Beyond Borders:

Gridded Demographic Data Sets and Web Mapping Applications for Population, Development, and Environmental Research

Introduction

Demographic data form the backbone of most analyses across the social and health sciences, as well as in the applied world of economic development, planning, and foreign aid. Easily accessible data and methods for data extraction can speed up the response to a crisis and improve the quality of the response (National Research Council 2007a). USAID's Famine Early Warning Systems Network (FEWS NET) was an early adopter of GIS technologies to facilitate widespread access to spatial population estimation for areas that do not conform to political boundaries (Jordan et al., 2010). Why is this important? And, how is this technique different? Consider any of the recent events listed on the fews.net newsfeed: increased rain deficits portend worsening ground condition for crops in parts of north central Nigeria[1], rise in staple food prices expected to compound the Boko Haram crisis[2], or the prevalence of coffee rust in Central America is leading to reduced incomes and a rise in vulnerability to price increases.[3] The weather, conflict, and disease all have a tendency to disobey the maps that leaders and bureaucrats draw in order to govern and collect information about population. The solution, for estimating populations within or across these lines, has been to take a different approach: draw a grid and populate the grid. The solution also follows from techniques that scientists use to survey weather, climate, and vegetation: collect satellite imagery, comprised of a grid, or pixels, of data. Clearly, if the grid cells are too large, there would be little improvement over administrative boundaries, but what demographers and geographers have been able to show over the years is that it is possible to refine population estimates to 1 km and even 100 m square grid cells, by a process called dasymetric mapping (Mennis 2003).

Though the idea to grid population maps is not new (Tobler, 1969; Tobler, 1979; Deichmann, 1996), the ability to do it well is. The earliest population grids showed little or no improvement over data available by administrative boundaries (Hay et al., 2005). Table 1 lists the presently available population grids, available for widespread distribution. Currently, the most widely used global population grids include the Gridded Population of the World (GPW), the Gridded Rural-Urban Mapping Project (GRUMP), and LandScan. Two of these, GRUMP (Balk et al., 2006) and LandScan (Dobson et al., 2000) offer population estimates at roughly a 1 km resolution, using dasymetric mapping. Dasymetric mapping involves the use of one or more ancillary datasets to better approximate the locations of populations living within administrative boundaries. Examples of ancillary data include: locations of roads (Qiu, Woler, and

[1] http://v4.fews.net/docs/Publications/afr_Jun06_2013.pdf
[2] http://v4.fews.net/docs/Publications/West_SR_Nigeria%20Impact_050413.pdf
[3] http://v4.fews.net/docs/Publications/SR_coffee_2013_03.pdf

Briggs, 2003; Reibel and Bufalino, 2005), building footprints, nighttime lights imagery, land cover (Chen, 2002; Eicher and Brewer, 2001, Tian, et al., 2005; Yuan, et al. 1997), slope and elevation data. Newly developed regional and country-specific models, which include AfriPop (Linard et al., 2012), AsiaPop (Gaughan et al., 2013), and Demobase (Azar et al., 2010; Azar et al., 2013), have been verified and validated, using different techniques to generate 100 m resolution, gridded datasets.

TABLE 1. LIST AND SOURCES OF AVAILABLE GRIDDED POPULATION DATASETS

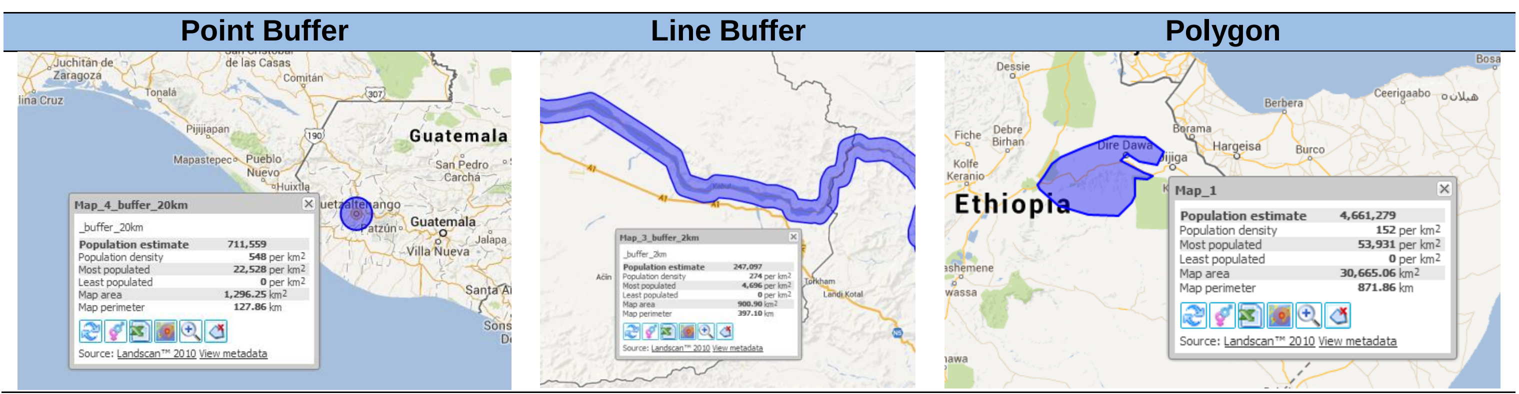
Name	Website	Information
Global Datasets:		
GPW	http://sedac.ciesin.columbia.edu/data/collection/grump-v1/about-us	2.5 arc minute (~10km), global population grid, 1990, 1994, 1995, 2000, 2005, 2010, 2015
GRUMP	http://sedac.ciesin.columbia.edu/data/collection/grump-v1/about-us	30 arc second (~1km), global population grid, 1990, 1995, 2000
LandScan	http://www.ornl.gov/sci/landscan/	2011 US Census estimates, 1km population grid, global
Continental Datasets:		
AfriPop	http://www.afripop.org/	2010 UN estimates for most countries, 2015 for some countries, 100m population grid
AsiaPop	http://www.asiapop.org/	2010, 2015 UN estimates for a number of countries across Asia, 100m population grid
GEOSTAT (EU & EFTA)	http://www.efgs.info/data and http://epp.eurostat.ec.europa.eu/portal/page/portal/gisco_Geographical_information_maps/popups/references/population_distribution_demography For methods: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Population_grids and http://epp.eurostat.ec.europa.eu/portal/page/portal/gisco_Geographical	2006 population grid, 1km, produced by the Austrian Institute for Technology (AIT) for EU and EFTA countries 2001, degree of urbanization data Sources: European Commission (Eurostat, Joint Research Centre and DG Regional Policy - REGIO-GIS)

	_information_maps/publications/geostat_population_grid_report	
Country Datasets:		
Demobase	http://www.census.gov/population/international/data/mapping/demobase.htm	2003 Haiti, 1998 Pakistan, 2002 Rwanda 100m population grids, produced by the US Census
Japan, Census Bureau	http://www.stat.go.jp/english/data/mesh/06.htm	1 km population grid, 2010
US Census Grids	http://sedac.ciesin.columbia.edu/data/collection/usgrid	30 arc-second grids (~1km), of 1990 and 2000 census data, including SF3 files.
China Census Grid	http://chinadataonline.org/	5 km, population density grid, 1995 (based on 1990 data), based on city lights

Web Mapping Applications for Borderless Population Estimates

Population Explorer, available at http://www.populationexplorer.com, offers food security analysts the ability to drill down to any area of interest on a global map and create a point buffer, line buffer, or polygon to retrieve a best estimate of the total population living in a specific user-defined area (see Figure 1).

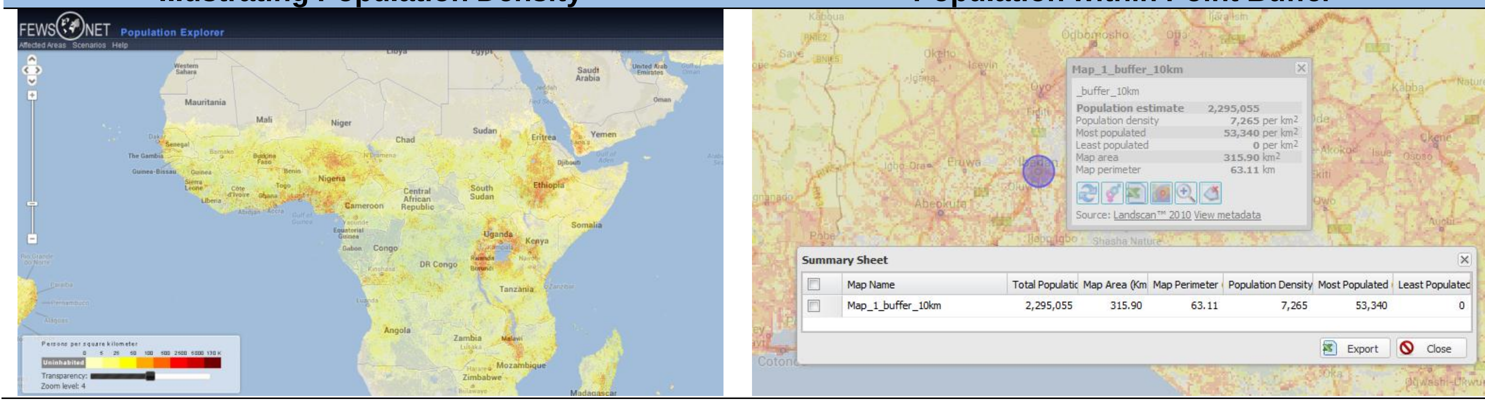
FIGURE 1. ILLUSTRATION OF POINT BUFFER, LINE BUFFER, AND POLYGON QUERY WITH POPULATION EXPLORER



Since its initial launch, Population Explorer has made substantial advances in usability and accessibility (see Figure 2). It now offers the full, updated, global LandScan population base. It also provides users the ability to see a thematic surface of LandScan's population base, with options to adjust the transparency. The interface has been updated at multiple intervals to match common web-mapping standards. Maps can be printed, cohort estimates are available globally, and data can be downloaded in excel format.

FIGURE 2. NOTABLE IMPROVEMENTS IN POPULATION EXPLORER

LandScan Grid Overlay, Illustrating Population Density	Export Data Functionality: Population within Point Buffer



Population Explorer exists in the much wider context of geographic information systems (GIS). A recent explosion of GIS applications, offered as stand-alone software packages, mobile applications, and websites has really opened up access to spatial data and geospatial modeling techniques to a wide variety of users. Accessibility to spatial data has also vastly improved, as evermore georeferenced information is collected and distributed by governments, NGOs, and private organizations. The biggest players in internet mapping continue to be Google and Microsoft, as well as private GIS software developers, ESRI and Autodesk. While these companies have extended the depth of the functionality of their software, individual developers have extended the breadth of software specific applications. Very specific GIS software can be downloaded just to map genetic variation in viral DNA over space (Gen-GIS), visualize the consequences of sea level rise using present day photographs of landmarks (NOAA's CanVis), or simulate the plume of airborne industrial pollutants for specific point emission sources (EPA's RSEI).[4]

In addition to commercial GIS options, open source options have become increasingly popular (Sherman and Mitchell, 2012). Open source software is free and open, meaning that all the source code used to generate the software is fully public. Gen-GIS, mentioned above, is open source. More fully-loaded GIS software packages, like Quantum GIS, have also been made available as open source software. Those in favor of open source software argue that government software development, or nationally funded projects, should be made available for public use, and that there should be broader access to all types of software in general. Academically, open source software has been favored because it offers a platform where all the processes in which data are analyzed become transparent, and therefore replicable. These

[4] For even more examples, see the Ecosystem-Based Management Tools Network (EBM Tools Database).

arguments have been extending into data availability and usage as well. Since the creation of the Federal Geographic Data Committee (FGDC), the development and population of a federal geospatial warehouse has become a priority for agencies in the US that produce geospatial data. Efforts toward this are visible in the data.gov project.

Emerging from the public health and epidemiology literature, the AfriPop and AsiaPop datasets, were developed with the intention of replacing existing global population datasets. First, because publicly available and transparent population datasets, like GRUMP, were no longer being updated (Gaughan, et al. 2013). Second, because alternative datasets, like LandScan, were developed with both methods and data that are confidential, and therefore not replicable (Linard and Tatem, 2012). And, last, because with the new availability of higher resolution global land cover datasets, it became feasible to generate higher resolution population datasets than previously constructed on a country-wide scale (Linard et al., 2012). Simultaneously, the US Census Bureau devised and thoroughly tested similar techniques for calculating a spatial population grid, which they did for Haiti (Azar et al., 2010), Pakistan (Azar et al., 2012), and most recently, Rwanda.

Extending from these datasets, the US Census Bureau also created one of two web-based applications that are comparable to Population Explorer: Demobase. The Center for International Earth Science Information Network (CIESIN) at Columbia University generated the other competitive web service for their Gridded Population of the World (GPW), version 3, 2005 dataset. Their application is simply called Population Estimation Service. Table 1 outlines the main similarities and differences of Demobase, the Population Estimation Service, and Population Explorer. The biggest advantage of Population Explorer over Demobase is that Population Explorer is global, whereas Demobase is for only two countries. The biggest advantage of Populaton Explorer over CIESIN's Population Estimation Service is that it provides more up to date population counts, using a 1 km, instead of 10 km grid. Demobase uses even older estimates, dating to the latest official census, with highly specific and validated methods for distributing local population values across a grid for the particular time period. Demobase offers data at a higher resolution, and high quality academic articles have been written on the specific processing of their two datasets.

Table 2. Comparison of Web-based, High-Resolution, Demographic GIS Applications

Application:	Population Explorer	Demobase*	Gridded Population of The World (GPW), v.3 - Population Estimation Service
Website:	http://populationexplorer.com/	http://www.census.gov/population/international/data/mapping/demobase.html Pakistan: http://egeoint.nrlssc.navy.mil/pakistan/ Haiti:	http://sedac.ciesin.columbia.edu/tools/population-estimation-mapclient (for PCs) http://sedac.ciesin.columbia.edu/tools/populatio

		http://egeoint.nrlssc.navy.mil/haiti (The two are at different stages of development. Haiti was produced first.)	n-estimation-mapclient/m (for mobile devices)
Data:	LandScan	U.S. International Program, Population Estimates, Official census for Haiti and Pakistan	Gridded Population of the World (GPW), v. 3
Scope:	Global, Official Datasets, where available	Limited, beta-version, for Haiti and Pakistan	Global
Resolution:	1 km grid	100 m grid	10 km grid
Tools:	Main Features: • Draw and summarize data by polygon • Buffer point, line, or polygon Ability to export summarized data as an Excel file • Shows the population grid, with the ability to alter its transparency Help Tools: • Text window on the functionality of different buttons on the interface and sources of the data used to calculate population Standard Web-GIS Tools: • Change map background • Pan/zoom/full extent/measuring tool	Main Features: • Draw and summarize data by polygon; • Draw hurricane (creates three variable sized buffers around user-defined line) • Draw earthquake epicenter (creates three variable sized buffers around user-defined point); • Select by administrative area, point-and-click • Search by administrative area (e.g. commune or department in Haiti), with drop down box or search box; • Show a thematic map and legend for population density • The Pakistan data includes by gender bar graphs of 10-year age groups, education, literacy, employment and activity, language, households (by rural and urban) Help Tools: • Training and tutorial videos Standard Web-GIS Tools: • Change map background • Show/hide basemaps • Pan/zoom/full extent/measuring tool	Main Features: • Draw and summarize data by polygon Help Tools: • Simple text drop-down menu describes how to use the website Standard Web-GIS Tools: • Change map background • Pan/zoom

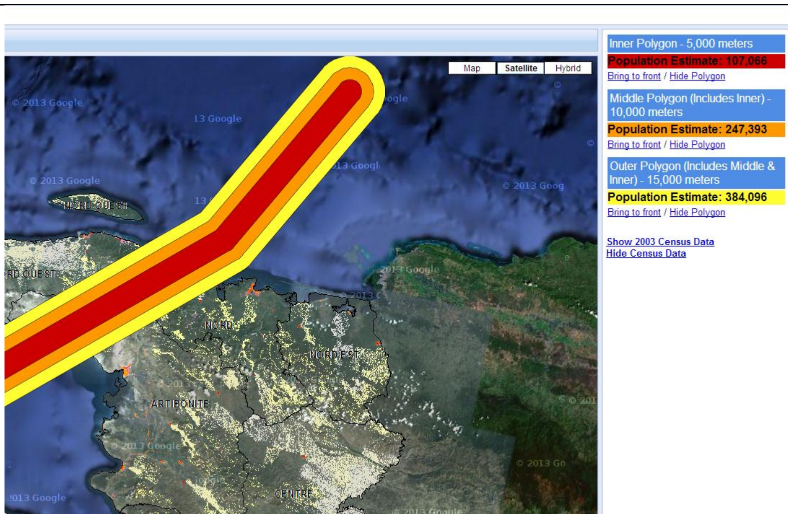
		Other information: lat/long, coordinate system (WGS84), caveats about data usage	
Attributes:	• Population count • Area • Perimeter • Population Density (Mean) • Population of Cell that's Highest (Maximum) • Population of Cell that's Lowest (Minimum) • Population by gender and age group • Population growth rates	• Population count • Area • Population Density (Mean) • Population by gender • Urban/rural population counts • Population graph (pie chart for rural and urban distributions) • Housing traits (total houses, urban houses, rural houses, family units, urban vs. rural family units)	• Population Count • Land and Unit Area • Population Density (Mean) • Population of Cell that's Highest (Maximum) • Population of Cell that's Lowest (Minimum)

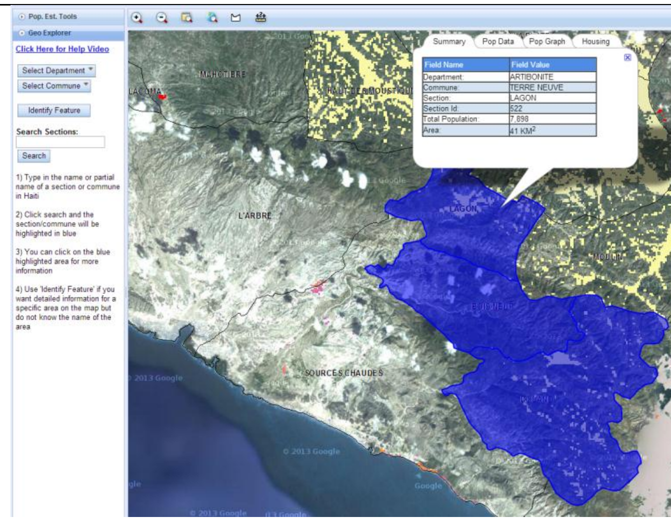
*Demobase lists Population Explorer in its "Related Links" section.

Beyond the differences in the underlying databases that the three web applications offer, there are a few notable differences in the user-interfaces, illustrated in Figures 3 and 4. For example, Demobase offers an intuitive way to query administrative boundaries, which are illustrated in simple, but effective video tutorials. The upper left image in Figure 3 shows the draw hurricane tool, which generates a series of nested line buffers. The upper right image shows the Geo Explorer feature in Demobase. Above the Geo Explorer tab is a tab for Pop. Est. Tools, which are similar to Population Explorer's tools. But the Geo Explorer tab allows users to query specific administrative boundaries, first by department, then by commune. The identify features tool opens a pop-up box as well as a window on the right with local population data. The lower left image shows the earthquake tool, which again generates nested buffers, but for a point location.

FIGURE 3. DEMOBASE USER-INTERFACE

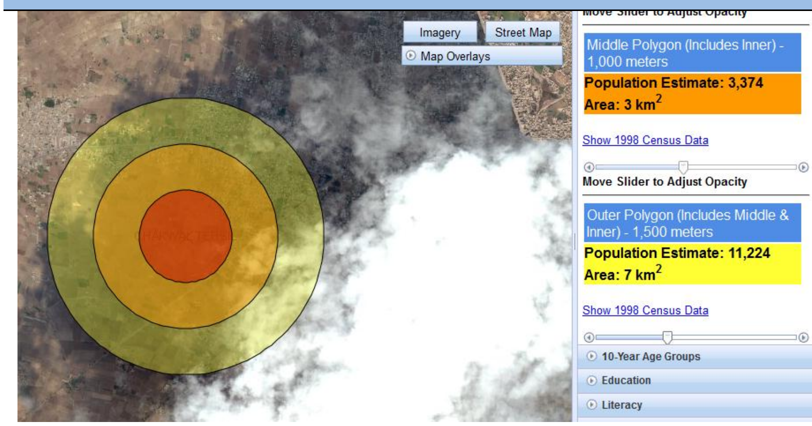
Draw Hurricane Tool	Geo Explorer, in Haiti Interactive Map





Draw Earthquake Tool

Geo Explorer, in Pakistan Interactive Map



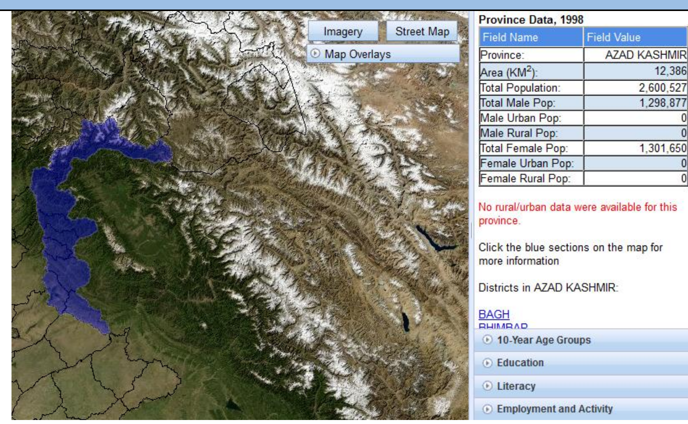
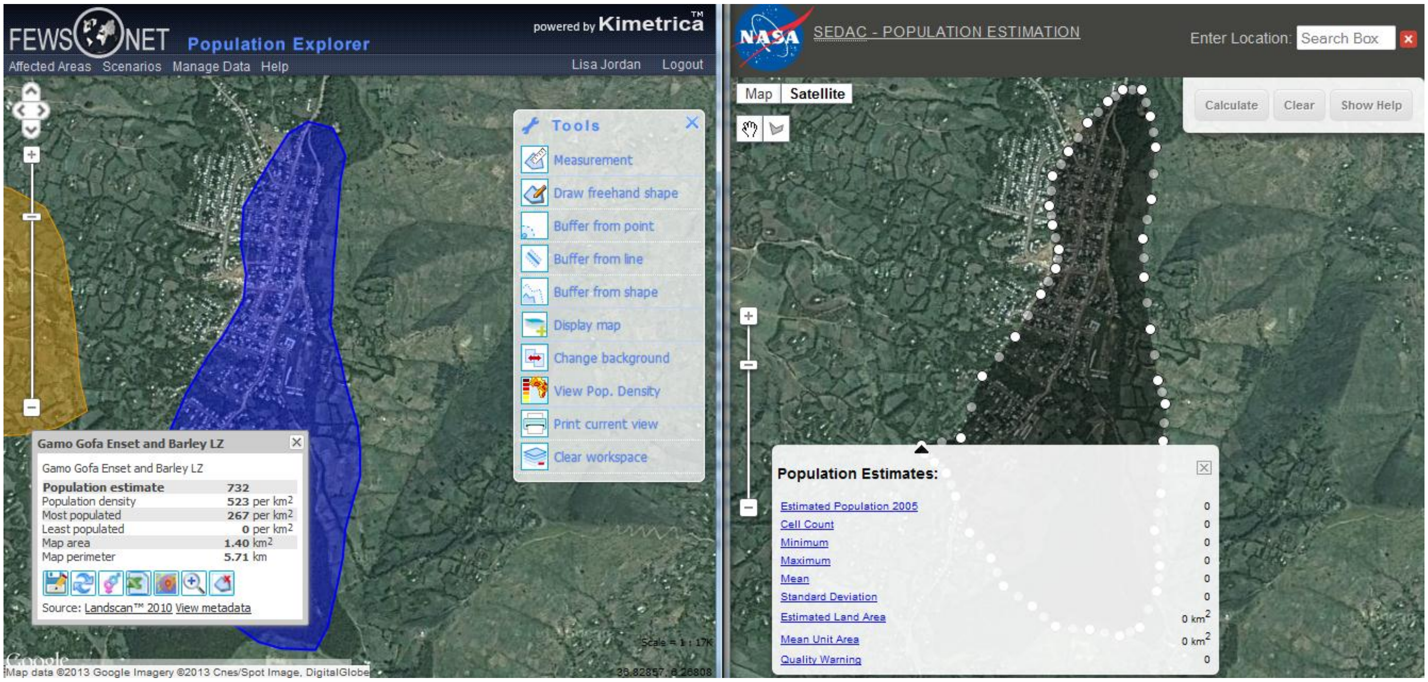


FIGURE 4. COMPARISON OF POPULATION EXPLORER AND SEDAC – POPULATION ESTIMATION SERVICE



CIESIN's Socioeconomic Data Analysis Center's (SEDAC) Population Estimation Service offers a simple tool to draw a polygon anywhere on a map-interface, in order to retrieve population values. There are a few glitches with this service, as shown in Figure 4. Since the GPW data set works with a population grid at roughly 10 km per cell, it is possible to query areas that do not intersect a grid's center point. With no data, the population count returned is zero. Though there is a condition in the software to generate a warning for areas with inadequate data, the warning does not always appear. However, when used at smaller cartographic scale, the population service works well and quickly. Also, the population service works not only through the website, but also through queries sent through stand-alone GIS software, like ArcGIS, via a Web Processing Service (WPS) or REST/SOAP Services.

While data and techniques for population geography have become increasingly open, with even the first massively open online course in GIS being offered this summer[5], the field of web-GIS software to enable local population queries is very limited in scope. In fact, as Table 3 outlines, most mash-ups and web uses of population data have been primarily experiments in dazzling flash animated displays of census data, rather than enabling analytical capabilities for the user.

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[5] "Maps and the Geospatial Revolution," taught by Anthony Robinson at Penn State, through Coursera, will be the first MOOC course in GIS, available at https://www.coursera.org/course/maps .

Table 3. List of Web-based GIS Applications with Creative Use of Population Analysis

Name	Website and Example
Identifying Populations and Assets at Risk: Dynamic Mapping of Israeli Coastline	http://ccg.huji.ac.il/dynamicmap/index.html Clicking the "Population at Risk" tab enables users to change the sea level rise scenario and scroll over a trendline that displays population within the flood zone. Clicking on the flood zone displays total population count, disabled population and total monthly income. The authors use highly accurate population data, with population estimates at the level of individual buildings (Lichter and Felsenstein 2012).
Census Mapping Applications	A great deal of emphasis on census data over the web has been in mashups that produce better *visualizations* of data than available through official census websites (as opposed to analyzing the census data). Examples include: The New York Times, Mapping the 2010 U.S. Census, http://projects.nytimes.com/census/2010/map National Public Radio, changes in Hispanic population in the US, http://www.npr.org/censusmap iPolitics, Interactive Census Map of Canada, http://www.ipolitics.ca/2012/05/29/census-interactive-how-does-your-community-compare/ CUNY, 1940s New York, used digitized phone book data to create historic maps of New York, http://www.1940snewyork.com/

Comparison of Spatial Population Datasets

In terms of data needs to supply the population grid for web mapping applications, there are now no global, updated alternatives to LandScan to supply a 1 km grid. However, for specific countries and regions, there are alternatives, in an exciting phase of development that enable the generation of 100 meter population grids. The main advantage of AfriPop and AsiaPop, and Demobase, over LandScan is the availability of data at a higher resolution. The improvements have been validated, using official population data for administrative units that are small in size (Gaughan et al., 2013). LandScan does not provide forecasts. GPW has forecasts for 2015, but again, the estimates are at much lower resolutions than AfriPop and AsiaPop. Where available, the forecasts for AfriPop and AsiaPop offer the highest resolution grids.

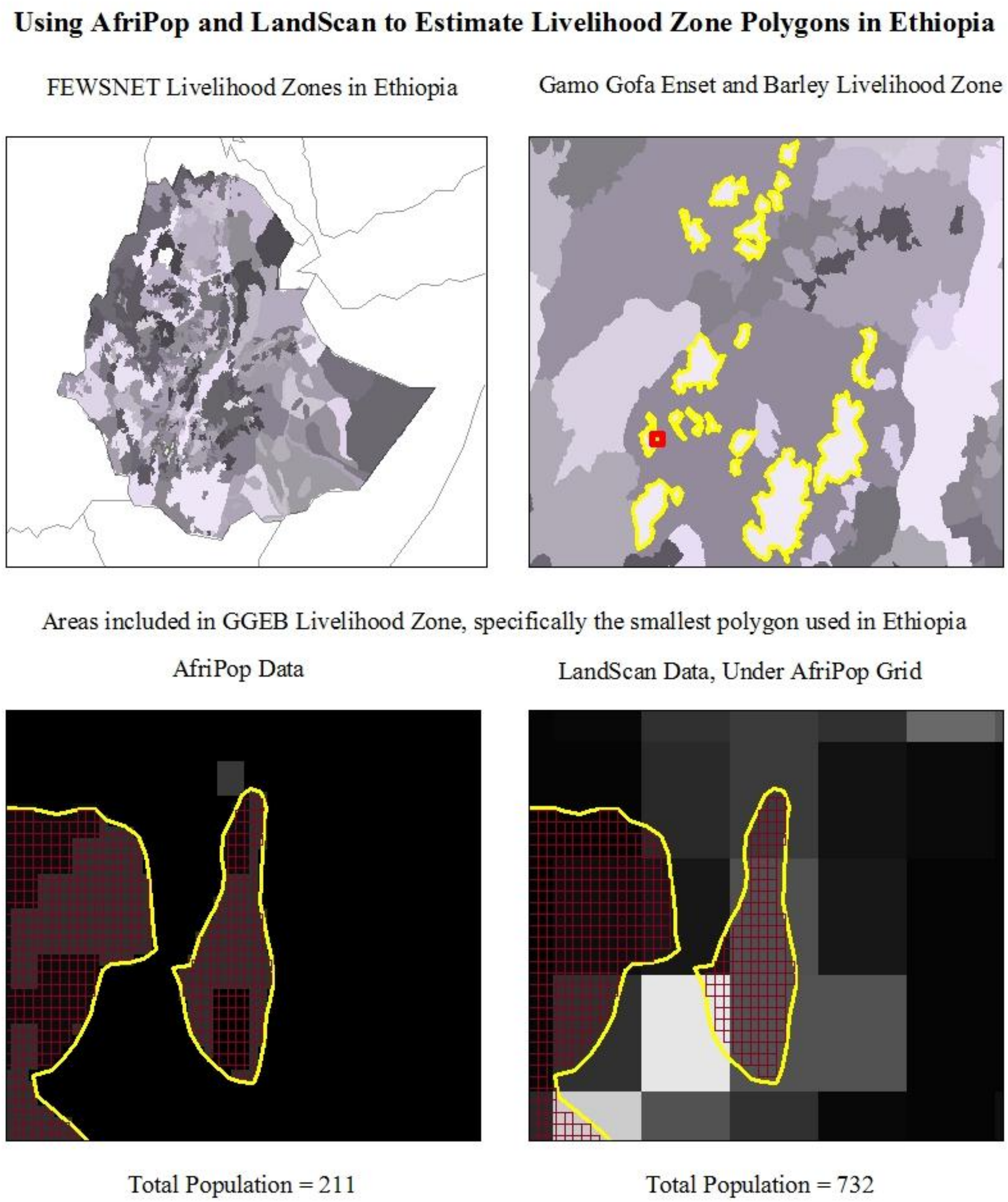
No one has tested the improvement in interim years, 2011-2014, of the UN population estimates for comparability with LandScan. LandScan has released data for 2011, and in September ORNL will release the 2012 version of LandScan. AfriPop and AsiaPop data may be imputed for 2011-2014, with modest GIS analysis skills. For example, raster map algebra could be used to subtract the 2010 grid from the 2015 grid, and reassign incremental population changes across 2011, 2012, 2013, and 2014 to produce annualized or semi-annual grids. This would result in a time-series of 100 meter grids, for 2011-2014, but the benefits of improved resolution from AfriPop and AsiaPop are difficult to weigh. The incremental intervals would all produce forecasted values, rather than values based on updated data. A trade-off exists between the highest resolution, 100 meter grids, with forecasted data, and LandScan's annual data updates, with $1km^2$ grid cells.

Specifically, LandScan's annualized data sets are difficult to assess. Censuses are costly and resource intensive projects, even if they are essential to running a state. Many countries conduct a decennial census, or a census count every ten years. But, not all countries are able to administer a consistent, decennial census, and for the ones that do, the schedules vary. In other words, census counts happen in different years in different countries, not just on years ending in a zero or five. Even when data are collected on years ending in a zero or five, it can take a number of years for figures to be tabulated, verified, and distributed. If LandScan incorporates updated census data for countries every year, then it is very likely that their dataset is a better estimate of "true" population than AfriPop and AsiaPop, though the resolution is lower.

Glimpses of LandScan methodology that are available from assorted publications (Graesser et al., 2012) do suggest that the data and techniques being employed are very high quality and advanced, but it is impossible to know, for any given country, which gridded data set is best, without also having verification from local data. Another kink in weighing the benefits of different data sets lies in the differences in the quality of estimates across countries. What AsiaPop has done to verify the quality of estimates for Thailand is difficult to apply to the quality of estimates for Somalia. Land cover and land use used to distribute population counts over space vary considerably by country, and of course, the original population estimates for conflict-ridden states used to distribute across a grid are suspect.

Though intuitively it is easy to understand that a population grid with ten times the resolution would have advantages, it becomes even more apparent when looking at the differences visually. Figure 5 demonstrates the advantage of high resolution population data, when identifying population for small polygons in Ethiopia. Livelihood zones in Ethiopia are small and dispersed. To investigate the issue further, the maps below illustrate the smallest polygon in the Ethiopia livelihood shapefile. The polygon has an area of 1.4 km^2, and is one of a series of twenty-one polygons that comprise the Gamo Gofa Enset and Barley Livelihood Zone. Using AfriPop, 162 grid cells fall within the smallest polygon, totaling to a population count of 211. Using LandScan, only a few grid cells fall within the smallest polygon, adding to a population count of 731.

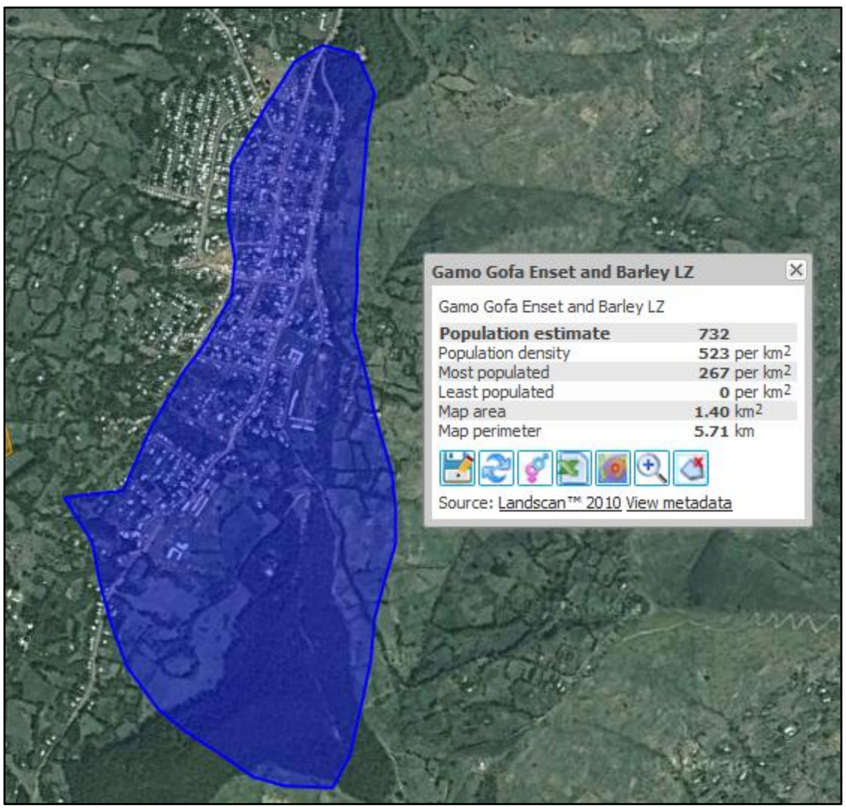
FIGURE 5. COMPARISON OF AFRIPOP AND LANDSCAN ESTIMATES IN ETHIOPIA



In food security analysis with livelihood zones, however, higher resolution may not necessarily be better, especially if it means working with older data. For the entire Gamo Gofa Enset and Barley Livelihood Zone, with polygons ranging in size from 1.4 km^2 to 614 km^2, AfriPop estimates the population at 390,450, and LandScan estimates the population within this zone at 381,915. Most of the livelihood zone polygons are much larger than a few LandScan grid cells. We also do not know the true population of this zone from official population sources. These are two guesses. For the smallest polygon, AfriPop is more conservative. For the livelihood zone as a whole, LandScan is more conservative. In a few months, Population Explorer will be updated with 2011 LandScan data, and another guess will be available, but that one will offer an estimate of 2011 population, instead of 2010. In September, ORNL will release 2012 data. There are currently no plans to release 2011 or 2012 AfriPop data.

To further complicate this point, Figure 6 shows the smallest Ethiopian livelihood zone polygon draped over a Google Earth, satellite land cover surface. Visually, the boundaries do not appear to match the land use on the ground. Part of a settlement and part of surrounding settlement areas are included. A review of fews.net shapefiles failed to uncover any metadata regarding the construction of the specific livelihood zones to indicate a preferred scale for analysis or the extent of uncertainty in boundary definitions. Perhaps the uncertainty in livelihood zone boundaries more closely matches the resolution of LandScan grid cell sizes: 1 km^2, as opposed to 100 m^2.

FIGURE 6. SMALLEST LIVELIHOOD ZONE POLYGON IN ETHIOPIA ANALYZED USING POPULATION EXPLORER



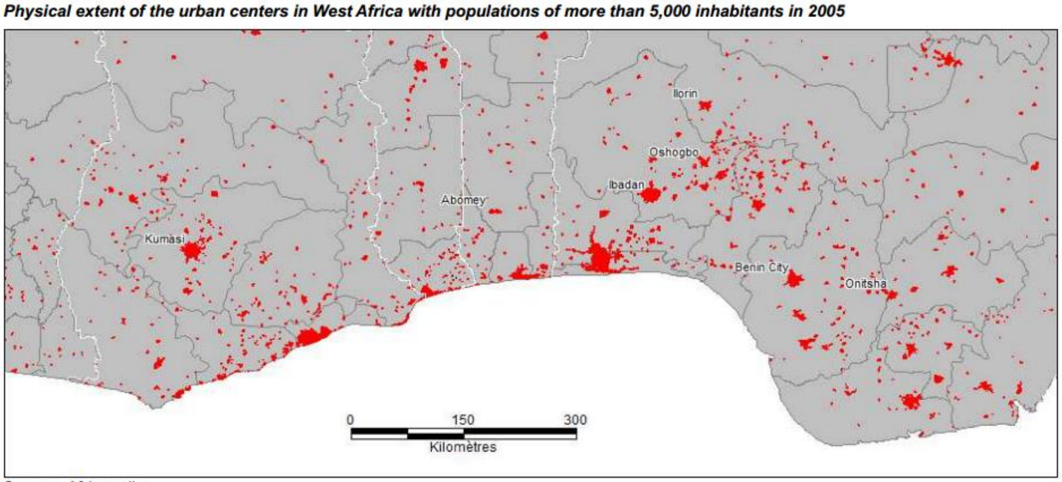
Noticeably missing from this and other reviews of spatial population data is the availability of historical datasets. LandScan refuses distribution of historical data and strongly advises against temporal analysis of their datasets, which have been distributed yearly for over a decade. Their concern is that the techniques that they have used to generate spatial population distributions over a grid have changed over time, and therefore render their data noncomparable. The benefits of historic population grids are numerous, but for food security analysis are twofold. First, historic datasets could be used to better estimate and forecast population change. Second, over thirty years of land cover data are enabling the study of historic drought conditions, and gridded historic population databases would enable these studies to include calculations on the impacts of drought and famine over time.

Another issue surrounding population data use in food security analysis is the source of the data. Both best available estimates, as well as official, state population estimates are desirable. AfriPop and AsiaPop use UN Estimates, except for Taiwan, where US Census estimates are used. LandScan used US Census population estimates, up until 2010. Techniques pioneered by the USAID FEWSNET project enable LandScan distributions to be appropriated for use with official population counts provided by individual state governments (Jordan et al., 2010). Specifically, official population data can be imputed across a LandScan probability grid, so that all the grid cells formally add up to official population statistics, instead of LandScan estimates. Theoretically, the same could be done for AfriPop and AsiaPop probability surfaces as well.

Last, researchers at the University of Paris, Diderot have developed an historic time series, spatial population dataset of urban areas, extending all the way back to 1900 (Moriconi-Ebrard et al., 2008). This project, called Geopolis, has its origins in enumerating urban population change in Africa, producing a database called Africapolis. Information about these databases can be found on various websites (Denis and Moriconi-Ebrard, 2009) and assorted publications (Potts, 2012), but the website (www.e-geopolis.eu) and complete dataset are not presently available. Figure 7 below illustrates a sample of Africapolis, as the dataset has appeared in publications (Moriconi-Ebrard et al, 2008).

FIGURE 7. EXAMPLE OF AFRICAPOLIS SETTLEMENT DATA, AS SHOWN IN PUBLICATIONS (SOURCE: MORICONI-EBRARD ET AL., 2008)

Physical extent of the urban centers in West Africa with populations of more than 5,000 inhabitants in 2005



Source: *Africapolis*

The most relevant datasets for food security analysis in Africa are outlined in Table 3. LandScan still offers the best, global, gridded population dataset. AfriPop offers 100 m gridded population data for Africa. Last, Africapolis, if developed and distributed, would provide a very helpful source of urban data, as well as temporal data.

TABLE 3. COMPARISON OF POPULATION DATASETS

Dataset:	LandScan	AfriPop	Africapolis
Website	http://www.ornl.gov/sci/landscan/	http://www.afripop.org/	http://www.afd.fr/lang/en/home/publications/travaux-de-recherche/archives-anciennes-collections/NotesetEtudes/Africapolis
Resolution, Unit of Analysis	1 km grid	Subnational, 1 km (alpha version) grid, 100 m (beta version)	Urban areas of 10,000 or more, Vector Polygons, Shapefiles
Scope	Global	Africa, Asia (AsiaPop, http://www.asiapop.org/)	Africa (16 countries, West Africa), India (Indiapolis), Europe (Europolis), Global (e-Geopolis)
Data Sources	US Census, International Programs	For age distribution, ratios: National censuses (~18 countries), census microdata (~7 countries), and household surveys (~16 countries), 1998-2013, year varies by country, (see link to image about midway down screen), surveys include the AIDS Indicator Survey, Demographic and Health Survey, Multiple Indicator Cluster Survey, Malaria Indicator Survey For total counts: United Nations Population Division, CIESIN	Administrative boundaries are obtained from national statistical offices, land cover imagery from Google Earth, USGS, or other other sources is used to classify the built environment. If over half of the administrative areas is classified as "built up," then the area is classified as urban. Population data from national statistical office are obtained for various years (see p. 29 of full report).
Methodology	Smart interpolation, or dasymetric mapping, based on land cover, roads, slope, urban areas, village locations, and satellite imagery.	Aerial weighting based on GlobeCover (land cover data) and settlement extents (from sources such as OpenStreetMap and GRUMP) are used to create a density surface, by which population totals may be allotted.	Agglomerations are identified as areas where features of the built environment are no more than 200 m apart (subtracting water surfaces, where they intersect agglomerations)
Attributes	Total population count, per grid cell, most recently for 2011	Total counts, children under 5, women of childbearing age (15-49), 5-year groupings for age	Urban population counts, 1900 to the present

		composition, by gender, population growth rates (forthcoming): 2000, 2005, 2010, and 2015	
Authors, Developers	Oak Ridge National Laboratory (ORNL), J. Dobson, B. Bhaduri	Andrew Tatem, University of Florida http://www.epi.ufl.edu/?q=node/178 Catherine Linard, Universite Libre de Bruxelles, Belgium	AFD, SEDET, CNRS Universite Paris Diderot, Catherine Chatel, Director, Eric Denis, and contact from OECD, Prof. Francois Moriconi-Ebrard, fme@noos.fr
Purpose	Global population grid	Malaria Atlas Project (Bill & Melinda Gates), Emerging Pathogens Institute, UF	Study temporal changes in urbanization
Endorsements	Oak Ridge National Laboratory (ORNL)	Global Land Project, Global Atlas of Helminth Infections, The Human Mobility Mapping Project	OECD
Selected Publications	(Bhaduri et al., 2002; Bhaduri et al., 2007; Dobson et al., 2000)	(Linard, Gilbert, & Tatem, 2011)	(Moriconi-Ebrard, 2008)

Extensions of Web Mapping Application

Historical, spatial population data is needed for understanding the extent of previous droughts (land cover data accumulated by USGS, NASA, USDA), in order to make forecasts of potential future impacts of droughts. However, reliable historical population grids are not yet available at a high resolution. The Integrated Public Use Microdata Series (IPUMS) offers international census data, including cross-sectional and time series datasets, as well as associated GIS files, though not in gridded formats. The US Census International Programs also has plans to release a global, geographic population dataset, at a variety of administrative levels (again, not gridded). Both of these databases provide the preliminary datasets needed to generate historic grids, and perhaps with their improved accessibility, creation of historic grids will follow. Another project under development by the Minnesota Population Center, called Terra Populus, claims that it will offer census data extraction services, from IPUMS, combined with global environmental data. While not available at present, future population datasets may be better equipped to help forecast drought and food insecurity.

The crux of existing web mapping applications that use population grids is to provide the best available population data, allowing users to define their own boundaries. However, it also makes sense to envision an extension of these applications that integrates ancillary non-population datasets. Table 4 roughly outlines a number of spatial databases that may be relevant to food security and population estimation. Noticeably not listed and less discussed is the issue of population migration and mobility. Migration has always been very difficult to estimate and infer, even in rich countries. A few newer attempts to understand mobility, using classified or private data, such as cell phone GPS data hint at the feasibility of understanding population movements, but are a very long way from becoming accessible and public use. Likewise, purchase and acquisition of high resolution satellite imagery offer the possibility of digitizing and tracking information on changing informal settlements and refugee camps, but these data are often difficult to come by and costly to process. It is unlikely that these forms of mobility information will be broadly incorporated into food security analysis in the very near future.

TABLE 4. POTENTIALLY USEFUL AUXILIARY DATASETS

Name	Website and Example
ACLED: Armed Conflict Location and Event Dataset	http://www.acleddata.com/ Data from 1997-2012 on conflict in developing countries. Real-time data is available on a few high-risk states in Africa.
EM-DAT: International Disaster Database	http://www.emdat.be/ Disaster event database, 1900 to the present.
Adaptation Aid, Malawi	http://www.strausscenter.org/aid.html Geocoding and climate coding active aid projects in Malawi, 1990-present.
SCAD, Social Conflict in Africa Database	http://www.strausscenter.org/scad.html Data from 1990-2001 on protests, riots, strikes, and other forms of social conflict in Africa.

In addition to the conflict, disaster, and aid datasets listed in Table 6, the USGS and the National Weather Service (NWS) routinely generate both gridded and vector data files that may be useful to integrate into web mapping applications. Populations affected by earthquakes or hurricanes could be identified quickly, using formal environmental or scientifically identified boundaries, to help populations in need. Data from the World Health Organization or the FAO could facilitate a better understanding of diseases in humans, plants, and wildlife that affect populations in developing countries.

Conclusion

In a world of GIS that is oftentimes split between amateurs (Google-users) and experts (ESRI-users), both platforms are needed. However, the more accessible the data to a wider user-population, the more useful it will be. Population Explorer is an example of a web-based GIS model that takes a complicated modeling and analytical toolkit and renders it available to a much wider and needier user-base. The work that goes on behind the scenes to make such web mapping applications more widely useable, in terms of datasets and queries, will help it to reach even more users.

An important caveat to acknowledge, regarding all population GIS tools and all spatial population databases, is that continued government-led, routine population censuses are crucial. The population grids that have been developed are absolutely not a replacement to censuses. On the contrary, to even create a high quality population grid requires carefully administered, updated, and distributed census data. Ideally, population grids would be accompanied with measures to indicate the error or fuzziness of the estimate, but this has often been disregarded, because of the complexities that it adds to the process, and for the simple fact that errors in the estimates for some countries and some locations are not even known. However, in the case of food security, what is often needed is a best guess, and at high-resolutions, population grids provide the answer.

There is widespread hope that new digital infrastructures to 'leapfrog' development will help the populations that need it the most.[6] In many ways, web mapping applications that access population grids provide one set of tools to facilitate this strategy. This paper has briefly reviewed the development and updating of web mapping applications for estimating population, surveyed existing and upcoming spatial population datasets that might fit best with these applications, and suggested extensions of existing toolkits into areas of conflict studies, public health, climate analysis, and foreign and domestic aid programs in developing countries. I conclude, optimistically, that the continued development of gridded population datasets, and expanded acquisition and distribution of georeferenced data position demographers and geographers nicely to expand their leadership in web-based, flexible population analysis.

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[6] Adam Rogers (2013). Life After Warfare: How a Digital Map Could Help Revive Mogadishu. Retrieved June 5, 2013, from http://www.wired.com/wiredscience/2013/06/fa_mogadishu/.

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