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MD EJSCREEN v2.0: Visualizing Overburdening of Environmental Justice Issues Using the Updated Maryland Environmental Justice Screening Tool

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ABSTRACT

Geographic information system tools analyze the environmental hazards and injustice throughout the United States. This article highlights the updated Maryland Environmental Justice Screening Tool (MD EJSCREEN v2.0), a state-specific resource for visualizing local environmental justice and health disparities in Maryland. Four new functions for screening and visualizing environmental justice indicators are described and demonstrated: the Select Feature and EJScreenChart, Side-by-Side Mapper, Report Tool, and Base Map Selector. The article identifies and compares census tracts in Maryland with highest and lowest Maryland Environmental Justice Scores (MD EJScores): Johnston Square, Baltimore, Maryland, and Churchville, Maryland, respectively. This article also characterizes the spread of MD EJScores across Maryland's 1384 census tracts. The case study results indicate that, while the median MD EJScore across the state is 0.30, several of Maryland's communities of color and low-wealth communities are disproportionately and highly impacted by high exposure to air pollution, close proximity to hazardous facilities, and high rates poor health outcomes—especially in the 90th percentile of MD EJScores, which can be as much as three times the statewide median. The tool can be used by local policymakers, regulators, and community leaders in a decision-support capacity to inform strategies for reducing environmental injustice.

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PURPOSE OF THE TOOL

Background on environmental justice mapping

GIVEN THE INHERENT SPATIAL CONTEXT of all environmental justice issues, geographic information system (GIS) applications are invaluable for visualizing and analyzing physical distribution trends relevant to environmental hazards and health disparities.[1] These ''EJ mappers'' allow users to overlay environmental justice indicators of interest, such as locations of emission sources and vulnerable populations, to determine potential drivers of poor health outcomes and resultant impacts. This layering or ''screening'' is particularly advantageous for tracking cumulative impacts as virtually all environmental justice communities are burdened by more than one environmental hazard source.[2]

For community members, mapping and screening tools provide access to spatial data in an easily digestible format, allowing users to become better informed on environmental risks specific to their region, state, county, zip code, census tract, or even census block group.[3] Public participation GIS (PPGIS) further enhances this goal by building community context directly into mapping tools, melding quantitative geospatial data with qualitative lived experiences.[4,5,6,7] PPGIS approaches can be top-down, where software architects gather sociodemographic data to develop tools that are tailored to the needs and concerns of local residents, or bottom-up, where community members are directly engaged and trained in the development and testing of these tools to ensure that their needs (including ease of use and understanding) are satisfied.[8,9] Story mapping and community asset mapping are classic examples of bottom-up PPGIS.[10,11,12]

Importance of state-level environmental justice mapping tools

The United States Environmental Protection Agency's Environmental Justice Screening Tool (U.S. EPA EJSCREEN) serves as the national archetype for environmental justice PPGIS tools. Publicly released in 2015 and updated annually, the EJSCREEN tool is a direct answer to Executive Order 12898, which mandates that federal agencies ''collect, maintain, and analyze information assessing and comparing environmental and human health risks borne by populations identified by race, national origin, or income.''[13] The tool informs the EPA outreach and engagement initiatives as well as its implementation of permitting, enforcement, and compliance monitoring.[14]

Despite the breadth of data and subsequent use cases afforded by the U.S. EPA EJSCREEN, it is not an adequate replacement for a contextualized and nuanced tool

[1]Gary Higgs and Mitch Langford. ''GIScience, Environmental Justice, & Estimating Populations at Risk: The Case of Landfills in Wales.'' *Applied Geography* 29 (2009): 63–76.

[2]Charles Lee. ''A Game Changer in the Making? Lessons from States Advancing Environmental Justice through Mapping and Cumulative Impact Strategies.'' *Environmental Law Reporter* 50 (2020): 10203–10215.

[3]Michael Keith McCall. *Participatory Mapping and Participatory GIS (PGIS) for CRA, Community DRR and Hazard Assessment*. (ProVention Consortium, CRA Toolkit, Participation Resources, 2008).

[4]Aubree Driver, Crystal Mehdizadeh, Samuel Bara-Garcia, Coline Bodenreider, Jessica Lewis, and Sacoby Wilson. ''Utilization of the Maryland Environmental Justice Screening Tool: A Bladensburg, Maryland Case Study.'' *International Journal of Environmental Research and Public Health* 16 (2019): 348.

[5]Paul Juarez, Patricia Matthews-Juarez, Darryl Hood, Wansoo Im, Robert Levine, Barbara Kilbourne, Michael Langston, Mohammad Z. Al-Hamdan, William L. Crosson, Maurice G. Estes, Sue M. Estes, Vincent K. Agboto, Paul Robinson, Sacoby Wilson, and Maureen Y. Lichtveld. ''The Public Health Exposome: A Population-Based, Exposure Science Approach to Health Disparities Research.'' *International Journal of Environmental Research and Public Health* 11 (2014): 12866–12895.

[6]Sacoby M. Wilson, Rianna T. Murray, Chengsheng Jiang, Laura Dalemarre, Kristen Burwell Nanny, and Herb Fraser-Rahim. ''Environmental Justice Radar: A Tool for Community Based Mapping to Increase Environmental Awareness and Participatory Decision Making.'' *Progress in Community Health Partnerships: Research, Education, and Action* 9 (2015): 439–446.

[7]Sacoby Wilson, Aaron Aber, Lindsey Wright, and Vivek Ravichandran. ''A Review of Community-Engaged Research Approaches Used to Achieve Environmental Justice and Eliminate Disparities.'' In: Ryan Holifield, Jayajit Chakraborty, and Gordon Walker (eds). *The Routledge Handbook of Environmental Justice*, 1st ed. (Routledge), 283–296.

[8]Sarah Elwood. ''Critical Issues in Participatory GIS: Deconstructions, Reconstructions, and New Research Directions.'' *Transactions in GIS* 10 (2006): 693–708.

[9]Renee Sieber. ''Public Participation Geographic Information Systems: A Literature Review and Framework.'' *Annals of the Association of American Geographers* 96 (2006): 491–507.

[10]Elizabeth Hulen, Lisa J. Hardy, Nicolette Teufel-Shone, Priscilla R. Sanderson, Anna L. Schwartz, and R. Cruz Begay. ''Community Based Participatory Research (CBPR): A Dynamic Process of Health Care, Provider Perceptions and American Indian Patients' Resilience.'' *Journal of Health Care for the Poor and Underserved* 30 (2019): 221.

[11]Tuan Nguyen, Savannah Edwards, Nick J. Rahall, Marcia Scott, and Jeff Cragle. *GIS Story Maps: A Tool to Empower and Engage Stakeholders in Planning Sustainable Places*. (University of Delaware, 2016).

[12]Daniel Z. Sui. *Alternative GIS (alt. gis) and the Six Senses of the New Mind: Is alt. gis Transforming GIS into a Liberation Technology?* (Springer International Publishing, 2015), 1–11.

[13]USEPA. ''How Does EPA Use EJSCREEN?'' 2016. <https://www.epa.gov/ejscreen/how-does-epa-use-ejscreen>. (Last accessed on June 10, 2022).

[14]Ibid. Wilson *et al.* (2015).

that highlights environmental hazards and socio-demographics at the state level.[15] This is due, in large part, to the fact that the EPA only includes environmental and demographic indicator data from nationally standardized data sets (e.g., U.S. Census Bureau, EPA National Air Toxics Assessment, EPA Comprehensive Environmental Response, Compensation, and Liability Information System, EPA Resource Conservation and Recovery Act, and other federally managed databases).[16] This is sensible on the part of the Agency because there are countless environmental justice issues existing in unique locations and including all of them could require immense server capacity and negatively impact the tool's ease of use and function.

However, this means that, for example, agricultural feeding operation and park location data from a state's department of natural resources or neighborhood asthma rates from a local county health department, while quality assured and validated at these local government-managed scales, cannot be natively included in EPA EJSCREEN. Given the inherently small scale at which environmental injustice and overburdening occurs, state-level mapping and screening tools are necessary and better-suited for identifying areas of environmental justice concern.

The Maryland Environmental Justice Screening Tool

The Maryland Environmental Justice Screening Tool (MD EJSCREEN) is a state-level mapping tool attuned to Maryland's environmental justice context and concerns (Fig. 1). MD EJSCREEN was built based on feedback from community members and stakeholders to create a resource for identifying social, economic, health, and environmental disparities; particularly between racial/ethnic groups. Indicators included in MD EJSCREEN v1.0 were decided upon through public community-engaged discussions, community member surveys, in-person focus groups, and other community-based participatory research practices.[17] The tool enables users to interact with map layers that display an array of pollution burden indicators and population characteristics. Environmental Justice Indicators are divided into two categories (Pollution Burden and Population Characteristics) and four domains: (1) Exposure, (2) Environmental Effects, (3) Sensitive Populations, and (4) Socioeconomic Factors.[18] Data sources and descriptions for these indicators have been published previously.[19]

A composite Maryland Environmental Justice Score (MD EJScore) allows for a ranking of census tracts based on their relative level of environmental justice concern (Fig. 2). Higher MD EJScores represent more overburdening of exposure, environmental effect, health outcome, and structural socioeconomic disadvantages—that is, less overall environmental justice and higher priority for corrective policy or regulatory action. The national-scale EPA EJSCREEN tool, by contrast, does not have a scoring component. Additionally, MD EJSCREEN includes Maryland-specific ''Context Layers,'' providing visualization of railroads, infrastructure, food access, housing value estimates, and more. This marks an improvement when comparing MD EJSCREEN with EPA EJSCREEN as many of these locally focused data sets are not available at the national scale and, therefore, are not included in the national tool.[20]

This article discusses the latest improvements included in the tool's newest version—MD EJSCREEN v2.0. Four new features for visualizing and screening environmental justice (the Select and EJSCREEN Chart tool, Side-by-Side Map Viewer, Report Generator, and Base Map Gallery) are showcased and demonstrated. Furthermore, a case study analyzing the overall extent of environmental justice throughout Maryland (given by the MD EJScore) in addition to a specific highlight on highest and lowest scoring census tracts in Maryland illustrates the tools functionality to users across fields—from community members to policymakers to government officials. Archived versions of MD EJSCREEN v1.0 are available online for comparison to the newest version.[21,22]

RATIONALE FOR DEVELOPING MD EJSCREEN v2.0

MD EJSCREEN v1.0 was presented publicly before various stakeholder groups including the Prince George's County Planning Board as part of the 2018 Speaker Series[23] and a mixed audience of community members, researchers, and policymakers at the fourth and fifth University of Maryland Symposia on Environmental Justice and Health Disparities in 2018 and 2019, respectively. Feedback from these public demonstrations identified priority improvements to MD EJSCREEN v1.0 (Box 1).

[15]Rachel Morello-Frosch, Manuel Pastor, and James Sadd. ''Environmental Justice and Southern California's 'Riskscape': The Distribution of Air Toxics Exposures and Health Risks among Diverse Communities.'' *Urban Affairs Review* 36 (2001): 551–578.

[16]United States Environmental Protection Agency. ''Limitations and Caveats Using EJSCREEEN.'' <https://www.epa.gov/ejscreen/limitations-and-caveats-using-ejscreen>. (Last accessed on May 3, 2021).

[17]Ibid. Driver *et al*. (2019).

[18]Ibid.

[19]Ibid.

[20]Ibid.

[21]National Center for Smart Growth. ''Prince George's EJ Screen Mapping.'' ArcGIS Web Application. <https://uofmd.maps.arcgis.com/apps/webappviewer/index.html?id=63dcbfb775d44aa594a17f5ffa257caa>. (Last accessed on April 26, 2021).

[22]National Center for Smart Growth. ''Baltimore EJ Screen.'' <https://uofmd.maps.arcgis.com/apps/webappviewer/index.html?id=69a3b4817a2a472883dd78ceebf0f912>. (Last accessed on April 26, 2021).

[23]''Environmental Justice and Health Equity in Prince George's County'' Prince George's County, MD Planning Department, August 27, 2018. Video, 1:36:41. <https://www.youtube.com/watch?v=r2URRHx5I3E>. (Last accessed on June 10, 2022).

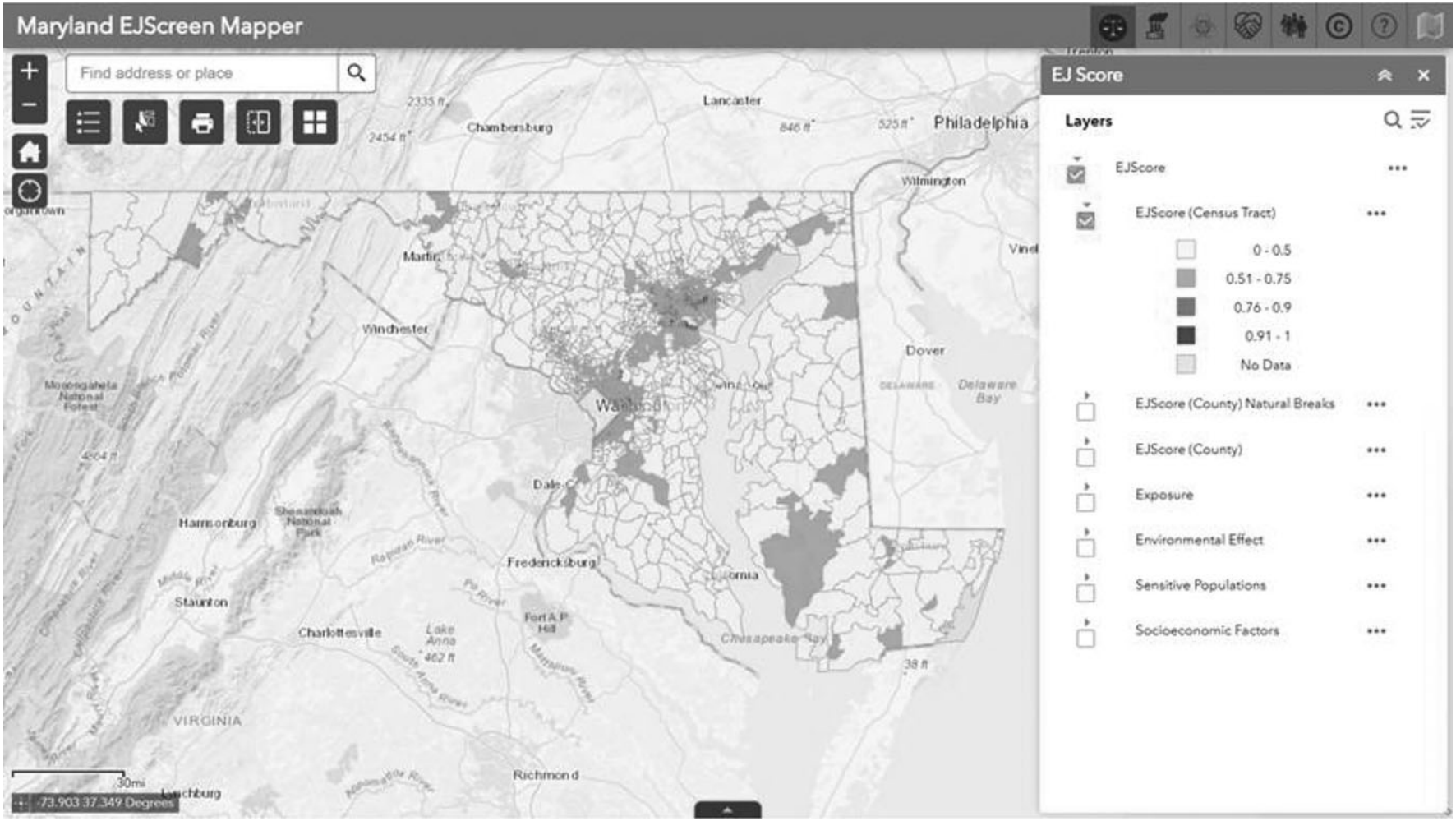

FIG. 1. MD EJSCREEN v2.0 Home View. The Home View of the tool displays all 1394 census tracts in the state of Maryland. The tool's default layer is the MD EJScore—a composite of the scores from each of the following domain scores: Exposure, Environmental Effects, Sensitive Populations, and Socioeconomic Factors. MD EJScore, Maryland Environmental Justice Score; MD EJSCREEN, Maryland Environmental Justice Screening Tool.

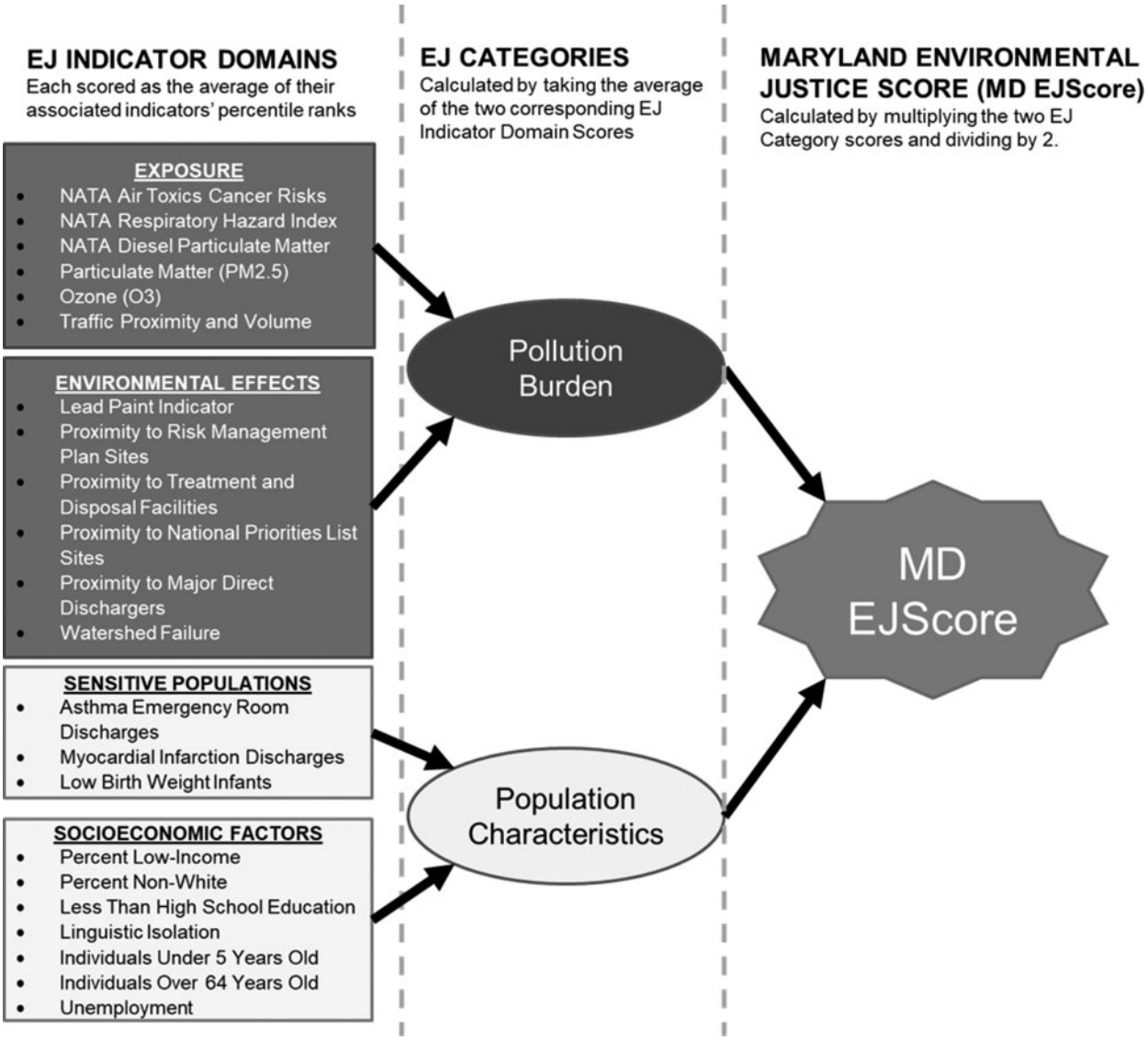

FIG. 2. Scoring Methodology for MD EJSCREEN. Each census tract in Maryland is assigned a percentile rank across 22 environmental justice indicators, each belonging to one of four Environmental Justice Indicator Domains. The score for the domain is calculated as the average of their representative indicators. Domains are sorted into either of two categories. The Exposure and Environmental Effects domains are then assigned to the Pollution Burden Category, whereas the Sensitive Populations and Socioeconomic Factors domains are assigned to the Population Characteristics Category. Category scores are calculated as the average of their two representative domain scores. Finally, the overall MD EJScore is calculated by multiplying the Pollution Burden and Population Characteristics scores and dividing the product by 2.

Box 1. Community Stakeholder Suggestions for Improving Maryland Environmental Justice Screening Tool Version 1.0

- Reduce loading time upon opening
- Resolve lagging issues during use
- Include data from areas beyond Prince George's County and Baltimore City
- Add ability to save and print a report from the mapping session
- Add ability to draw a buffer (as in U.S. EPA EJSCREEN) around a point of interest
- Add ability to view layers side-by-side (as in U.S. EPA EJSCREEN)

PROCESSES USED TO UPDATE MD EJSCREEN

New data layers in v2.0

The data sources of each environmental justice indicator and scoring methodology for MD EJSCREEN v1.0 have been published previously and remain unchanged in MD EJSCREEN v2.0.[24] To address user feedback on the tool's loading speed and performance, the tool was migrated from the ESRI, Inc. ArcGIS® Online cloud server

[24]Ibid. Driver *et al.* (2019).

Table 1. Additional Context Layers Available in MD EJSCREEN Versions 1.0 and 2.0

Additional Context Category	*Additional Context Layer*	*Description*	*Source*	*Available in MD EJSCREEN v1.0*	*Available in MD EJSCREEN v2.0*
Other	MD COVID-19 Cases (10/16/20)	Total cases of COVID-19 in Maryland reported by zip code and apportioned to census tracts using population-weighted averages.	Maryland Department of Health (2020). *MDCOVID19 MASTER ZIP CODE CASES*. Retrieved 10/16/2020 from https://coronavirus.maryland.gov/datasets/mdcovid19-master-zip-code-cases		X
Segregation	Gini Index	The Gini coefficient ranges from perfect equality (Score = 0, all households in a census tract receive equal income) to perfect inequality (Score = 1, one household in a census tract receives all income).	U.S. Census Bureau (2019). *Gini Index of Income Inequality (TableID: B19081), Census Tract, American Community Survey 5-year estimate*. Retrieved from https://data.census.gov/cedsci/table?q=ACSDT1Y2019.B19083&tid=ACSDT1Y2019.B19083		X
Boundaries	Zip Codes Boundary	Outlines zip code boundaries for the state of Maryland.	Maryland Geographic Information Office (2020). *Maryland Political Boundaries - ZIP Codes - 5 Digit*. Retrieved from https://data.imap.maryland.gov/datasets/maryland-political-boundaries-zip-codes-5-digit		X
	Municipal Boundaries	Outlines incorporated municipal boundaries in Maryland.	Maryland Geographic Information Office (2020). *Maryland Political Boundaries – Municipal Boundaries*. Retrieved from https://data.imap.maryland.gov/datasets/bd486d7feeec443c89a822dde5b86a1e_2		X
	County Boundaries	Outlines county boundaries in Maryland.	Maryland Geographic Information Office (2020). *Maryland Political Boundaries – County Boundaries*. Retrieved from https://data.imap.maryland.gov/datasets/maryland-physical-boundaries-county-boundaries-detailed	X	X
	Legislative Districts	Outlines Maryland State Legislative Districts as adopted on February 24, 2012.	Maryland Department of Planning (2021). *Maryland Election Boundaries – Maryland Legislative Districts 2012*. Retrieved from https://mdpgis.mdp.state.md.us/Legis_District/index.html	X	X
Food Access	Super-markets	Locations of large format grocery stores that typically (a) sell produce, meat, seafood, canned goods, and packaged goods, (b) have at least $2M in annual food sales, and (c) have three or more cash registers.	John Hopkins University Center for a Livable Future (2019). *Maryland Food Stores 2017 – 2018*. Retrieved from https://gis.mdfoodsystemmap.org/server/rest/services/FoodMapMD/MD_Food_Map_Services/MapServer/218	X	X
	Small Grocery & Corner Stores	Locations of small format grocery stores and corner stores. Small grocery stores typically (a) are independently owned and operated, (b) have less than $2M in annual sales, (c) have limited to no food departments, and (d) primarily sell groceries. Corner stores are typically small, located on street corners and primarily sell snacks over groceries.	John Hopkins University Center for a Livable Future (2019). *Maryland Food Stores 2017 – 2018*. Retrieved from https://gis.mdfoodsystemmap.org/server/rest/services/FoodMapMD/MD_Food_Map_Services/MapServer/218		X
Education	Public Schools	Maryland's K - 12 public school system ranks first overall based on the latest data in six graded categories. Maryland ranks second in the achievement category and third in teaching as well as transitions and alignment.	Maryland State Department of Education (2018). *Maryland Education Facilities - K thru 12 Education (Public Schools)*. Retrieved from https://data.imap.maryland.gov/datasets/f49c4bb1a9a74029ae974e6d6fd08b71_5	X	X

(*continued*)

Table 1. (Continued)

Additional Context Category	*Additional Context Layer*	*Description*	*Source*	*Available in MD EJSCREEN v1.0*	*Available in MD EJSCREEN v2.0*
Green Space	Parks	Locations of parks and protected lands managed by Maryland state agencies.	Maryland Department of Natural Resources (2016). *Park Locations.* Retrieved from https://gisapps.dnr.state.md.us/arcgis2/rest/services/Society/ParkLocations/MapServer		X
	Urban Heat Island	This 30-meter raster image layer contains the relative heat severity for every pixel for every city in the United States. The layer was derived from Landsat 8 imagery band 10 (ground-level thermal sensor) from the summers of 2018 and 2019.	Trust for Public Land (2019). *Urban Heat Islands for U.S. Cities*. Retrieved from https://chesbay.maps.arcgis.com/home/item.html?id=4f6d72903c9741a6a6ee6349f5393572		X
Transit	Public Transit Stops	MDOT Maryland Transit Administration Bus Stops including CityLink, LocalLink, and Commuter Bus services.	Maryland Department of Transportation (2019). *MTA Bus Stops*. Retrieved from https://geodata.md.gov/imap/rest/services/Transportation/MD_Transit/FeatureServer/9		X
Industrial Pollution Sources	Combined Sewer Outfalls	Point location of regulated facility outfalls releasing to surface waterbodies	Maryland Department of Environment (2019). *Maryland Point Source Discharges – Point Source Discharges.* Retrieved from https://data.imap.maryland.gov/datasets/a4153ffcad5843b4ac8262d2ac010882_1		X
	Waste-water Treatment Plants	Point locations of significant wastewater treatment plants in Maryland	Maryland Department of the Environment (2019). *Maryland Point Source Discharges – Significant Wastewater Treatment Plants.* Retrieved from https://data.imap.maryland.gov/datasets/maryland-point-source-discharges-significant-wastewater-treatment-plants?geometry=-79.308%2C38.100%2C-75.188%2C39.597		X
	Solid Waste Landfill Facilities	Point locations of permitted solid waste landfill facilities in Maryland	Maryland Department of the Environment Solid Waste Program (2020). *Permitted Solid Waste Acceptance Facilities.* Retrieved from https://mde.maryland.gov/programs/LAND/SolidWaste/Documents/Permitted_Solid_Waste_Facilities.pdf		X
	Toxic Release Inventory (TRI) Facilities	Point locations of industrial and federal facilities reporting to the US EPA Toxics Release Inventory (TRI) Program (n = 453 facilities)	US Environmental Protection Agency (2020). 2019 Maryland TRI Basic Data File. Retrieved from https://www.epa.gov/toxics-release-inventory-tri-program/tri-basic-data-files-calendar-years-1987-2019?		X
	Power Plants	Point locations of petroleum-, natural gas-, and coal-fired power plants in addition to nuclear- and renewable-based facilities.	Maryland Department of Natural Resources Power Plant Research Program (2020). *Power Plant Locations In and Around Maryland.* Retrieved from https://dnr.maryland.gov/pprp/Pages/PowerPlant-Locations.aspx		X
	EPA Superfund Sites	Point locations of EPA-designated Superfund sites on the National Priorities List.	US Environmental Protection Agency (2020). *List of Superfund Sites in Maryland.* Retrieved from https://www.epa.gov/md/list-superfund-sites-maryland	X	X

(*continued*)

Table 1. (Continued)

Additional Context Category	*Additional Context Layer*	*Description*	*Source*	*Available in MD EJSCREEN v1.0*	*Available in MD EJSCREEN v2.0*
	Meat Packing Plants	Point locations of livestock processing facilities in Maryland	US Department of Agriculture Food Safety Inspection Service (2018). Meat, Poultry, and Egg Inspection Directory. Retrieved from https://planning.maryland.gov/Documents/YourPart/773/Livestock-Processing-Facilities-brochure.pdf		X
	Concentrated Animal Feeding Operations	Point locations of feedlots or facilities where (a) non-aquatic animals are confined, fed, and maintained for at least 45 days in any 12-month period; and (b) crops, vegetation, forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility	Maryland Department of the Environment (2020). AFO Public Participation Process Application Portal. Retrieved from https://mdedataviewer.mde.state.md.us/Public/Land/CAFO/Public%20Search%20Tool	X	X
Healthcare Infra-structure	Health Profess-ional Shortage Areas (HPSA)	Areas experiencing shortages of primary care health providers in Maryland.	Health Resources & Services Administration (2020). *HPSA – Primary Care: Area HPSA Component Boundaries.* Retrieved from https://data.hrsa.gov/data/download		X
Socio-economics	200% Federal Poverty Level	Census tracts (using Census 2010 boundaries) that have a median household income less than or equal to $51,400, which is roughly 200% of the 2018 Federal Poverty Level for a family of four.	United States Census Bureau (2020). *American Community Survey 2014 – 2018 5-year estimates.* Retrieved from https://data-clf.hub.arcgis.com/datasets/16cf6aa531bf46f79384da68b56b7175_457	X	X
	USDA Low Income and Low Food Access	The Food Access Research Atlas defines this measure as being a low-income census tract with at least 500 people or 33 percent of the population living more than ½ mile (urban areas) or more than 10 miles (rural areas) from the nearest supermarket	US Department of Agriculture (2019). *2013 USDA Low Income and Low Access.* Retrieved from https://hub.arcgis.com/datasets/07bc8c4c961443a398ec5ffed9f1f65f_128	X	X

EPA, Environmental Protection Agency; HPSA, Health Professional Shortage Areas; MD EJSCREEN, Maryland Environmental Justice Screening Tool; MDOT, Maryland Department of Transportation; TRI, Toxic Release Inventory; USDA, U.S. Department of Agriculture.

to a local on-site server at the University of Maryland Center for Geospatial Information Science. This greatly improved the responsiveness of MD EJSCREEN v2.0 with load-times reduced from >10 to <3 seconds. To expand the tool's spatial extent to encompass all of Maryland, shapefiles for each census tract in the state were downloaded from the U.S. EPA EJSCREEN resource page (https://gaftp.epa.gov/EJSCREEN/2019/) and added to the web GIS platform for MD EJSCREEN v2.0.

Additional context layers were gathered from various national- and state-level agency and institutional data sources including the Maryland Health Department, Maryland Department of Planning, Johns Hopkins University, and more (Table 1). All shapefile and database data underlying MD EJSCREEN v2.0 is open source and publicly available via our GitHub© repository.[25] Additionally, a tutorial for using the tool is now available at the MD EJSCREEN v2.0 website.[26]

USES FOR MD EJSCREEN

The latest version of MD EJSCREEN includes four new function tools: the Selection and MD EJSCREEN Chart, Side-by-Side Map Viewer, Report Generator, and Base Map Gallery. These four functions represent a marked improvement in how MD EJSCREEN data can be visualized and translated into useful and meaningful formats for users. The following sections and figures illustrate how these tools can be used to identify an array of environmental justice concerns in Johnston Square, Baltimore, Maryland, and Churchville, Maryland—the highest scoring (least environmentally just) and lowest scoring (most environmentally just) census tracts in the state, respectively (Fig. 3).

Select Function and MD EJSCREEN Chart

Selecting census tracts of interest is not a new feature in MD EJSCREEN v2.0, however, while selecting a census tract in the previous version of the tool only revealed a text box with the associated data, MD EJSCREEN v2.0 shows a series of bar charts that compare the selected tract's indicator domain score data to the median scores for the corresponding county and the rest of the state (Fig. 4). There is also a newly added function that allows users to select multiple census tracts at a time. This update adds to the tool's utility in identifying environmental justice concerns at scales relevant to communities and larger organizations because, while census tracts are more spatially specific than counties or zip codes, their population-based determination can limit their size to be smaller than a full neighborhood.

For example, Census Tract 24025303102, which represents northern Churchville and has a population of 2814, encompasses an area of 8.07 square miles. However, Census Tract 24510100100, representing central Johnston Square's population of 2233 people, has a square area of only 0.18 miles. In Baltimore's densely populated urban core, an 8 square mile circle with Johnston Square at its center would include 58 census tracts (Fig. 5).

Report Generator

The Report Generator function outputs a downloadable PDF with data on the selected census tract(s). In addition to providing a map and scale bar, the report also includes the bar chart or box plot shown in the main tool, as well as descriptive statistics values for the selected census tracts. These reports can be used as supplemental documentation to accompany grant submissions, legal and policy reports, white papers, and more. A sample report generated from the Johnston Square area selection in Figure 5 is included as a supplemental attachment to this article (Supplementary Appendix SA1).

Side-by-Side Mapping

See Figure 6.

Base Map Gallery

See Figure 7.

RELEVANT RESEARCH FINDINGS: MARYLAND'S CENSUS TRACTS WITH THE FEWEST AND MOST ENVIRONMENTAL ISSUES

As noted in the introduction, a higher MD EJScore indicates more environmental justice issues or concerns in a given census tract (i.e., census tracts with the highest scores can be considered to be the least environmentally just). Across Maryland's 1384 census tracts, MD EJScores range from 0.09 (most environmentally just) to 0.96 (least environmentally just) (Table 2). The mean and median MD EJScores for the state are relatively low—0.34 and 0.30, respectively. Examining the spread of the data, with particular attention paid to the 90th percentile and higher, reveals an exponential growth trend where the highest scores are nearly three times the median value (Fig. 8). On the opposite end of the spectrum, the lowest MD EJScore (0.09) is nearly three times less than the median for the state.

LIMITATIONS, LESSONS LEARNED, AND BEST PRACTICES

Even with the improvements implemented in MD EJSCREEN v2.0, limitations remain. In public health research, census tracts are used as proxies for neighborhoods, an approach that respects residents' rights to anonymity when investigating environmental concerns and

[25]University of Maryland-College Park Center for Geospatial Information Science. 2021. ''gisumd/EJScreen.'' GitHub© Repository. <https://github.com/gisumd/EJScreen/>. (Last accessed on June 10, 2022).

[26]University of Maryland-College Park Center for Geospatial Information Science. Maryland Environmental Justice Screening Tool (MD EJSCREEN). 2021. <https://p1.cgis.umd.edu/mdejscreen/>. (Last accessed on June 10, 2022).

FIG. 3. Highest and Lowest Environmental Justice Scoring Census Tracts in Maryland. This screen capture of the MD EJSCREEN highlights Johnston Square (bottom left) and Churchville (top right)—the highest and lowest scoring census tracts in Maryland, respectively. These two census tracts at opposite ends of the scoring distribution are ~30 miles away from each other.

health impacts. However, for some environmental justice issues such as green space, stormwater infrastructure, and pedestrian-friendliness (e.g., quality and availability of sidewalks, biking trails, walking trails), it is better to assess disparities at a lower unit of analysis. Therefore, future iterations of this tool will seek to include data at the census block group unit of analysis. Note that transforming data to model more spatial granularity can have its own challenges for data reliability and accuracy.[27]

Currently, MD EJSCREEN shows bias toward environmental justice issues in urban counties rather than rural counties. This mainly due to the Pollution Burden: Exposure domain environmental indicators relying heavily on federally managed air pollution data. In fulfilling its mandate under the Clean Air Act, the U.S. EPA (and state agency proxies) monitors concentrations of criteria air pollutants in densely populated high traffic areas.[28] This approach can create regulatory gaps and misclassified air pollution exposure—especially in rural areas.[29] Secondarily, there are a number of environmental hazards located in Western Maryland, Southern Maryland, and the Eastern Shore that are not included in the tool as environmental indicators.

For instance, in Western Maryland, an area with traditional oil and gas extraction, oil and gas wells[30] are not

[27]Seth E. Spielman, David Folch, and Nicholas Nagle. ''Patterns and Causes of Uncertainty in the American Community Survey.'' *Applied Geography* 46 (2014): 147–157.

[28]Matthew Potoski and Neal D. Woods. ''Dimensions of State Environmental Policies: Air Pollution Regulation in the United States.'' *Policy Studies Journal* 30 (2002): 208–226.

[29]Daniel M. Sullivan and Alan Krupnick. ''Using Satellite Data to Fill the Gaps in the US Air Pollution Monitoring Network.'' *Resources for the Future Working Paper* (2018): 18–21. <https://media.rff.org/documents/RFF20WP-18-21_0.pdf>. (Last accessed on June 10, 2022).

[30]Thurka Sangaramoorthy and Emilia M. Guevara. ''Immigrant Health in Rural Maryland: A Qualitative Study of Major Barriers to Health Care Access.'' *Journal of Immigrant and Minority Health* 19 (2017): 939–946.

FIG. 4. Select Function and MD EJSCREEN Chart. As in previous versions of the tool, users can click on any single census tract on the map to display a pop-up window (right) that provides scores for each of the four MD EJSCREEN indicator domains (Pollution Burden, Environmental Effects, Sensitive Populations, and Socioeconomic Factors). In the latest version, users can view this information as an automatically generated bar chart, comparing the selected tract to average scores for the tract's county as well as the state. Here, we see that Churchville, Maryland's MD EJScore (0.09) is far lower than the Harford County and Maryland medians. In fact, Churchville has low scores for each of the four environmental justice indicator domains, indication low pollution burden; low proximity to hazardous facilities; low prevalence of asthma, heart attacks, and low birth weight infants; and low proportions of socioeconomic disadvantage.

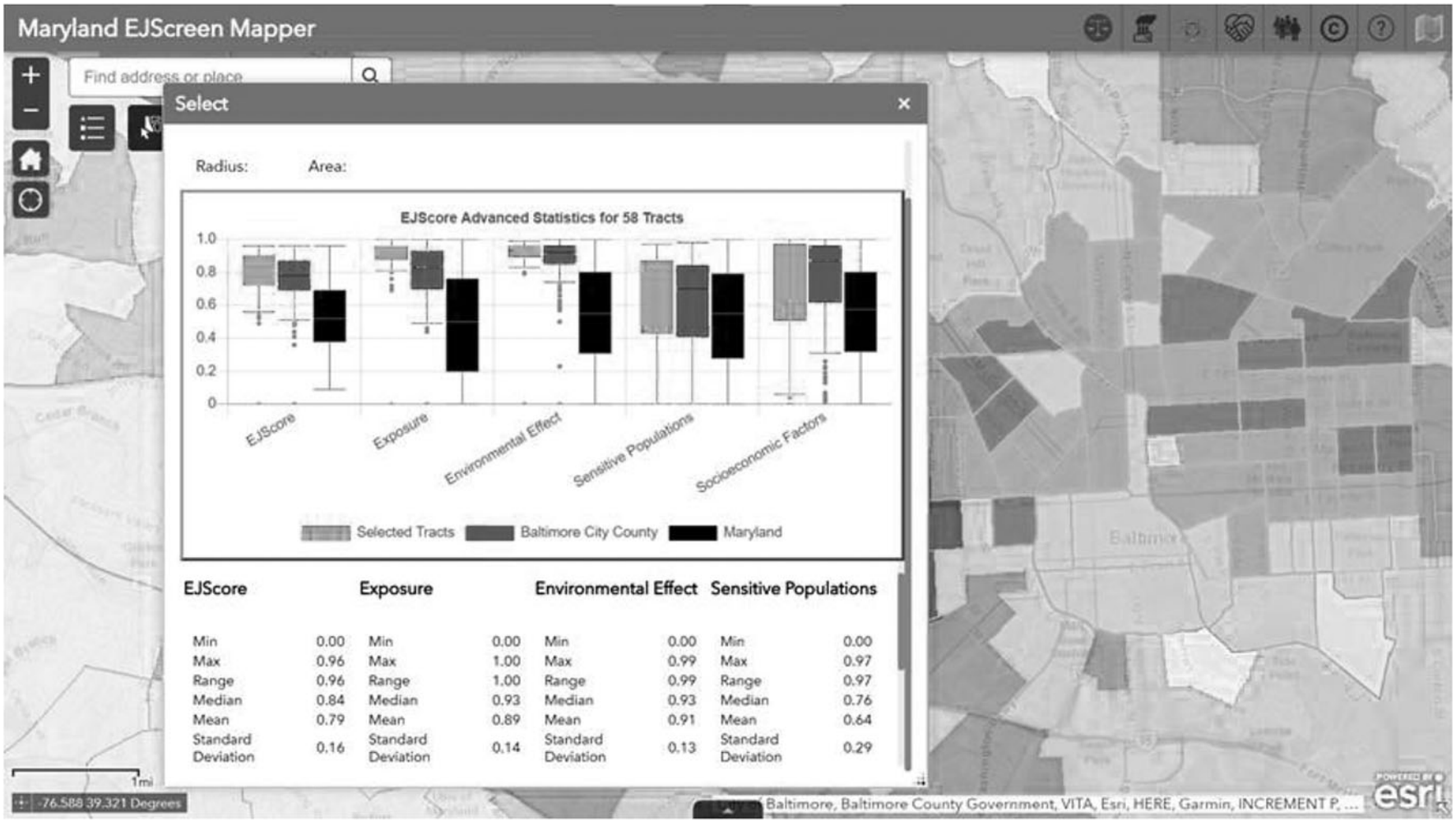

FIG. 5. Selecting Multiple Tracts and Box Plot Data Visualization. Unlike the previous version, MD EJSCREEN allows users to select multiple tracts. When users draw a circle around the area of interest, the selection snaps to the census tract boundaries of the selected area (highlighted in purple above). The 58 census tracts selected here in Baltimore, Maryland, encompass approximately the same eight square mile area as the single census tract for Churchville, Maryland. Users can choose to view the data for the selected tracts as a box and whisker plot. By doing so, users can compare the spread of the data for the selected area to the spread of the same indicator data in the county and state. Note that the median for the 58 selected census tracts in Baltimore is higher than the medians for Baltimore City County and the state of Maryland.

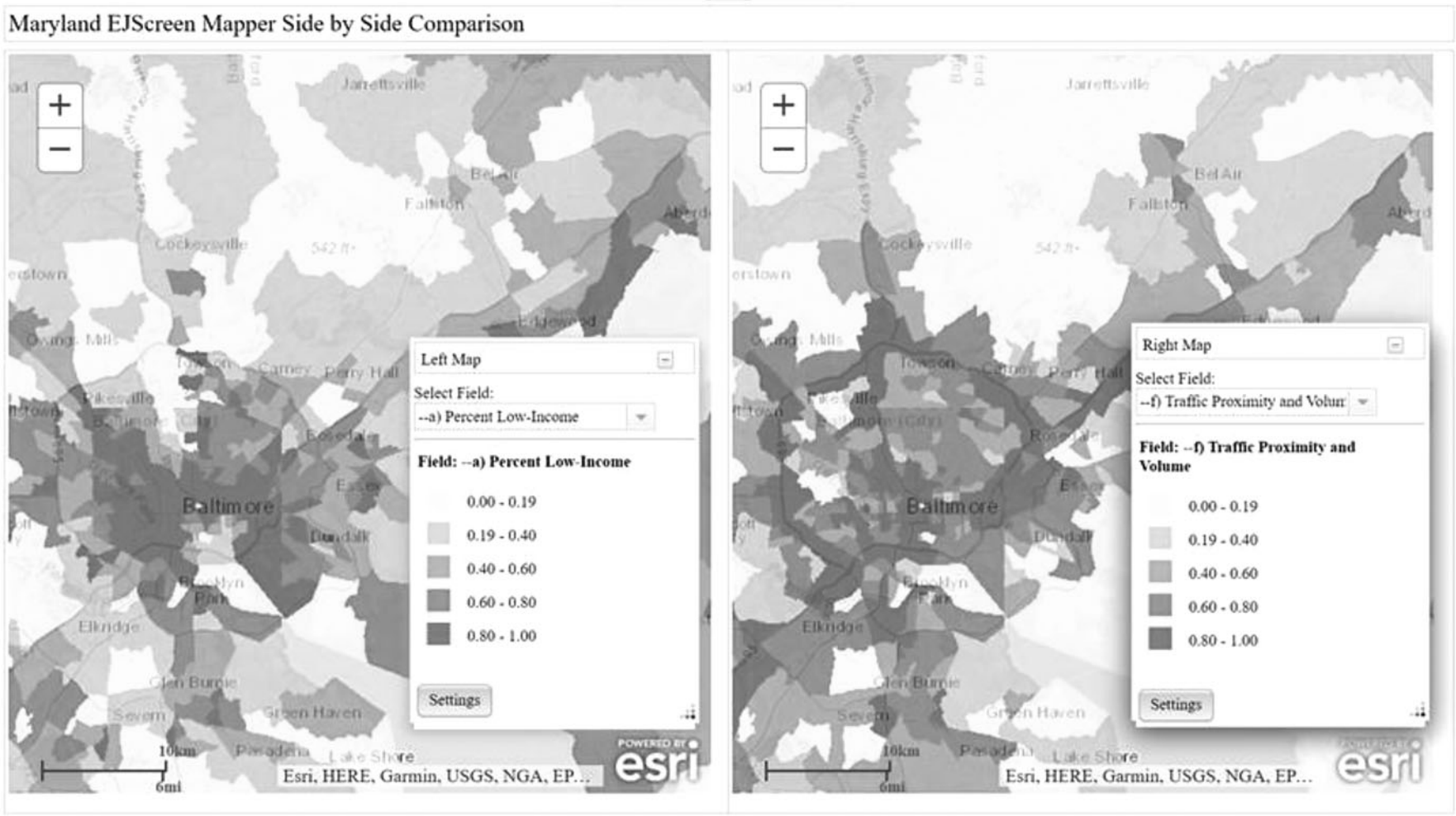

FIG. 6. Side-by-Side Map Viewer. This function tool provides users with another way of visualizing overlapping features in MD EJSCREEN v2.0. Users can compare any of the indicators from the four scored domains to each other. This tool is useful in identifying overlapping burdens and disparities in Maryland communities. Above, Percent Low-Income (Socioeconomic Factors domain) and Traffic Proximity and Volume (Pollution Exposure domain) are shown side-by-side, revealing that the central census tract in Johnston Square, Baltimore, Maryland (bottom-left), is in the highest scoring class (80th—100th percentile) for each of the two indicators—indicating a double burden—while Churchville is in the lowest scoring class (0th–19th percentile) for both.

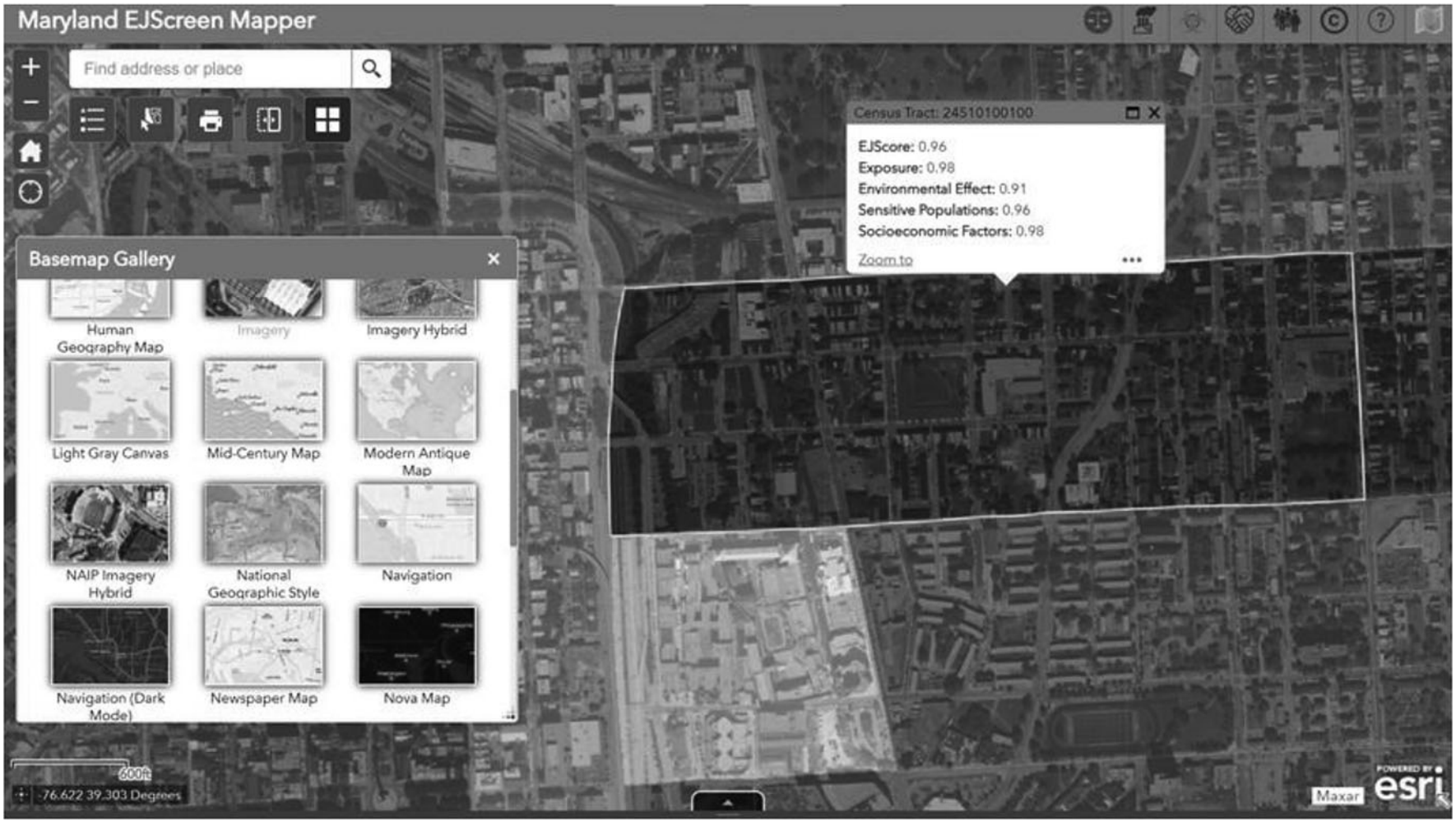

FIG. 7. Base Map Gallery. This feature allows users to change the tool's underlying base map to any of the available selections in the ESRI© base map library. For example, the satellite imagery base map shown above allows for quick identification of residential neighborhoods (e.g., selected area), industrial or commercial areas (gray tract below selected area), green space, and roadways, in Johnston Square, Baltimore, Maryland. This is especially useful for locating potential industrial sites not marked by an existing layer. Adjusting the transparency slider (not shown) allows users to control the extent to which the active layer is displayed. ESRI, Environmental Systems Research Institute, Inc.

Table 2. Summary Table for Maryland Environmental Justice Score ($N = 1384$ Maryland Census Tracts)

Mean = 0.3400194	Standard error = 0.0043256
Standard deviation = 0.1609227	Range = 0.8683130
Minimum value = 0.0954324	Lower 95% confidence limit = 0.3315339
Maximum value = 0.9637454	Upper 95% confidence limit = 0.3485049
Median = 0.3010977	Skewness = 1.1884161
Sample size (N) = 1384	Interquartile range = 0.20159

included in the tool. Oil and gas extraction have been associated with air and water quality problems and public health impacts for local populations. Additionally, there are several communities differentially burdened by power plants,[31] pipelines,[32] and a natural gas liquefaction facility[33] in Southern Maryland. In the Eastern Shore region, more than 200,000,000 chickens are raised on industrial animal operations[34] producing 400,000 tons of manure each year.[35]

These concentrated animal feeding operations can cause *Campylobacter* contamination[36] and release harmful chemicals including volatile organic compounds, endotoxins, PM2.5, among others.[37,38] While the MD EJSCREEN v2.0 Additional Context Layers (Table 1) do include location data for these industrial farming operations, they are not currently scored. Future iterations of the tool will seek to create new Environmental Effect data layers that reflect scoring based on proximity to these and other hazardous facilities in rural areas.

POLICYMAKING IMPACTS OF MD EJSCREEN v2.0

MD EJSCREEN is one of many mapping tools that use GIS and PPGIS for environmental justice screening at the state level. Similar tools include the California Communities Environmental Health Screening Tool 3.0 (CalEnviroScreen), the Houston–Galveston–Brazoria region Environmental Justice screening tool (HGBEnviroScreen), and the Washington Health Disparities Map. CalEnviroScreen, which MD EJSCREEN is modeled after, utilizes the same four domains as the Maryland tool, but the specific indicators vary (e.g., the former includes indicators for Pesticide Use and Drinking Water Contaminants while the latter does not). Notably, the variables within the Socioeconomic Factors domain are very different between MD EJSCREEN and CalEnviroScreen.

While both include Unemployment, Linguistic Isolation, Low-Income Households, and Education Level, only MD EJSCREEN provides a race/ethnicity indicator (percent non-White) as well as indicators for education status, and age. The Washington Health Disparities Map was developed using the same four indicator domains and 19 variables included in the CalEnviroScreen.[39] As such, the Washington Health Disparities Map differs from the MD EJSCREEN domains and variables in the same way that CalEnviroScreen does. HGBEnviroScreen and MD EJSCREEN have similar domains, but HGBEnviroScreen includes flooding and environmental sources as well. Flooding is a feature not seen in other screening tools but is included due to the frequency of flood events in Texas's Gulf Coast communities.[40]

As MD EJSCREEN provides data at different levels of spatial granularity (region, county, legislative district, and census tract), the tool has a wide array of applications for various stakeholders and decision makers. For example, county officials can utilize the tool to inform planning and zoning policy by (a) investigating and regulating pollution sources vis-à-vis the rules on setback ordinances, chemical storage restrictions, and chain-of-custody and emissions reporting mandates, and (b) implementing health-promoting infrastructure in areas of need (e.g., green spaces to mitigate air pollution and heat in highly urbanized communities).

[31]Sacoby Wilson and CEEJH. *Environmental Justice Plan 2025*. (School of Public Health, the University of Maryland-College Park, 2018).

[32]Finley-Brook, Mary, Travis L. Williams, Judi Anne Caron-Sheppard, and Mary Kathleen Jaromin. ''Critical energy justice in US natural gas infrastructuring.'' *Energy Research & Social Science* 41 (2018): 176–190.

[33]Federal Energy Regulatory Commission. *Environmental Assessment for the Cove Point Liquefaction Project* (General Technical Report CP13-113-000). (U.S. Department of Energy, Office of Energy Projects, Federal Energy Regulatory Commission, 2014). <https://www.energy.gov/sites/prod/files/2014/11/f19/EA-1942-FEA-2014%20%282%29.pdf>. (Last accessed on June 10, 2022).

[34]USDA National Agricultural Statistics Service. ''Census of Agriculture AG Atlas Maps.'' 2019. <https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Ag_Atlas_Maps/>. (Last accessed on June 10, 2022).

[35]Jeremy Cox. ''After Millions Spent, Solution for Excess Manure Still Elusive.'' Maryland Reporter. February 7, 2019. <https://marylandreporter.com/2019/02/07/after-millions-spent-marylands-solution-for-excess-manure-still-elusive/>. (Last accessed on June 10, 2022).

[36]Ana M. Rule, Sean L. Evans, and Ellen K. Silbergeld. ''Food Animal Transport: A Potential Source of Community Exposures to Health Hazards from Industrial Farming (CAFOs).'' *Journal of Infection and Public Health* 1 (2008): 33–39.

[37]David Osterberg and David Wallinga. ''Addressing Externalities From Swine Production to Reduce Public Health and Environmental Impacts.'' *American Journal of Public Health* 94 (2004): 1703–1708.

[38]Bin Yuan, Matthew M. Coggon, Abigail R. Koss, Carsten Warneke, Scott Eilerman, Jeff Peischl, Kenneth C. Aikin, Thomas B. Ryerson, and Joost A. de Gouw. ''Emissions of Volatile Organic Compounds (VOCs) from Concentrated Animal Feeding Operations (CAFOs): Chemical Compositions and Separation of Sources.'' *Atmospheric Chemistry and Physics* 17 (2017): 4945–4956.

[39]Molly Blondell, Wakako Kobayashi, Bryan Redden, and Arianna Zrzavy. 2020. ''Environmental Justice Tools for the 21st Century.'' <https://deepblue.lib.umich.edu/handle/2027.42/154874>. (Last accessed on June 10, 2022).

[40]Sharmila Bhandari, P. Grace Tee Lewis, Elena Craft, Skylar W. Marvel, David M. Reif, and Weihsueh A. Chiu. ''HGBEnviroScreen: Enabling Community Action through Data Integration in the Houston–Galveston–Brazoria Region.'' *International Journal of Environmental Research and Public Health* 17 (2020): 1130.

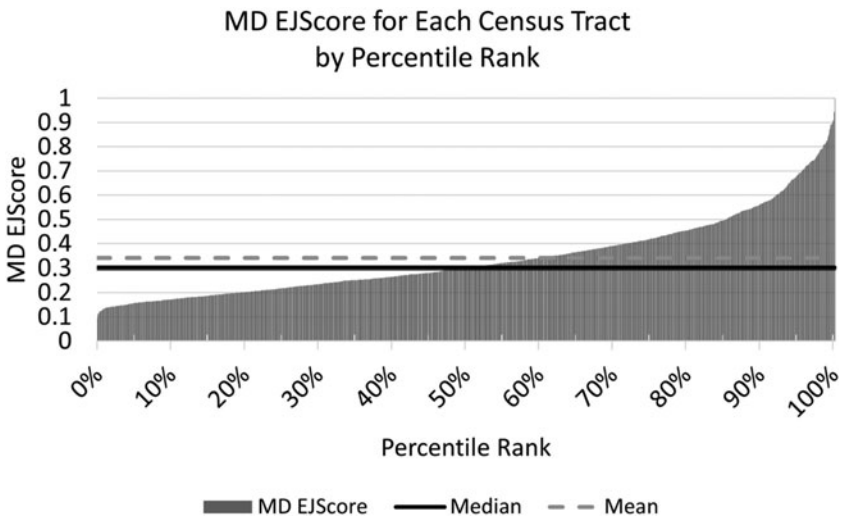

FIG. 8. Distribution of Census Tracts' MD EJScores with Reference to the Median. The above chart shows that the distribution of MD EJScores is heavily skewed to the left, with 85% of Maryland census tracts scoring below 0.50. However, note the steep increase in scores above the median (0.30) and especially above 0.50. At the extreme, the census tracts scoring in the 95th percentile have MD EJScores that are at least 0.7, 2.3 times the median.

The State legislature can use the tool to identify specific environmental justice threats at regional, county, and census tract levels—providing opportunities to design legislation that targets both broad action as well as the specific local needs of overburdened and underserved communities. Comparing EJScores across the state can also inform levels of climate change impact in both coastal and landlocked areas, an increasingly important measure for environmental policymakers and regulators.

There are also opportunities to use MD EJSCREEN in greenhouse gas tracking and reduction and the tracking of energy justice. For example, Washington uses its Environmental Health Disparities Map for the implementation of the Clean Energy Transformation Act, which acknowledges the clean energy needs of vulnerable populations.[41] In California, the government is required to ''identify disadvantaged communities'' and use this information in decision making (Senate Bill 619).[42] Data collected by CalEnviroScreen can be used to establish green zones, which provide a foundation for turning overburdened communities into healthy neighborhoods.[43] According to the Prince George's County Environmental Justice Plan 2025,[44] zoning officials have failed to recognize the importance of environmental justice issues in decision-making processes. The tool can be used to help modify zoning to improve access to green infrastructure and equitable development in overburdened and underresourced communities.[45]

CONCLUSIONS

The updates to MD EJSCREEN allow for more in-depth analysis and visualization of environmental hazards, exposures, and population characteristics in and across different communities in the state of Maryland. Through the use of the updated Select and EJChart tools, an analysis comparing and contrasting all 24 counties showed disparities among different communities. Baltimore City showed the highest environmental justice with an EJScore at 0.86, with Prince Georges County following closely behind with a score of 0.6.

Based on these data, county officials and stakeholders should take into consideration the environmental justice issues in Prince George's County and Baltimore City when deciding where to allocate county funds and implement zoning initiatives that reduce hazards, improve health, and enhance quality of life in overburdened communities. Although environmental justice issues were shown in rural counties, MD EJSCREEN is biased toward urban areas. Future revisions to the tool should cover environmental justice issues in rural counties as well as urban counties.

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AUTHORS' CONTRIBUTIONS

All authors have read and approved this work.

[41]Ibid.
[42]Ibid.
[43]California Environmental Justice Alliance. ''About the Green Zones Initiative.'' October 29, 2018. <https://calgreenzones.org/about-the-green-zones-initiative/>. (Last accessed on June 10, 2022).
[44]Ibid. Wilson and CEEJH. (2018).
[45]Ibid.

AUTHOR DISCLOSURE STATEMENT

The authors have no conflicts of interest to disclose.

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SUPPLEMENTARY MATERIAL

Supplementary Appendix SA1

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