Empowering Global AMR Research Community: Interactive GIS Dashboards for AMR Data Analysis and Informed Decision-Making

Stephen Obol Opiyo[1], Racheal Nalunkuma[2], Stella Maris Nanyonga[3], Nathan Mugenyi[4], and Andrew Marvin Kanyike[2]

[1]Patira Data Science, LLC, Westerville, Ohio 43081, USA.
[2]Mengo Hospital, Kampala, Uganda.
[3]University of Oxford, UK.
[4]Mbarara University of Science and Technology, Uganda.

Abstract

Antimicrobial Resistance (AMR) poses a significant threat to global public health, necessitating effective Research, data analysis and decision making tools. This study introduces a novel approach to empower the global AMR research community through development of interactive Geographic Information System (GIS) dashboards for comprehensive data analysis of antimicrobial resistance (AMR) across multiple countries. These dashboards provide comprehensive data analysis capabilities and facilitate informed decision making processes in combating AMR. The GIS dashboards serve as powerful tools for visualizing and analyzing diverse data sets related to AMR, including AMR Antimicrobial usage (AMU), resistance patterns, and the geographic distribution. By integrating and harmonizing data from various sources, such as clinical laboratories, surveillance networks, and public health agencies, these dashboards provide a comprehensive view of the global AMR landscape. Objective 1 focuses on a dashboard encompassing all countries, providing valuable insights and visualization tools. Objective 2 creates a focused dashboard for Kenya and Uganda, facilitating comparative analysis. Objective 3 involves generating a simulated dataset specifically for Kampala, Uganda, to augment limited data. The dashboards offer researchers, policymakers, and healthcare professionals a centralized platform for data exploration, analysis, and informed decision making. The study concludes that these GIS dashboards empower stakeholders to gain valuable insights and inform strategies for addressing AMR globally.

Introduction

The team composed of participants from Uganda, United States, and United Kingdom expressed interest in participating in the Vivli AMR Surveillance Open Data Re-use Data Challenge (1. However, they discovered that there are no available datasets from Uganda in the Vivli database (2. To overcome this limitation, the team plans to leverage AI techniques and utilize data from Kenya to develop models that can be applied to the context of Uganda. They submitted an Expression of Interest titled **"Unleashing the Power of AI: Harnessing Vivli Data from Kenya to Unlock the Untapped Potential of AMR Data from Uganda."** The team were given access to the dataset 2023_06_15 atlas_antibiotics.csv for their research.

a) 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.

b) Methods

Descriptive statistical analysis

The dataset underwent descriptive statistics analysis using the R (3 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 Wikipedia (4). 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 Esri (5). 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.

c) 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 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 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 2A).** 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 2B).** The dashboard can be accessed using the link provided below. https://patira.maps.arcgis.com/apps/dashboards/d89c5b039552464f8f04103f05ac889f

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 3A).** Users can apply filters based on these variables. For example, **Figure 3B** 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 link.https://patira.maps.arcgis.com/apps/dashboards/a1324c58e49e4561ac9505936db7743a

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 4A**). 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 4B**). Access the dashboard via the provided link.
https://patira.maps.arcgis.com/apps/dashboards/095acc30606c4c7a8bc8260e6160c511

d) 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.

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.

e) Tables/Figures

Tables
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.

	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.

	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.

	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

Figures
Figure 1. A screenshot of Environment: Searchamr-AMR database searched by Country.

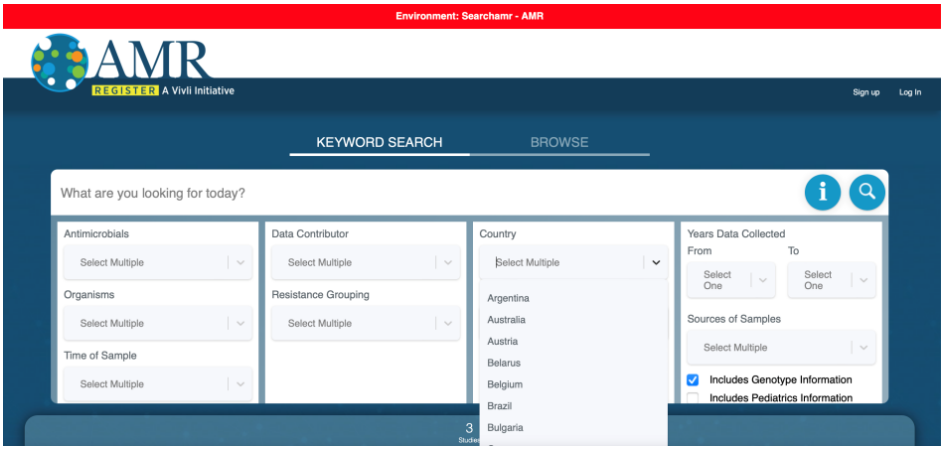


Figure 2. Interactive GIS dashboards: A) for all countries, B) for Uganda

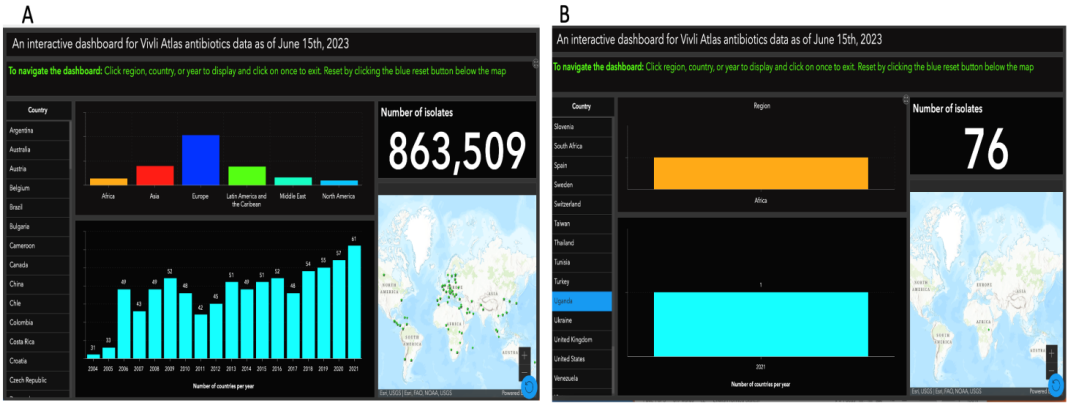


Figure 3. Interactive GIS dashboards:A) Kenya and Uganda, B) Performance of antibiotics on *E.coli*

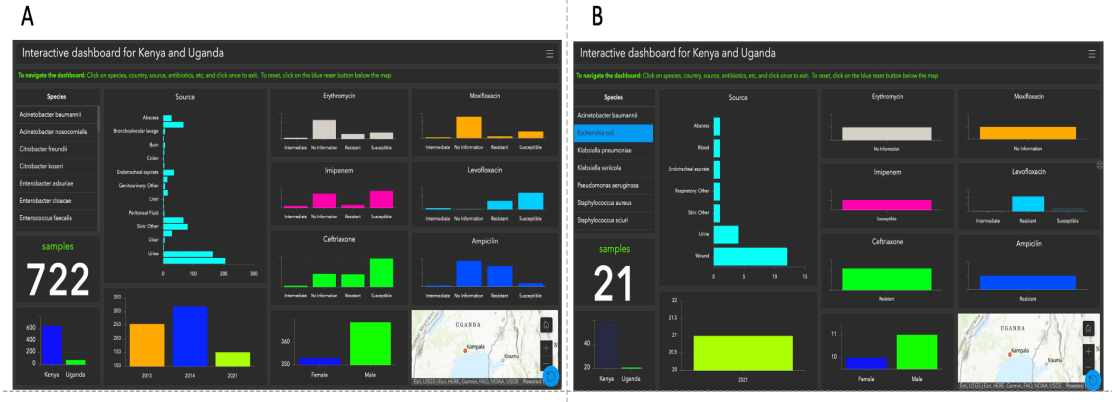
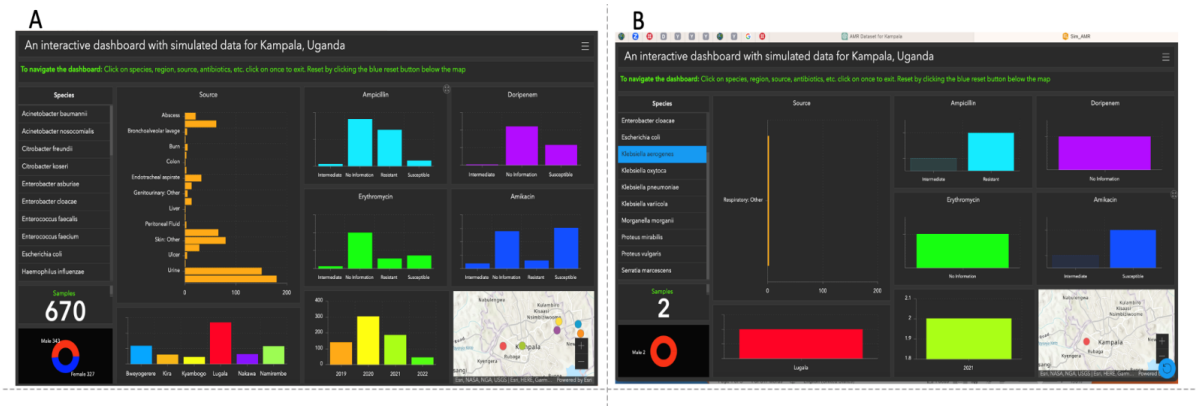


Figure 4. Interactive GIS dashboards:A) simulated Kampala data, B)Klebsiella aerogenes from only Lugala



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6. This publication is based on research using data from (2023_06_15 atlas_antibiotics; Pfizer), obtained through https://amr.vivli.org