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RESEARCH ARTICLE

Empowering Global AMR Research Community: Interactive GIS dashboards for AMR data analysis and informed decision-making [version 1; peer review: awaiting peer review]

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Abstract

Background

Antimicrobial Resistance (AMR) is a critical global public health concern, demanding effective tools for research, data analysis, and decision-making. This study proposes a groundbreaking approach to empower the global AMR research community by introducing interactive Geographic Information System (GIS) dashboards. These dashboards aim to facilitate comprehensive data analysis of AMR across multiple countries, providing insights into antimicrobial usage (AMU), resistance patterns, and geographic distribution.

Methods

The novel approach involves the development of GIS dashboards that integrate and harmonize data from diverse sources, including clinical laboratories, surveillance networks, and public health agencies. Objective 1 focuses on creating a dashboard encompassing all countries, offering comprehensive data analysis capabilities and visualization tools. Objective 2 entails building a focused dashboard specifically for Kenya and Uganda, allowing for comparative analysis of AMR in these regions. Objective 3 involves the generation of a simulated dataset for Kampala, Uganda, addressing data limitations in that specific area.

Results

The GIS dashboards serve as powerful tools for visualizing and analyzing AMR-related datasets, providing stakeholders with a comprehensive view of the global AMR landscape. These dashboards offer valuable insights into antimicrobial usage, resistance patterns, and geographical distribution. The centralized platform facilitates data exploration and analysis, aiding researchers, policymakers, and healthcare professionals in making informed decisions to combat AMR.

Conclusions

In conclusion, the study demonstrates that the developed GIS dashboards empower stakeholders by providing valuable insights and informed decision-making capabilities. The dashboards serve as essential tools for addressing the global challenge of AMR, allowing for a deeper understanding of the problem and informing effective strategies. The approach outlined in this study has the potential to significantly contribute to the ongoing efforts to combat AMR on a global scale.

Plain Language Summary

Imagine a world where common infections become increasingly difficult to treat because the usual medicines don't work anymore. This is a real and growing problem called Antimicrobial Resistance (AMR), which poses a serious threat to global health. Now, picture a solution a powerful tool like a super-smart map that helps researchers, doctors, and policymakers understand and fight against AMR. This tool is like a special kind of map, called a Geographic Information System (GIS) dashboard, which brings together information from different sources like labs and health agencies. The first goal is to create a big map covering the whole world. It lets experts analyze and visualize data about how antibiotics are used, where resistance is high, and how it spreads across countries. The second goal is to make a more focused map just for Kenya and Uganda, helping experts compare the situation in these specific regions. Lastly, a simulated dataset is created for Kampala, Uganda, to fill in gaps where real data might be missing. The results are impressive – these smart maps provide a clear picture of how AMR looks globally. They show how antibiotics are used, where the medicines are becoming less effective, and how it's spreading on the map. These maps help researchers, policymakers, and doctors make smart decisions to tackle the problem. In simple terms, these maps are like superhero tools in the fight against AMR, giving us a better understanding of the problem and helping us find ways to stop it from getting worse. This new approach could make a big difference in the worldwide effort to overcome the challenge of AMR.

Keywords

Antimicrobial Resistance (AMR), Geographic Information System (GIS) dashboards, Data analysis, Informed decision making



This article is included in the [Vivli AMR Open](#)

[Data Reuse Data Challenge](#) collection.

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Introduction

AMR stands as a formidable global challenge, deeply intertwined with the framework of public health and healthcare systems across the world¹. Despite its significant impact in Sub-Saharan Africa, there remains a scarcity of data on the region's AMR burden. Urgency mounts for improved antibiotic utilization and the formulation of empirical treatment guidelines, particularly in East Africa, where rates of microbiologically confirmed urinary tract infections (UTIs) soar, largely due to multidrug-resistant (MDR) *Escherichia coli* and *Staphylococcus spp*². Research spotlighting antibiotic usage in hospitalized neonates reveals elevated mortality rates linked to culture-positive sepsis and notable antibiotic resistance³. Diverse antibiotic regimens, often divergent from global guidelines, underscore the need for pragmatic trials to identify effective antibiotic protocols in regions grappling with substantial AMR challenges. Attention shifts to peri-urban smallholder poultry systems in Kenya, shedding light on prevalent antibiotic use in farming practices without prescriptions, prompting concerns about AMR and drug quality, necessitating interventions to promote responsible antibiotic use⁴. Studies examining hurdles in implementing antimicrobial use (AMU) surveillance in Tanzania and Uganda highlight issues such as poor data quality, limited digitalization, and inadequate resources, underscoring the necessity for capacity building and continuous quality improvement⁵. The evolution of national AMR surveillance systems in African countries from 2017 to 2019 is discussed, emphasizing constraints like limited laboratory capacity and staffing⁶.

A sustained increase in resistance among commonly used antibiotics in surgical wards of a Ugandan hospital from 2014 to 2018 underscores the need for ongoing monitoring, surveillance, and infection prevention and control practices⁷. The introduction of the One Health Evaluation of Antimicrobial Use and Resistance Surveillance (OHE-AMURS) tool allows for a detailed assessment of progress in integrated AMR and AMU surveillance in Canada, facilitating a systematic evaluation of the complex surveillance system⁸. Progress and challenges in achieving comprehensive, integrated AMR/AMU surveillance in Canada are discussed, highlighting persistent gaps and the urgent need for policy changes, increased resources, and prioritization by government entities⁹. An examination of AMR surveillance in Nepal reveals challenges in data reporting and the adoption of digital tools to enhance accuracy, with standardized data contributing to a One Health AMR surveillance portal, enabling evidence-based decision-making¹⁰.

Addressing the multifaceted AMR requires an integrated approach. A collaborative team comprising members from Uganda, the United States, and the United Kingdom expressed interest in participating in the Vivli AMR Surveillance Open Data Re-use Data Challenge¹¹. However, they face a significant obstacle due to the absence of datasets from Uganda in the Vivli database¹². To overcome this limitation, the team suggests employing advanced AI techniques and making use of available data

from Kenya to create models that are relevant to the context of Uganda.

However, accessing this data necessitated the submission of a 300-word abstract. The team submitted an abstract¹³, by the title “**Unleashing the Power of AI: Harnessing Vivli Data from Kenya to Unlock the Untapped Potential of AMR Data from Uganda.**”

Following the submission, the team was granted access to the Pfizer Atlas dataset dated June 15, 2023, specifically the file named “**2023_06_15 atlas_antibiotics.csv**”. More information about the data available under data availability.

Objectives

2023_06_15 atlas_antibiotics.csv dataset

Upon receiving access to the dataset, we promptly downloaded it and performed a preliminary descriptive statistical analysis to obtain an overview of its contents. However, we encountered several challenges during our analysis. The dataset had limited data from African countries, making it difficult to generalize findings across the continent. Furthermore, the available data from African countries covered less than five years, reducing its usefulness for comprehensive analysis. Although we discovered a dataset from Uganda, it only contained information for 2021, while the dataset for Kenya spanned 2013, 2014, and 2021. Consequently, we adjusted our research approach to develop tools that address these challenges and identify patterns of AMR, benefiting future researchers', health professionals, and policymakers beyond this competition. To fulfill this aim, we outlined the following objectives:

Objective 1. Develop an interactive Geographic Information System (GIS) dashboard encompassing all countries within the Vivli dataset. This dashboard offers a comprehensive data analysis platform for researchers, policymakers, and health professionals to gain valuable insights across various countries.

Objective 2. Create an interactive GIS dashboard specific to the Vivli datasets from Kenya and Uganda. This focused dashboard would provide researchers, policymakers, and health professionals with a more detailed view of the datasets from these two countries, allowing for comparative analysis and targeted investigations.

Objective 3. Generate a simulated dataset specifically for Kampala, Uganda. By creating a representative dataset for this region, we could augment the limited data available from Uganda and expand the scope of analysis for researchers, policymakers, and health professionals interested in studying AMR patterns in Kampala.

By accomplishing these objectives, we aimed to develop dashboards that would serve as valuable tools for researchers, policymakers, and healthcare professionals. Ultimately, our goal is to provide a comprehensive solution that could be

utilized beyond the scope of this competition. Our dashboards provide realtime updates, customized visualization of AMR data and user friendly interfaces.

Methods

Descriptive statistical analysis

The dataset underwent descriptive statistics analysis using the R¹⁴ statistical software version 4.2.2.

Chi-square test of proportions

A chi-square test of proportions was performed to examine the distribution of isolates across different regions, including Africa, Asia, Europe, Latin America and the Caribbean, Middle East, and North America. Additionally, another chi-square test was performed to assess the distribution of years of available number dataset across these regions.

Identification of coordinates

To develop an interactive GIS dashboard, it is essential to have latitude and longitude positions for each country. To accomplish this, a coordinate was assigned to the capital city of each country, utilizing information from Wikipedia¹⁵. These coordinates were then incorporated into the dataset, enabling accurate geographical representation and visualization within the dashboards.

Development of GIS web-based dashboards

The dashboards were developed using online ArcGIS from Esri¹⁶. The dashboards at Esri are GIS-based and utilize web technology. They are constructed in the cloud, leveraging Esri's platform, and rely on datasets containing latitude and longitude coordinates.

Results

Descriptive statistical analysis

The dataset analyzed in this study consists of 83 countries and a total of 858,233 isolates. It encompasses 126 variables and includes information on 345 species. [Table 1](#) provides an overview of the distribution of isolates across different regions and the availability of data over the years. The African region has the lowest number of datasets and the fewest years of available data, while Europe has the highest numbers. Chi-square tests confirmed that both the proportion of isolates in the region and the proportion of countries with at least 9 years of data significantly deviate from the expected proportion of 0.17 ($p < 0.001$, [Table 2](#) and [Table 3](#)).

Development of web-based interactive GIS dashboards
Objective 1. Develop an interactive Geographic Information System (GIS) dashboard encompassing all countries. This dashboard is a valuable tool for researchers, policymakers, and

Table 1. Descriptive statistic results of the Atlas dataset as of June 15th, 2023: The dataset contains a total of 863,509 isolates. To determine the proportion, the number of isolates in each region is divided by the total number of isolates. Europe has the most extensive collection of datasets and the longest historical data, contrasting sharply with Africa, which possesses the least abundant dataset count and the shortest temporal coverage.

	Africa	Asia	Latin America and Caribbean	Middle East	Europe	North America
Number of isolates	22,717	116,845	96,309	37,112	419,496	171,030
Proportion of isolates per region	0.03	0.14	0.11	0.04	0.49	0.20

Table 2. The Atlas dataset, as of June 15th, 2023, shows the distribution of countries with 18 years of available data from 2004 to 2021. We set a criterion where each country should have at least 9 years of data out of the total 18-year period. The proportion was calculated by dividing the number of countries with at least 9 years of data by the total number of countries in each region. Isolates are unevenly distributed across various regions, such as Africa, Asia, Europe, Latin America, and the Caribbean, with Africa having only 13 representatives.

	Africa	Asia	Latin America and Caribbean	Middle East	Europe	North America
Number of countries	13	14	15	8	31	2
Number of countries with at least 9 years of dataset	2	11	8	4	23	2
Proportion of countries with at least 9 years of dataset	0.15	0.79	0.53	0.50	0.74	1.00

Table 3. Chi-square tests of proportions for the distribution of isolates across regions, and of distribution of countries with at least 9 years of dataset. The availability of dataset years varies among different regions, encompassing Africa, Asia, Europe, Latin America, and the Caribbean, with Africa exhibiting the shortest duration of available data.

	Chi-square	Df	p-value
Proportion of isolates per region	85.713	5	< 0.001
Proportion of countries with at least 9 years of dataset	69.717	5	< 0.001

healthcare professionals to analyze and explore data across multiple countries. It offers insights on various aspects, including a map, country selection, regional breakdown, number of isolates, number of countries per year, and navigation instructions (Figure 1A). To examine the number of isolates in Uganda and the data collection duration, simply go to the “Country” section, find Uganda, and click on it. This will display only Uganda’s data, removing other countries from view. The dashboard’s visually appealing presentation simplifies data interpretation, aids monitoring and evaluation efforts, and provides comprehensive information for hypothesis formulation (Figure 1B). The dashboard can be accessed using the link¹⁷.

Objective 2. Create an interactive GIS dashboard specific to the datasets from Kenya and Uganda. The specialized dashboard aims to provide a comprehensive and detailed perspective on data from two specific nations. Its main purpose is to empower researchers, policymakers, and healthcare professionals by facilitating comparative analysis and focused investigations. The dashboard offers a comprehensive overview of data points such as species, country, sample sources, sample count, gender, and antibiotics (Figure 2A). Users can apply filters based on these variables. For example, Figure 2B illustrates the antibiotic resistance of *E.coli* samples from Uganda. Ampicillin, Levofloxacin, and Ciprofloxacin were ineffective in 21 samples (Resistant), while all samples responded positively to Imipenem (Susceptible). The interactive dashboard simplifies the visualization of antibiotic response, making analysis more accessible. Access the dashboard via the provided link¹⁸.

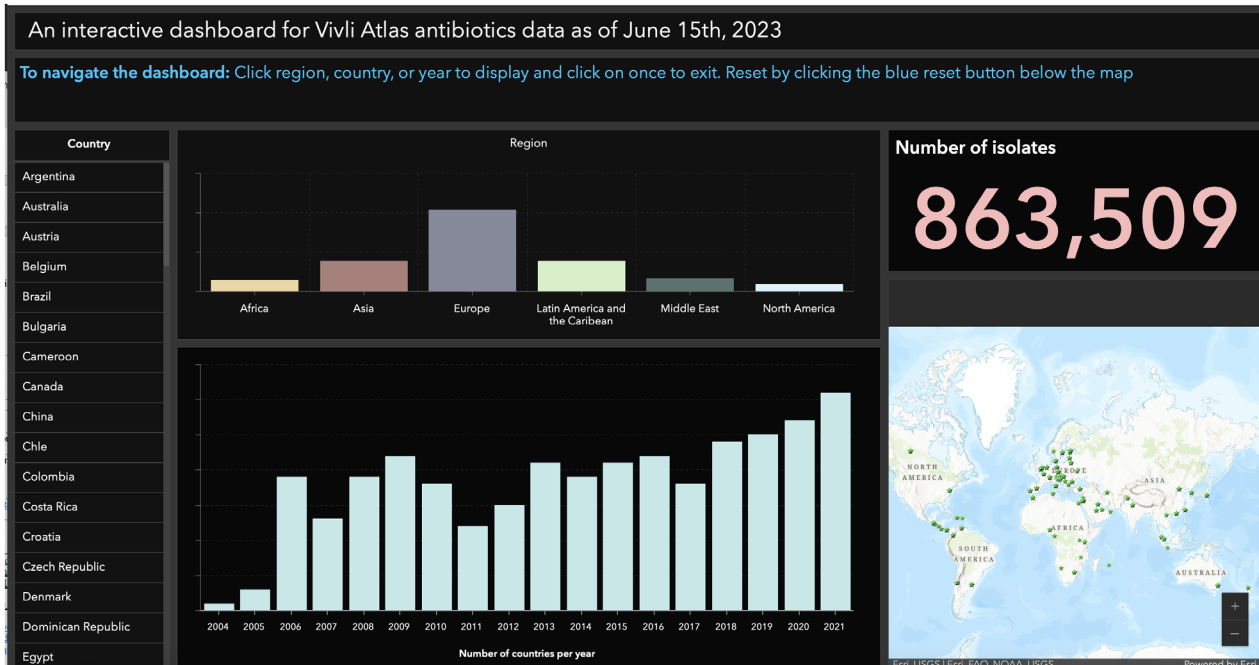
Objective 3. Generate a simulated dataset specifically for Kampala, Uganda. To apply information gained from the two previous dashboards discussed above we simulated a dataset, for researchers, policymakers, and healthcare professionals studying antimicrobial resistance (AMR) patterns in Kampala, Uganda, it is crucial to create a comprehensive and representative dataset for the region. This dataset would fill the existing data gaps and provide valuable insights, empowering stakeholders with a broader understanding of AMR trends and enabling them to make more informed decisions. In our simulated data, we examined various regions within Kampala

(Figure 3A). Specifically, let’s focus on *Klebsiella aerogenes*. In 2021, this bacterium was detected solely in Lugala. It exhibited resistance to Ampicillin but was susceptible to Amikacin (Figure 3B). Access the dashboard via the provided link¹⁹.

Impact of the work

The GIS web-based dashboards described are comprehensive and versatile tools designed to assist researchers, policymakers, and healthcare professionals in their AMR data exploration and analysis efforts. They offer a wide range of functionalities and aims to provide valuable insights specifically focused on multiple countries. By utilizing the dashboards, users can access and examine various datasets relevant to their respective fields. These datasets may include information related to healthcare, public health, demographics, economics, and other relevant factors. The dashboard acts as a centralized hub, aggregating and organizing these datasets for easy access and analysis. Researchers can leverage the dashboards to delve into the available data, perform complex queries, and conduct in-depth analyses. They can explore patterns, trends, and correlations across different countries, facilitating cross-country comparisons and enabling the identification of similarities and differences. Policymakers can benefit from the dashboards by utilizing the insights gained from the data to inform their decision-making processes. They can examine the impact of different policies or interventions in specific countries, evaluate the effectiveness of existing strategies, and identify areas that require attention or improvement. Healthcare professionals can also leverage the dashboards to gain a better understanding of healthcare systems, AMR prevalence, healthcare outcomes, and other relevant metrics across multiple countries. This knowledge can contribute to the development of evidence-based practices, policies, and interventions aimed at improving healthcare delivery and patient outcomes. Overall, these dashboards act as powerful tools that empower researchers, policymakers, and healthcare professionals to explore, analyze, and derive valuable insights from available AMR datasets pertaining to multiple countries. Its broad scope and functionality make them valuable assets in the pursuit of knowledge, evidence-based decision-making, and improvement of AMR research worldwide.

A)



B)

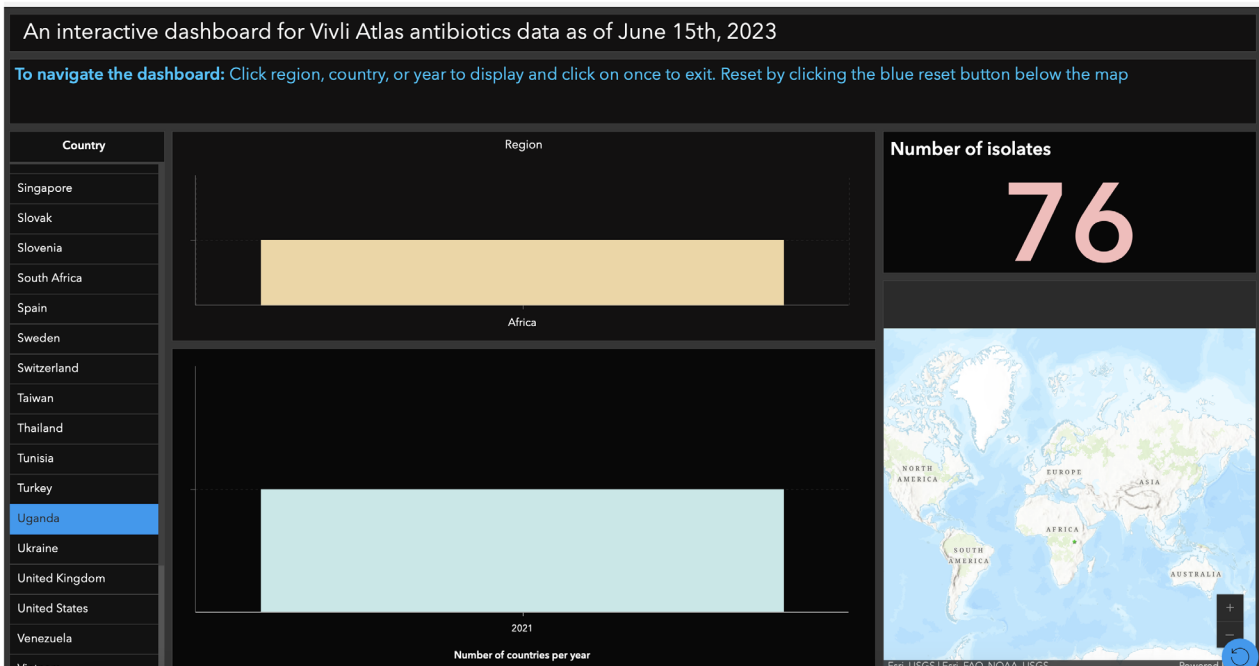
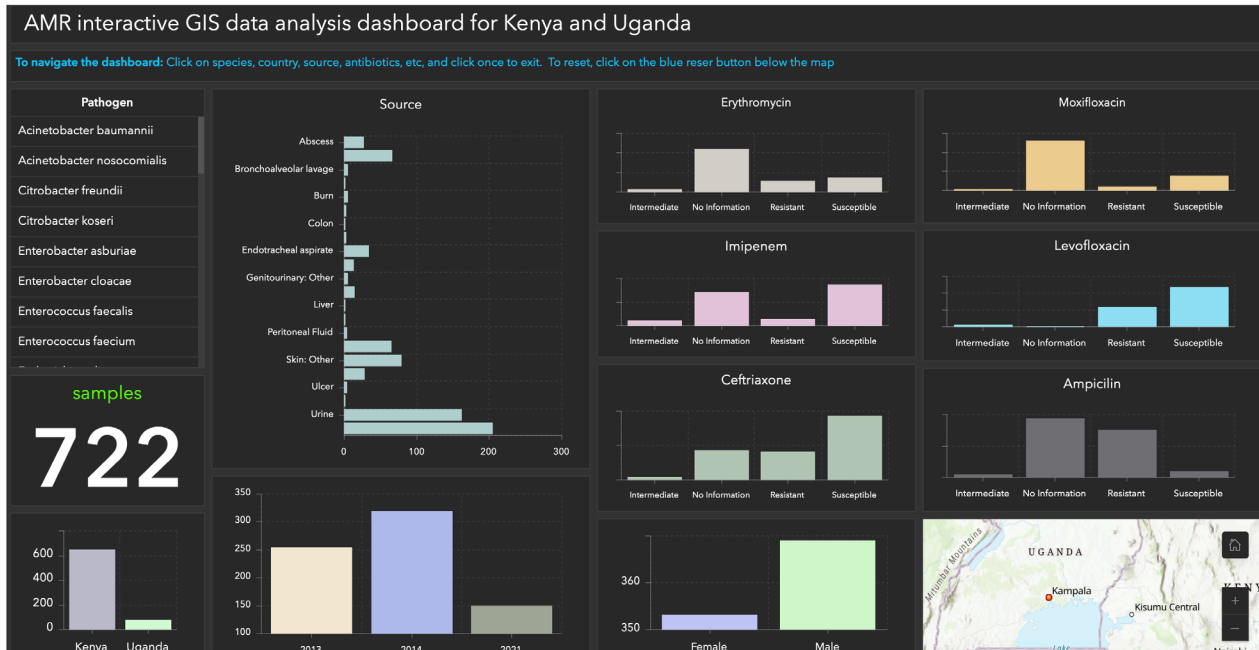


Figure 1. Interactive GIS dashboards: **A)** for all countries, **B)** for Uganda. Figure 1A presents a comprehensive dashboard tailored for researchers, policymakers, and healthcare professionals, providing tools like a map, country selection, regional breakdown, and clear navigation instructions for analyzing and exploring data across multiple countries. Meanwhile, Figure 1B offers a visually appealing presentation with a focus on Uganda, simplifying data interpretation, aiding monitoring and evaluation efforts, and providing comprehensive information for hypothesis formulation, particularly emphasizing the examination of the number of isolates and data collection duration in the country.

A)



B)

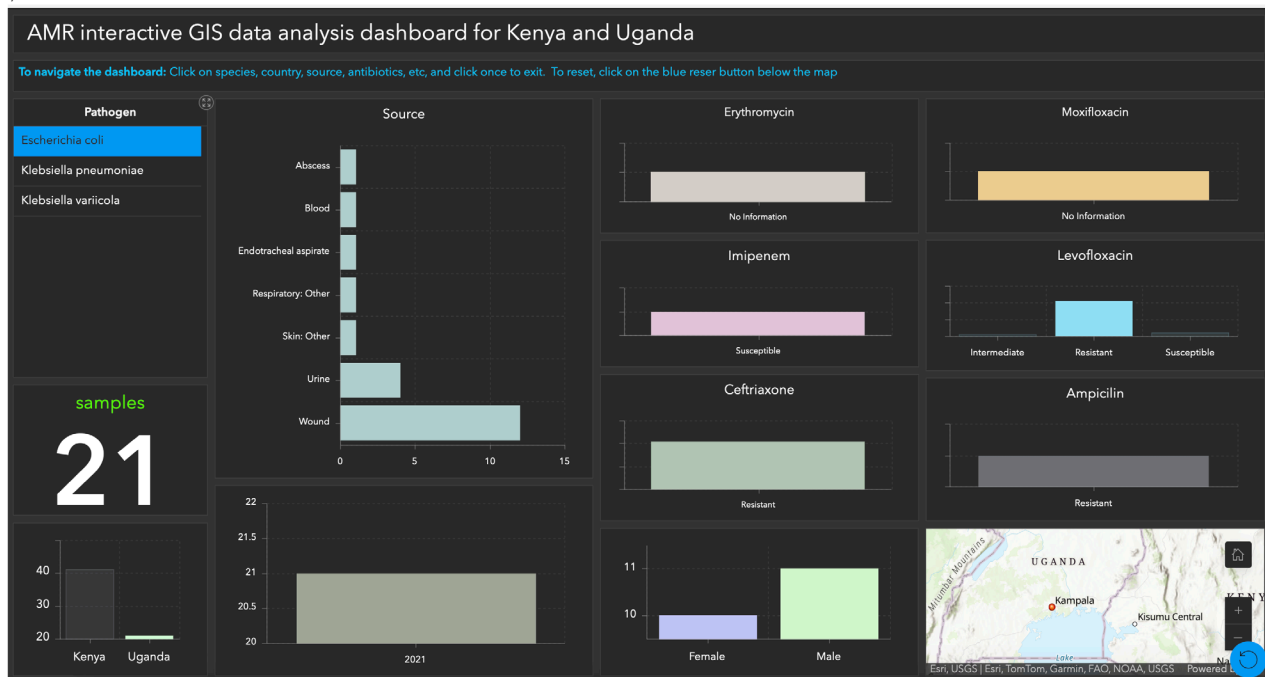
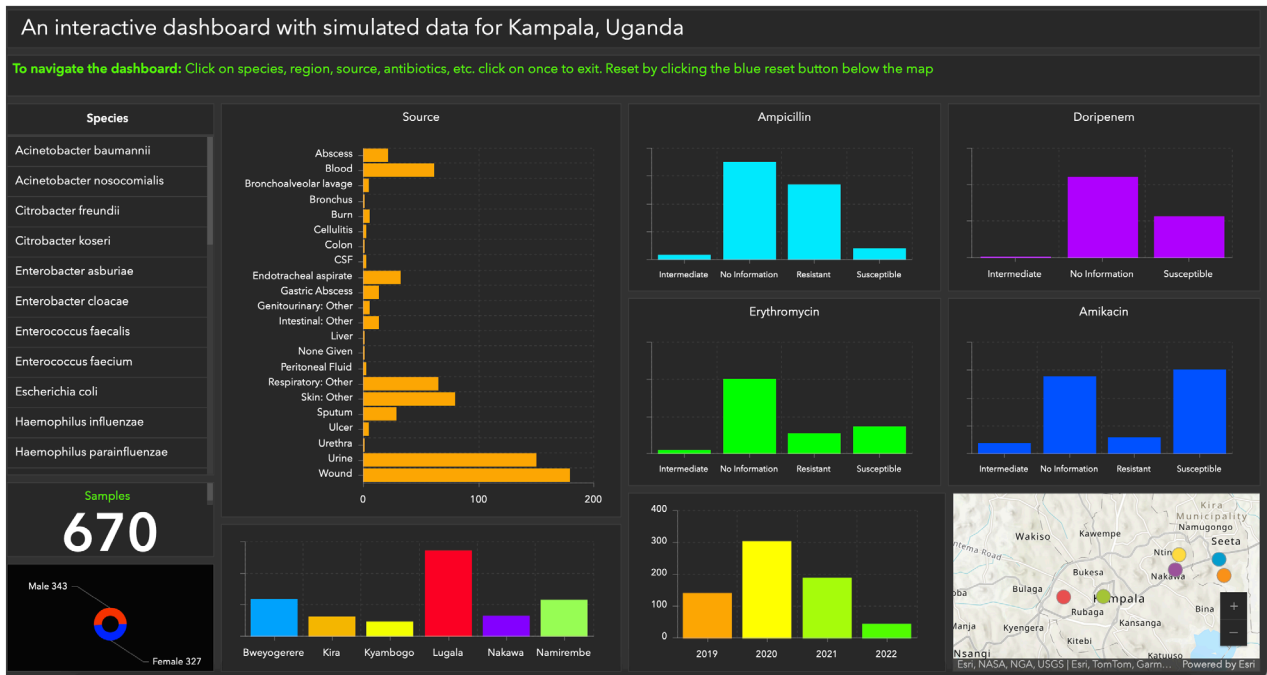


Figure 2. Interactive GIS dashboards: **A)** Kenya and Uganda, **B)** Performance of antibiotics on *E.coli*. Figure 2A provides a comprehensive dashboard overview, highlighting key data points such as species, country, sample sources, count, gender, and antibiotics. Figure 2B illustrates antibiotic resistance in *E. coli* samples from Uganda, revealing resistance to Ampicillin, Levofloxacin, and Ciprofloxacin in 21 samples, while all samples displayed susceptibility to Imipenem.

A)



B)

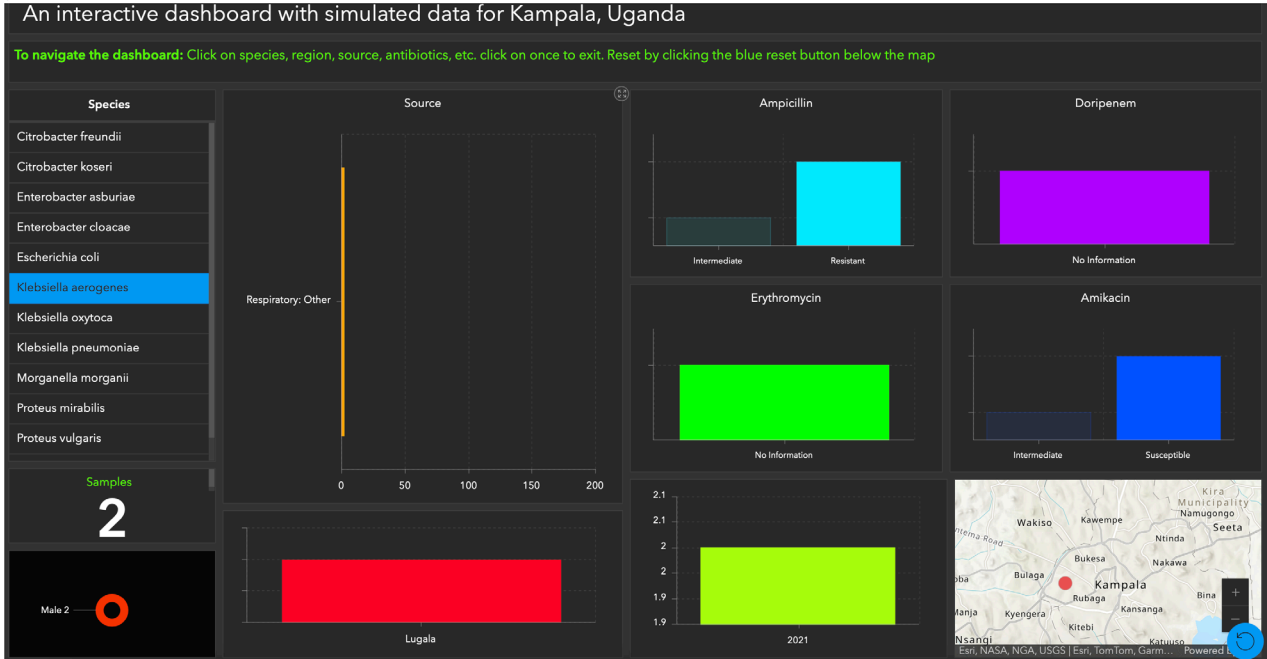


Figure 3. Interactive GIS dashboards: **A)** simulated Kampala data, **B)** *Klebsiella aerogenes* from only Lugala. Figure 3A displays the simulated data examining various regions within Kampala, while Figure 3B highlights the 2021 detection of *Klebsiella aerogenes* exclusively in Lugala, revealing resistance to Ampicillin but susceptibility to Amikacin. This simulated dataset, offers crucial insights into AMR trends and can be used to empower stakeholders for more informed decision-making.

Conclusion

The development of interactive GIS Dashboards represents a significant advancement in empowering the global AMR Research community. By providing comprehensive data analysis capabilities and facilitating informed decision making processes, these dashboards contribute to the fight against AMR on a global scale.

Ethics and consent

Ethical approval and consent were not required.

Data availability

The data cannot be made available as it is under license by a third party. However, the dataset can be requested from 20 using the following information: Data contributor name: Pfizer (AMR); DOI: <https://doi.org/10.25934/PR00007930>; AMR ID: VIV00007930; and Dataset ID: ATLAS_Antibiotics

The team composed of participants from Uganda, United States, and United Kingdom obtained data for Vivli AMR Surveillance Open Data Re-use Data Challenge from Vivli²⁰. This publication is based on research using data from Pfizer, obtained through²⁰.

The dashboard creation codes are not available, as the dashboards were originally constructed using the graphical user interface (GUI) on ArcGIS. To replicate the dashboards, we can leverage open-source QGIS GIS software (<https://qgis.org/en/site/>), utilizing the information outlined in the materials and methods section.

The dataset is conveniently formatted in CSV, and city coordinates can be obtained from Wikipedia. The process involves recreating the dashboards using QGIS, drawing from the provided materials and methods, and utilizing the CSV dataset along with city coordinates.

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