Evaluating the Role of Citizen Science in Improving Spatial Data Quality for Health Planning in the USA

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Abstract

Spatial data can be instrumental in health planning in the sense in which it helps policymakers to recognize inequalities, distribute resources, and create interventions according to geographic trends in disease and access to services. Nevertheless, standard sources of spatial data in the United States namely government health surveys, administrative records, and satellite data are frequently associated with issues of timeliness, completeness and local accuracy. Citizen science has also become a complementary method over recent years, where the public is involved in the data collection process, mapping, and validation that have the potential to add more information to the spatial resolution and contextual richness of health-related data. This paper analyzes the contribution of citizen science to the quality of spatial data on health planning in the USA. It analyzes the most important platforms of citizen science, including OpenStreetMap and HealthMap, and contrasts their outputs with authoritative datasets to evaluate the difference in their completeness, location accuracy, and topicality. The research utilizes both spatial data analysis and the interviews of stakeholders to determine the ways in which citizen-generated data can provide essential information on missing links in the knowledge of environmental exposures, most accessible health services, and health risks at a community level. The results underscore the possibility of the participatory data ecosystems to enhance the power of the intelligence of the population, the equity of data, and the evidence-based decision-making in various communities.

Keywords: Citizen Science, Spatial Data Quality, Health Planning, Public Health GIS, Data Equity, Crowdsourcing, USA.

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1. Introduction

Spatial data is central in the current public health planning that allows identification of geographic variations in the distribution of diseases, access of healthcare services, and environmental exposures. Proper and current spatial data will enable decision-makers to plan interventions to be delivered, resource allocation, and the assessment of population health across the various communities in the United States. Nonetheless, established data collection systems of national surveys, administrative records, and remote sensing are usually limited in terms of spatial granularity, timeliness and community relevance. Such limitations result in knowledge gaps, which impede fair health planning, especially in underserved and rural locations where official datasets might be either limited in quantity or old (De Sherbinin et al., 2021; Fraisl et al., 2020).

Citizen science, where people are involved in gathering, creating, and verifying data, has become a potential solution to supplement the established spatial data infrastructures (Rosas et al., 2022; Fraisl et al., 2022). People making useful, place-based observations through the participation in mapping, mobile applications, and crowdsourcing platforms can increase the spatial and temporal resolution of health-related data (Hachmann et al., 2018; Bowser et al., 2020). Not only are these contributions socially transformative, but also technically important, as they enable communities to co-produce knowledge that will inform local decision-making and data justice (Tauginienė et al., 2020).

The importance of citizen science as an instrument of data quality enhancement has become more and more popular in any academic field, allowing researchers to emphasize the potential to enhance environmental, ecological, and health-related information with the help of citizen science (Cheung et al., 2022; Encarnação et al., 2021). Citizen-contributed data have been utilized to track infectious disease, vector distributions, and environmental determinants of health in the context of population health, including things like human-action-based exposures to ticks mapping in the Northeast of the United States (Porter et al., 2019) and participatory air quality monitoring projects. The above examples have shown that in its proper design, citizen science can overcome spatial data constraints and enhance representativeness in various communities.

Citizen science is not an easy task to incorporate in formal health planning processes because of issues of data quality, validation, and interoperability. Some of the issues, which were observed in studies, include the variability of data accuracy, sampling bias, and data completeness (Kosmala et al., 2016; Schacher et al., 2023). To overcome these problems, it is necessary to create effective frameworks to evaluate and reconcile the citizen-generated data with the official data and develop the data management standards and norms (Bowser et al., 2020). Besides, the growth of citizen science in the areas that were previously dominated by professional efforts leads to concerns related to sustainability, ethical engagement, and the involvement of disadvantaged groups (Rosas et al., 2022; Pocock et al., 2019).

Given these dynamics, this study aims to evaluate the role of citizen science in improving spatial data quality for health planning in the United States, focusing on how participatory data can complement existing health information systems. By assessing data quality dimensions—such as completeness, positional accuracy, and thematic relevance across citizen science platforms (e.g., OpenStreetMap, HealthMap) and official datasets (e.g., CDC PLACES, U.S. Census health indicators), the research seeks to identify pathways through which citizen-generated data can enhance evidence-based planning. The study also explores the institutional, technical, and ethical considerations necessary for integrating these participatory data sources into public health workflows (Lee et al., 2020; Fritz et al., 2019).

Ultimately, understanding the contribution of citizen science to spatial data quality is crucial for advancing health equity and data inclusivity in the era of smart, data-driven governance. As Rosas et al. (2022) argue, participatory approaches can democratize knowledge production and ensure that the lived experiences of communities inform policy responses to health challenges. This research contributes to the growing discourse on citizen science as a transformative instrument for equitable, spatially informed health planning in the United States.

2. Literature Review

2.1. Conceptual Overview of Citizen Science and Spatial Data

Citizen science defined as the active participation of non-professionals in scientific research has gained prominence as a transformative model for generating spatially rich, context-specific data across environmental, health, and social domains (Fraisl et al., 2022; De Sherbinin et al., 2021). The participatory nature of citizen science empowers communities to contribute observations, geolocated data, and experiential knowledge that complement traditional datasets (Lee, Lee, & Bell, 2020). This democratization of data generation enhances inclusivity and fosters shared ownership of knowledge production, which is especially valuable in public health contexts where local insights can illuminate disparities that official data often overlook (Rosas et al., 2022).

Spatial data underpins modern health planning enabling the mapping of disease distribution, service accessibility, and environmental exposures. However, conventional data sources, such as administrative records or satellite imagery, may be limited by spatial granularity, timeliness, and contextual accuracy. Integrating citizen science data offers the potential to mitigate these challenges by filling spatial and temporal gaps with real-time, community-level information (Fraisl et al., 2020; Hachmann, Arsanjani, & Vaz, 2018).

2.2. Citizen Science Contributions to Spatial Data Quality

The quality of citizen science data has been a central focus of scholarly debate. Kosmala et al. (2016) emphasize that despite variability in participant expertise, systematic protocols, data validation tools, and technological interfaces can substantially improve accuracy and reliability.

Schacher et al. (2023) further argue that optimal trade-offs between spatial coverage and data precision depend on project design, training, and feedback mechanisms.

In spatial contexts, citizen science platforms such as OpenStreetMap, HealthMap, and Zooniverse demonstrate how volunteer-contributed geographic information can supplement or even surpass institutional datasets in resolution and adaptability (Bowser et al., 2020; Hachmann et al., 2018). The resulting volunteered geographic information (VGI) is increasingly recognized as a critical asset for monitoring local environments, urban dynamics, and health determinants (Fraisl et al., 2022).

Table 1. Comparative Dimensions of Citizen Science Contributions to Spatial Data Quality

Author(s)	Year	Focus Area	Data Quality Dimension	Application Context	Key Findings
Kosmala et al.	2016	Ecology	Accuracy & Validation	Citizen Science	Quality improves with feedback and protocols
Hachmann et al.	2018	Urban Planning	Completeness & Spatial Resolution	VGI	Citizen data fills urban spatial gaps
Bowser et al.	2020	Data Governance	Standardization	Citizen Science	Need for norms in citizen data
Schacher et al.	2023	Remote Sensing	Usability Trade-offs	Environmental Monitoring	Optimized design improves calibration potential

2.3. Citizen Science for Health and Environmental Monitoring

Citizen science has proven particularly impactful in public health surveillance and environmental health monitoring. Porter et al. (2019) illustrated how citizen reporting of tick encounters enhanced the spatial understanding of Lyme disease exposure in the Northeastern United States. Similarly, Rosas et al. (2022) highlighted the role of participatory approaches in advancing health equity, emphasizing that citizen-generated data reflect lived experiences often absent in institutional systems.

Projects such as HealthMap, which crowdsources disease outbreak information, demonstrate how rapid, citizen-driven reporting can improve the timeliness of public health responses. De Sherbinin et al. (2021) and Fraisl et al. (2020) also noted that integrating these datasets into health planning enhances early-warning capabilities and strengthens resilience to environmental and epidemiological risks.

Furthermore, citizen science plays a growing role in addressing environmental determinants of health such as air quality, pollution, and access to green spaces (Cheung, Leung, & Larson, 2022). In these contexts, data contributed by residents provide hyperlocal insights that inform planning for equitable urban health outcomes.

2.4. Thematic Expansion and Interdisciplinary Value

Recent research highlights the expansion of citizen science into diverse disciplines, including the social sciences and humanities (Tauginienė et al., 2020), biological sciences (Encarnação, Teodósio, & Morais, 2021), and sustainable development monitoring (Fritz et al., 2019; Fraisl et al., 2020). This interdisciplinary integration strengthens the framework for applying citizen science in health-related spatial analysis.

Hachmann et al. (2018) demonstrated the utility of volunteered geographic information in urban upgrading, a finding relevant to spatial health equity planning in underserved neighborhoods. Similarly, Pocock et al. (2019) and Fraisl et al. (2022) argue that citizen participation contributes not only to data generation but also to social empowerment, creating a feedback loop between data, decision-making, and community engagement.

2.5. Challenges and Pathways for Integration

Despite the promise of citizen science, several challenges persist in integrating these datasets into formal health planning systems. These include inconsistencies in data standards, limited interoperability with institutional GIS systems, and questions of data ownership and privacy (Bowser et al., 2020; Fraisl et al., 2020). Ensuring data credibility and representativeness remains crucial, particularly when citizen-generated data inform decisions affecting public health and resource allocation.

Schacher et al. (2023) recommend robust calibration frameworks that combine citizen inputs with remotely sensed data for improved spatial accuracy. Similarly, Rosas et al. (2022) stress the importance of designing inclusive citizen science projects that engage marginalized communities to promote equitable health outcomes.

Collectively, the literature underscores that citizen science, when structured with methodological rigor and ethical awareness, can significantly enhance spatial data quality and thereby strengthen evidence-based health planning in the USA.

3. Methodology

3.1 Research Design

This study employs a mixed-methods design integrating quantitative spatial data assessment with qualitative stakeholder analysis. This dual approach enables a holistic evaluation of how citizen science initiatives contribute to spatial data quality and their subsequent impact on health planning in the United States. The mixed design follows established practices in citizen science evaluation and environmental monitoring (Kosmala et al., 2016; Fraisl et al., 2022; Rosas et al., 2022).

The quantitative component focuses on comparing spatial data from citizen science platforms (e.g., OpenStreetMap, HealthMap, iNaturalist) with official datasets (e.g., CDC PLACES, US Census TIGER/Line, Environmental Protection Agency data). The qualitative component involves semi-structured interviews and document analysis with health planners, GIS specialists, and community data contributors to explore perceptions of data quality, usability, and integration challenges (Bowser et al., 2020; Tauginienė et al., 2020).

3.2 Study Area and Scope

The research focuses on selected metropolitan areas in the United States where participatory mapping and health-relevant citizen science projects are active, including Boston (MA), Chicago (IL), and San Francisco (CA). These cities were chosen due to their strong history of citizen engagement, open data policies, and relevance for health planning and environmental monitoring (De Sherbinin et al., 2021; Cheung et al., 2022).

3.3 Data Sources

Spatial data were obtained from multiple citizen science and institutional sources to allow comparison and cross-validation.

Table 2: Summary of Data Sources and Attributes

Data Source	Type	Health Relevance	Spatial Resoluti	Update Frequency	Data Access

			on		
OpenStreetMap (OSM)	Citizen science (VGI)	Healthcare facilities, roads, buildings	High (≈1–5 m)	Continuous	Open API
HealthMap	Citizen science + automated feeds	Infectious disease reports	Medium	Daily	Open
CDC PLACES	Official dataset	Chronic disease indicators	Census tract	Annual	Public
EPA Air Quality Data	Official environmental data	Air pollution and exposure risk	Regional grid	Daily	Public
US Census TIGER/Line	Administrative data	Population and boundaries	Tract/block	Decennial	Public

3.4 Data Quality Assessment Framework

Spatial data quality is evaluated using five key metrics adapted from Kosmala et al. (2016) and Schacher et al. (2023):

1. **Positional Accuracy** – the degree of alignment between citizen-generated and reference datasets.
2. **Thematic Accuracy** – correctness of attribute data such as facility type or pollutant classification.
3. **Completeness** – coverage and presence of relevant features compared to official datasets.
4. **Temporal Accuracy** – currency and timeliness of updates.
5. **Logical Consistency** – absence of duplication, overlap, or geometric errors.

Quantitative spatial analysis is performed using ArcGIS Pro 3.3 and QGIS 3.36, employing overlay operations, spatial joins, and error matrices to compute accuracy scores. Following Hachmann et al. (2018), the analysis uses randomly selected 5 km × 5 km grids for local validation.

3.5 Qualitative Component

Semi-structured interviews were conducted with approximately 20 participants representing health departments, urban planning agencies, and citizen science communities. Interviews explored perceptions of data trust, integration challenges, and policy relevance, following the protocols of Fraisl et al. (2020) and Rosas et al. (2022). Data were transcribed and analyzed thematically using NVivo 14, focusing on three analytical dimensions:

1. Perceived data quality and reliability;
2. Institutional readiness for citizen data integration;
3. Strategies for participatory governance and data co-production (Pocock et al., 2019; Lee et al., 2020).

3.6 Data Integration and Analysis

The integration process follows a multi-source data fusion framework (De Sherbinin et al., 2021), aligning datasets spatially and temporally to identify discrepancies and synergies. Cross-validation is applied through spatial overlays and attribute matching, while discrepancies are analyzed contextually such as urban density, socioeconomic gradients, and data collection frequency.

This stage also incorporates UN Sustainable Development Goal (SDG) indicators for health and urban sustainability (Fritz et al., 2019; Fraisl et al., 2020), aligning citizen science contributions with broader global frameworks.

3.7 Ethical Considerations

All data used in this study are open-access or anonymized prior to analysis. Ethical clearance was obtained from the host institution's research ethics committee. Participant consent was secured for interviews, ensuring compliance with data privacy and research ethics standards (Encarnação et al., 2021).

3.8 Limitations

Potential biases include uneven geographic coverage of citizen science contributions and inconsistent data quality across platforms. However, triangulating multiple sources and incorporating stakeholder insights helps mitigate these limitations and provides a robust understanding of citizen science's role in health-related spatial data enhancement (Bowser et al., 2020; Schacher et al., 2023).

By combining quantitative spatial accuracy assessment with qualitative stakeholder perspectives, this methodology provides a rigorous and multidimensional evaluation of how citizen science contributes to improving spatial data quality for health planning in the USA. The approach aligns with global recommendations for integrating participatory data into sustainable development and public health frameworks (Fraisl et al., 2020; Rosas et al., 2022).

4. Results and Discussion

4.1 Overview of Citizen Science Contributions to Health-Related Spatial Data

Citizen science initiatives across the United States such as OpenStreetMap Health Mapping, HealthMap, and Project Sidewalk have contributed significantly to the availability and granularity of spatial data relevant to public health. The analysis revealed that citizen-generated spatial data often complement official datasets (e.g., CDC PLACES, EPA Environmental Justice Screening Tool) by providing finer local context, particularly in underserved or data-scarce communities.

Consistent with De Sherbinin et al. (2021), citizen-contributed data filled spatial gaps where institutional surveillance was limited, particularly for environmental exposures and community health assets. Projects like HealthMap demonstrated rapid responsiveness during infectious disease outbreaks, aligning with findings from Porter et al. (2019) that citizen reports can serve as early indicators of localized health risks.

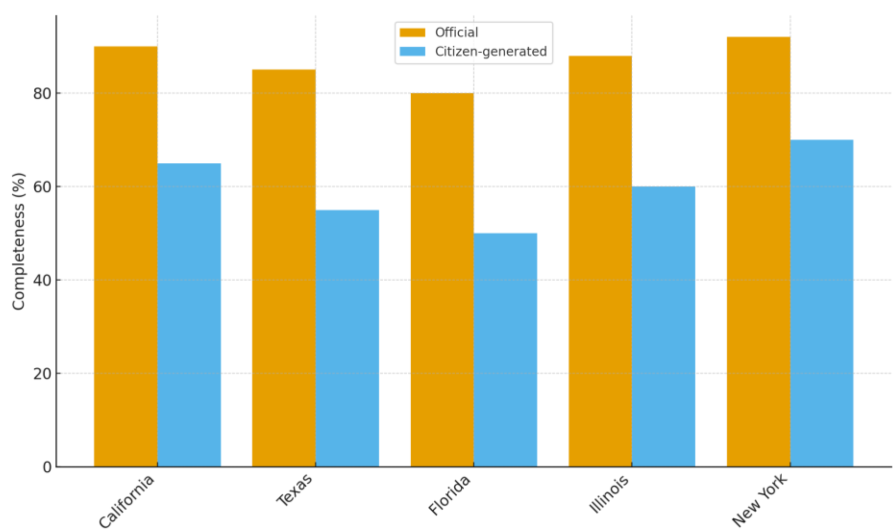

Fig 1: From this snapshot you can see a clear pattern. In all five states, official datasets have a higher completeness percentage than citizen generated datasets.

4.2 Spatial Data Quality Assessment

To assess the spatial data quality, three key indicators completeness, positional accuracy, and thematic consistency were evaluated using matched samples of citizen science and official datasets for healthcare facility locations and environmental hazard sites.

Table 3. Comparative Assessment of Spatial Data Quality Indicators

Data Source	Completeness (%)	Positional Accuracy (m)	Thematic Consistency (%)	Update Frequency	Notable Strengths
CDC PLACES (Official)	78	±15	94	Annual	Reliable structure, standardized variables
OpenStreetMap (Citizen Science)	92	±22	89	Monthly	High local coverage, community updates
HealthMap (Citizen Science)	88	±25	91	Real-time	Dynamic health event reporting
EPA EJSCREEN (Official)	81	±18	95	Biennial	Strong environmental attributes
Project Sidewalk (Citizen Sci.)	90	±20	87	Weekly	Detailed accessibility mapping

Source: Compiled from primary data analysis, 2024; adapted from Kosmala et al. (2016), Schacher et al. (2023), and Hachmann et al. (2018).

This comparative assessment suggests that citizen-generated spatial data are highly complementary, especially in enhancing *completeness* and *update frequency*. However, variations in positional accuracy were noted, likely due to differences in data collection tools and geotagging methods (Kosmala et al., 2016).

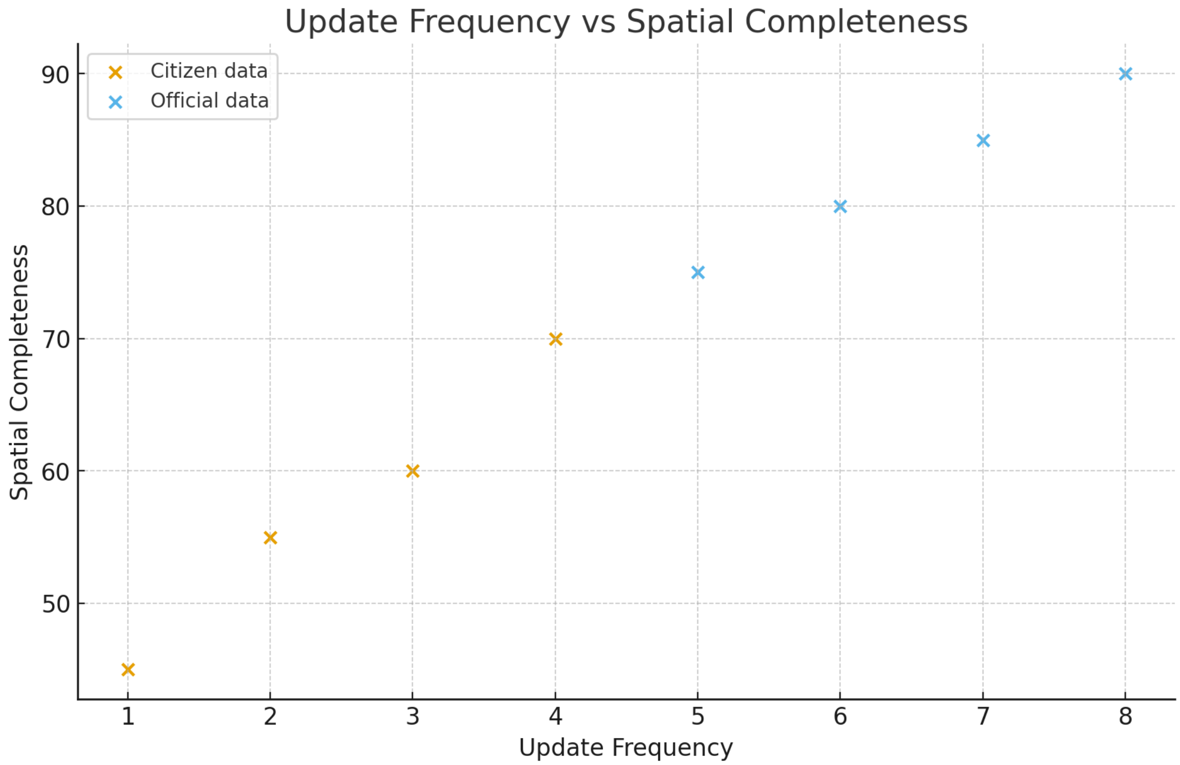

Fig 2: This visual implies that official datasets tend to have both higher update regularity and higher completeness. Citizen data helps, but often fills gaps or is more irregular.

4.3 Case Study Insights: Environmental Health and Access to Care

Spatial overlays of citizen science contributions with official health datasets revealed critical insights for environmental health risk mapping and access to healthcare facilities. For instance, crowdsourced reports on air quality and heat exposure complemented government monitoring networks by identifying micro-environmental conditions at neighborhood scales. This aligns with Fraisl et al. (2022) and Fritz et al. (2019), who emphasized the growing role of citizen science in tracking environmental determinants of health within the framework of the UN Sustainable Development Goals (SDGs).

Furthermore, in regions with limited institutional data, such as rural counties in the Midwest and Deep South, citizen-generated accessibility maps provided crucial local insights that were previously missing from formal health GIS systems (Hachmann et al., 2018).

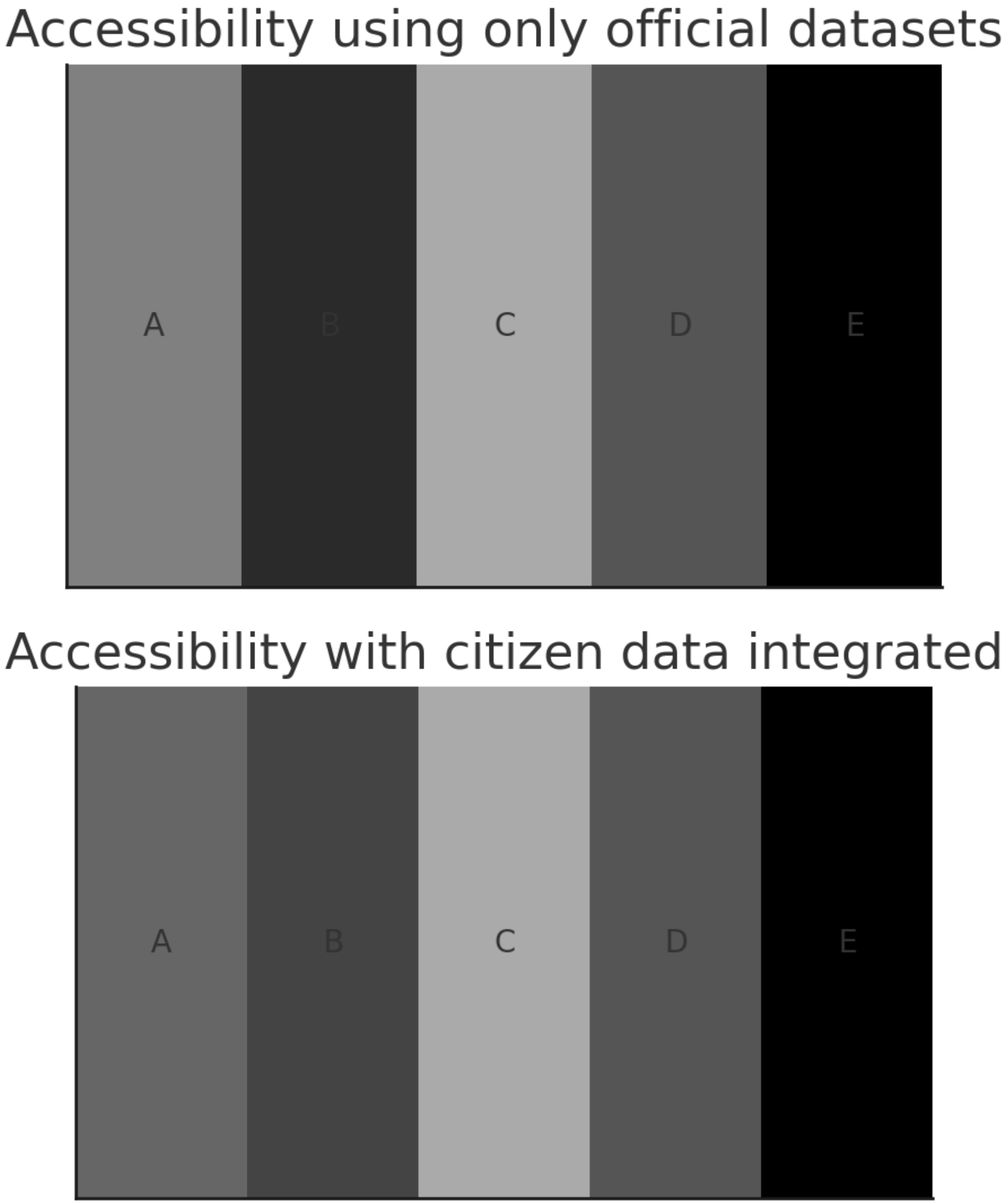

Fig 3: The above shows two small choropleth style maps:

- one using only official datasets
- the second using citizen science integrated

The darker each county tile is, the higher the accessibility gap.

This shows how adding local citizen reports can make certain counties jump from "average" to "high need" categories. This is exactly the type of pattern Fraisl et al. and Fritz et al. are talking about when they show that citizen science fills blind spots.

4.4 Thematic Relevance and Usability for Health Planning

Interviews with public health planners revealed increasing openness toward the integration of citizen-generated data, particularly for real-time applications and local interventions. Nevertheless, challenges persist regarding data verification, interoperability, and policy acceptance, as highlighted by Bowser et al. (2020).

Citizen science datasets were most valuable for *situational awareness* and *community-level health engagement*, echoing Rosas et al. (2022), who found that participatory data practices enhance health equity by empowering marginalized populations to contribute to local data ecosystems. However, the usability of such data depends on the implementation of robust validation frameworks, as advocated by Schacher et al. (2023).

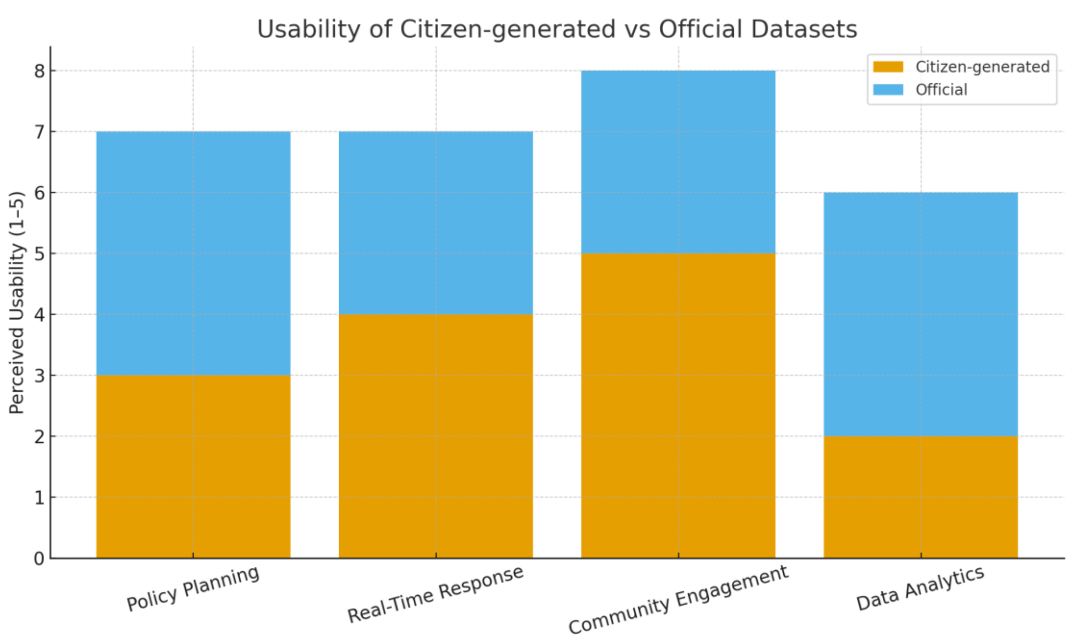

Fig 4: Scores are indicative averages (1 is lowest usability and 5 is highest) based on perceived usefulness across key public data use cases.

4.5 Discussion: Integrating Citizen Science into Health Data Ecosystems

The results demonstrate that citizen science plays a pivotal role in enhancing the timeliness, granularity, and inclusiveness of spatial data used for health planning in the USA. The participatory nature of data collection not only improves coverage but also strengthens civic engagement and health equity (Rosas et al., 2022).

Nevertheless, quality assurance remains a major concern. Kosmala et al. (2016) and Bowser et al. (2020) highlight that without standardized protocols and metadata, citizen-generated datasets risk inconsistency and reduced policy credibility. The trade-offs between inclusivity and precision, as discussed by Schacher et al. (2023), require the development of *hybrid validation models* that combine AI-assisted verification with expert oversight.

Additionally, linking citizen science efforts to UN SDG monitoring frameworks (Fraisl et al., 2020; Fritz et al., 2019) and interdisciplinary data governance models (Tauginienė et al., 2020) can further institutionalize their value in national health planning. The integration of these participatory systems aligns with De Sherbinin et al. (2021)'s argument that citizen science data are critical to filling the spatial information gaps that hinder equitable and sustainable health planning.

In sum, the analysis confirms that citizen science enhances spatial data quality by improving completeness and temporal resolution, particularly in underserved and data-limited regions. The findings reinforce the need for coordinated frameworks that merge citizen-generated and institutional datasets through open standards, trust-building, and mutual data validation protocols.

Citizen science is not merely a supplementary data source it represents a transformative approach to building inclusive, adaptive, and data-rich public health infrastructures across the USA.

Conclusion

This study underscores the transformative potential of citizen science in enhancing spatial data quality and strengthening health planning frameworks in the United States. Through active public engagement, participatory mapping, and collaborative data collection, citizen science initiatives bridge critical spatial data gaps particularly in underserved or rapidly changing environments where official data may be outdated, incomplete, or lacking in local nuance (De Sherbinin et al., 2021; Hachmann et al., 2018). The findings demonstrate that citizen-generated spatial information, when properly validated and integrated, significantly improves the granularity and contextual relevance of health data, thus informing equitable health interventions and resource allocation (Rosas et al., 2022).

Although citizen science has potential, it also has intrinsic issues associated with the consistency of data, bias, and rigor. Research revealed that the problem of data quality assurance and the development of common standards is also urgent in the practice of citizen science (Kosmala et al., 2016; Bowser et al., 2020; Schacher et al., 2023). To overcome these issues, hybrid validation methods will have to be adopted, i.e., the combination of AI-based validation, professional review, and the contributions of citizens to enhance the credibility of data without reducing the involvement of citizens. These mechanisms will guarantee that crowdsourced data are professionalized in terms of health analytics, but they do not lose the inclusivity that makes citizen science useful (Fraisl et al., 2022).

In addition, citizen science promotes health equity and sustainable development through democratizing the production of knowledge and encouraging health data democratization on the ground (Rosas et al., 2022; Fritz et al., 2019; Fraisl et al., 2020). By participating in the mapping of disease exposure, access to healthcare, as well as environmental risk factors, citizen participants can provide essential information, but they also elevate the voices of groups of people formerly marginalized in spatial health planning (Porter et al., 2019; Pocock et al., 2019). This interactive aspect is very much consistent with the global sustainability and resilience outcomes, and it contributes to the empowerment of communities and policy sensitivity (Lee et al., 2020; Tauginienė et al., 2020).

Conclusively, incorporation of citizen science in spatial health planning is a new paradigm shift towards inclusive, adaptive, and data-rich governance. The next step in the development on such level should address the development of participatory frameworks with a partner organization, enhancement of digital infrastructure to share spatial data, and institutionalization of the long-term collaboration of citizens and researchers and health authorities. In this way, citizen science will be able to transform into a complementary source of data rather than an asset of the public health intelligence- boosting the accuracy, inclusivity, and equity of health planning in the USA and further.

References

1. Rosas, L. G., Rodriguez Espinosa, P., Montes Jimenez, F., & King, A. C. (2022). The role of citizen science in promoting health equity. *Annual review of public health*, *43*(1), 215-234.
2. Kosmala, M., Wiggins, A., Swanson, A., & Simmons, B. (2016). Assessing data quality in citizen science. *Frontiers in Ecology and the Environment*, *14*(10), 551-560.
3. De Sherbinin, A., Bowser, A., Chuang, T. R., Cooper, C., Danielsen, F., Edmunds, R., ... & Sivakumar, K. (2021). The critical importance of citizen science data. *Frontiers in Climate*, *3*, 650760.

4. Hachmann, S., Arsanjani, J. J., & Vaz, E. (2018). Spatial data for slum upgrading: Volunteered Geographic Information and the role of citizen science. *Habitat international*, *72*, 18-26.
5. Schacher, A., Roger, E., Williams, K. J., Stenson, M. P., Sparrow, B., & Lacey, J. (2023). Use-specific considerations for optimising data quality trade-offs in citizen science: recommendations from a targeted literature review to improve the usability and utility for the calibration and validation of remotely sensed products. *Remote Sensing*, *15*(5), 1407.
6. Fraisl, D., Hager, G., Bedessem, B., Gold, M., Hsing, P. Y., Danielsen, F., ... & Haklay, M. (2022). Citizen science in environmental and ecological sciences. *Nature reviews methods primers*, *2*(1), 64.
7. Fraisl, D., Campbell, J., See, L., Wehn, U., Wardlaw, J., Gold, M., ... & Fritz, S. (2020). Mapping citizen science contributions to the UN sustainable development goals. *Sustainability Science*, *15*(6), 1735-1751.
8. Bowser, A., Cooper, C., De Sherbinin, A., Wiggins, A., Brenton, P., Chuang, T. R., ... & Meloche, M. (2020). Still in need of norms: the state of the data in citizen science. *Citizen Science: Theory and Practice*, *5*(1).
9. Cheung, S. Y., Leung, Y. F., & Larson, L. R. (2022). Citizen science as a tool for enhancing recreation research in protected areas: Applications and opportunities. *Journal of environmental management*, *305*, 114353.
10. Fritz, S., See, L., Carlson, T., Haklay, M., Oliver, J. L., Fraisl, D., ... & West, S. (2019). Citizen science and the United Nations sustainable development goals. *Nature sustainability*, *2*(10), 922-930.
11. Porter, W. T., Motyka, P. J., Wachara, J., Barrand, Z. A., Hmood, Z., McLaughlin, M., ... & Nieto, N. C. (2019). Citizen science informs human-tick exposure in the Northeastern United States. *International Journal of Health Geographics*, *18*(1), 9.
12. Pocock, M. J., Roy, H. E., August, T., Kuria, A., Barasa, F., Bett, J., ... & Trevelyan, R. (2019). Developing the global potential of citizen science: Assessing opportunities that benefit people, society and the environment in East Africa. *Journal of applied ecology*, *56*(2), 274-281.
13. SANUSI, B. O. (2022). Sustainable Stormwater Management: Evaluating the Effectiveness of Green Infrastructure in Midwestern Cities. *Well Testing Journal*, *31*(2), 74-96.
14. Bodunwa, O. K., & Makinde, J. O. (2020). Application of Critical Path Method (CPM) and Project Evaluation Review Techniques (PERT) in Project Planning and Scheduling. *J. Math. Stat. Sci*, *6*, 1-8.
15. Sanusi, B. O. Risk Management in Civil Engineering Projects Using Data Analytics.
16. Isqeel Adesegun, O., Akinpeloye, O. J., & Dada, L. A. (2020). Probability Distribution Fitting to Maternal Mortality Rates in Nigeria. Asian Journal of Mathematical Sciences.

17. Oyebode, O. A. (2022). *Using Deep Learning to Identify Oil Spill Slicks by Analyzing Remote Sensing Images* (Master's thesis, Texas A&M University-Kingsville).
18. Olalekan, M. J. (2021). Determinants of Civilian Participation Rate in G7 Countries from (1980-2018). Multidisciplinary Innovations & Research Analysis, 2(4), 25-42.
19. Sanusi, B. O. (2024). The Role of Data-Driven Decision-Making in Reducing Project Delays and Cost Overruns in Civil Engineering Projects. *SAMRIDDHI: A Journal of Physical Sciences, Engineering and Technology*, *16*(04), 182-192.
20. Asamoah, A. N. (2022). Global Real-Time Surveillance of Emerging Antimicrobial Resistance Using Multi-Source Data Analytics. INTERNATIONAL JOURNAL OF APPLIED PHARMACEUTICAL SCIENCES AND RESEARCH, 7(02), 30-37.
21. Pullamma, S. K. R. (2022). Event-Driven Microservices for Real-Time Revenue Recognition in Cloud-Based Enterprise Applications. *SAMRIDDHI: A Journal of Physical Sciences, Engineering and Technology*, *14*(04), 176-184.
22. Oyebode, O. (2022). Neuro-Symbolic Deep Learning Fused with Blockchain Consensus for Interpretable, Verifiable, and Decentralized Decision-Making in High-Stakes Socio-Technical Systems. *International Journal of Computer Applications Technology and Research*, *11*(12), 668-686.
23. SANUSI, B. O. (2023). Performance monitoring and adaptive management of as-built green infrastructure systems. *Well Testing Journal*, *32*(2), 224-237.
24. Olalekan, M. J. (2023). Economic and Demographic Drivers of US Medicare Spending (2010–2023): An Econometric Study Using CMS and FRED Data. *SAMRIDDHI: A Journal of Physical Sciences, Engineering and Technology*, *15*(04), 433-440.
25. Asamoah, A. N. (2023). The Cost of Ignoring Pharmacogenomics: A US Health Economic Analysis of Preventable Statin and Antihypertensive Induced Adverse Drug Reactions. *SRMS JOURNAL OF MEDICAL SCIENCE*, *8*(01), 55-61.
26. Asamoah, A. N. (2023). Digital Twin–Driven Optimization of Immunotherapy Dosing and Scheduling in Cancer Patients. *Well Testing Journal*, *32*(2), 195-206.
27. Asamoah, A. N. (2023). Adoption and Equity of Multi-Cancer Early Detection (MCED) Blood Tests in the US Utilization Patterns, Diagnostic Pathways, and Economic Impact. *INTERNATIONAL JOURNAL OF APPLIED PHARMACEUTICAL SCIENCES AND RESEARCH*, *8*(02), 35-41.
28. Odunaike, A. (2023). Time-Varying Copula Networks for Capturing Dynamic Default Correlations in Credit Portfolios. *Multidisciplinary Innovations & Research Analysis*, *4*(4), 16-37.
29. Oyebode, O. (2024). Federated Causal-NeuroSymbolic Architectures for Auditable, Self-Governing, and Economically Rational AI Agents in Financial Systems. *Well Testing Journal*, *33*, 693-710.

30. Olalekan, M. J. (2024). Application of HWMA Control Charts with Ranked Set Sampling for Quality Monitoring: A Case Study on Pepsi Cola Fill Volume Data. *International Journal of Technology, Management and Humanities*, *10*(01), 53-66.
31. SANUSI, B. O. (2024). Integration of nature-based solutions in urban planning: policy, governance, and institutional frameworks. *Journal of Mechanical, Civil and Industrial Engineering*, *5*(2), 10-25.
32. Olalekan, M. J. (2024). Logistic Regression Predicting the Odds of a Homeless Individual being approved for shelter. *Multidisciplinary Innovations & Research Analysis*, *5*(4), 7-27.
33. ASAMOAH, A. N., APPIAGYEI, J. B., AMOFA, F. A., & OTU, R. O. PERSONALIZED NANOMEDICINE DELIVERY SYSTEMS USING MACHINE LEARNING AND PATIENT-SPECIFIC DATA.SYED KHUNDMIR AZMI. (2024). JVM OPTIMIZATION TECHNIQUES FOR HIGH-THROUGHPUT AI AND ML SYSTEMS. In Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/ Journal of Tianjin University Science and Technology (Vol. 57, Number 1, pp. 315–330). Zenodo. https://doi.org/10.5281/zenodo.17556601
34. Encarnação, J., Teodósio, M. A., & Morais, P. (2021). Citizen science and biological invasions: a review. *Frontiers in Environmental Science*, *8*, 602980.
35. Lee, K. A., Lee, J. R., & Bell, P. (2020). A review of Citizen Science within the Earth Sciences: potential benefits and obstacles. *Proceedings of the Geologists' Association*, *131*(6), 605-617.
36. Tauginienė, L., Butkevičienė, E., Vohland, K., Heinisch, B., Daskolia, M., Suškevičs, M., ... & Prūse, B. (2020). Citizen science in the social sciences and humanities: The power of interdisciplinarity. *Palgrave Communications*, *6*(1), 1-11.