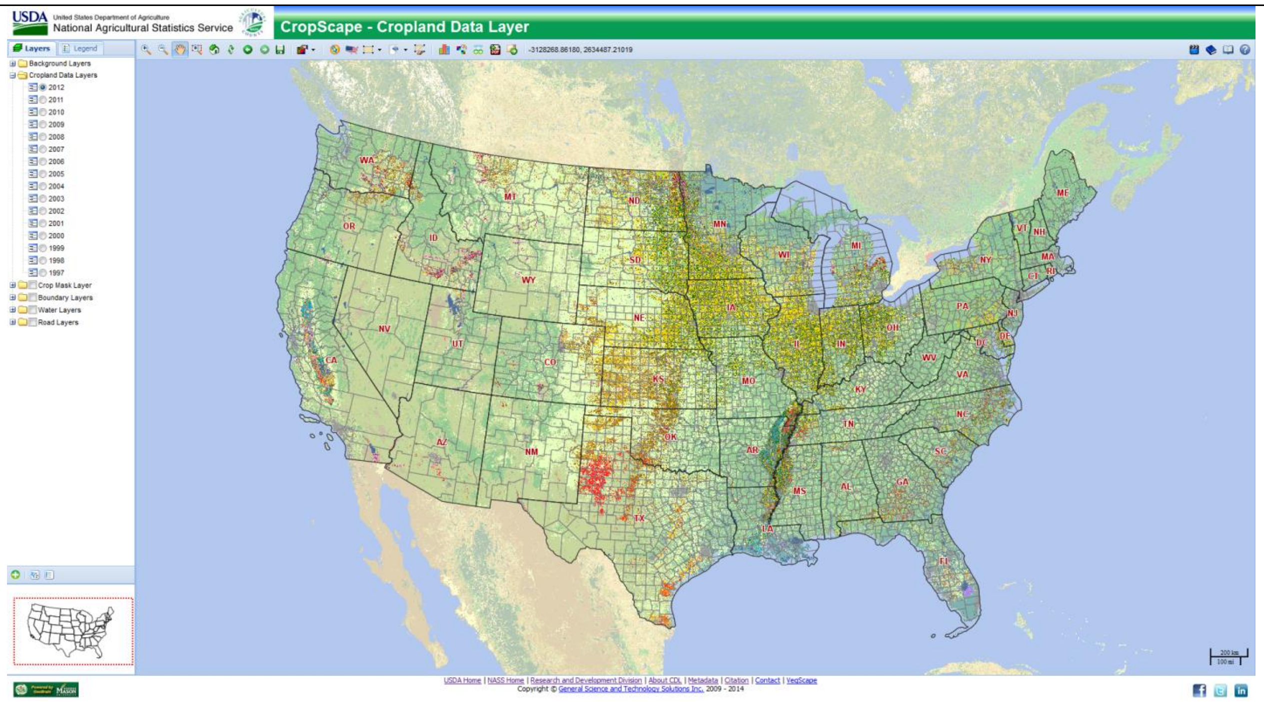


Figure 3a: CropScape website interface, note the CDL years of data available.

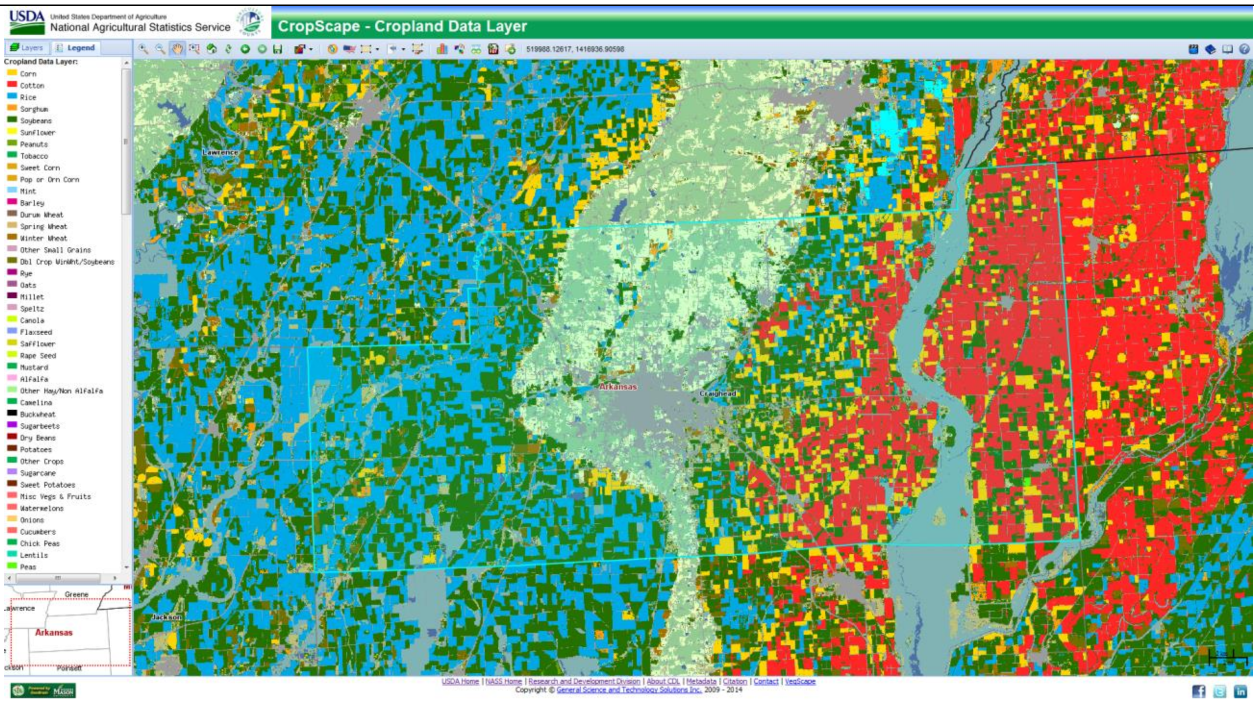


Figure 3b: A zoom enlargement of Craighead County, Arkansas 2012. The crop legend appears on the left side of the graphic.

5. Conclusion

The combinations of the CDL product disseminated with CropScape provide a unique one-of-a-kind, interactive, visual, and analytical experience. The ethos of data democracy were upheld, providing free and open access to digital geospatial data layers in an open standard web format, supporting a transparent and collaborative government initiative. Users can query, compute statistics, perform change analysis, map, and visualize the entire inventory of CDL data derived at 30m or .09 hectares resolution and show field level accuracy. The CDL is now a national level product, reproduced annually and publically disseminated just a few months upon completion of the growing season. The reported uses of CDL and CropScape in published peer-reviewed journals and literature were discussed.

The uses of CDL data have grown, where users leverage it for agricultural decision support and scientific research. And finally, perhaps the most successful use of CropScape and the CDL were related websites that have developed protocols whereby they either host CDL data or deliver it as part of web mapping services. That is the ultimate mash-up of technology and product success.

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