Date: 20th December 19, 2023
Course: Advance Database Systems

ETL Pipeline for Data Processing & Visualization on AWS QuickSight

Author: - Sarav Shah
Professor: Dr Joann Ordille
Rutgers Business School, NJ

Contents

1. ABSTRACT

This document outlines a streamlined ETL (Extract, Transform, Load) pipeline tailored for efficient data processing and visualization on AWS QuickSight. Utilizing AWS services such as S3 storage, AWS Glue, Lambda, Athena, Glue ETL jobs, and QuickSight, this pipeline seamlessly extracts data, preprocesses it with Lambda functions, and transforms it using Glue ETL jobs. The structured data is stored in S3 or loaded into a data warehouse for further analysis.

Key components include AWS Glue for metadata management, Lambda for data cleaning, Athena for SQL queries, and QuickSight for cloud-native visualizations. The serverless architecture ensures scalability, and QuickSight provides a user-friendly interface for creating interactive dashboards and reports. This ETL pipeline exemplifies the integration and efficiency of AWS services, offering organizations a robust solution for data-driven decision-making.

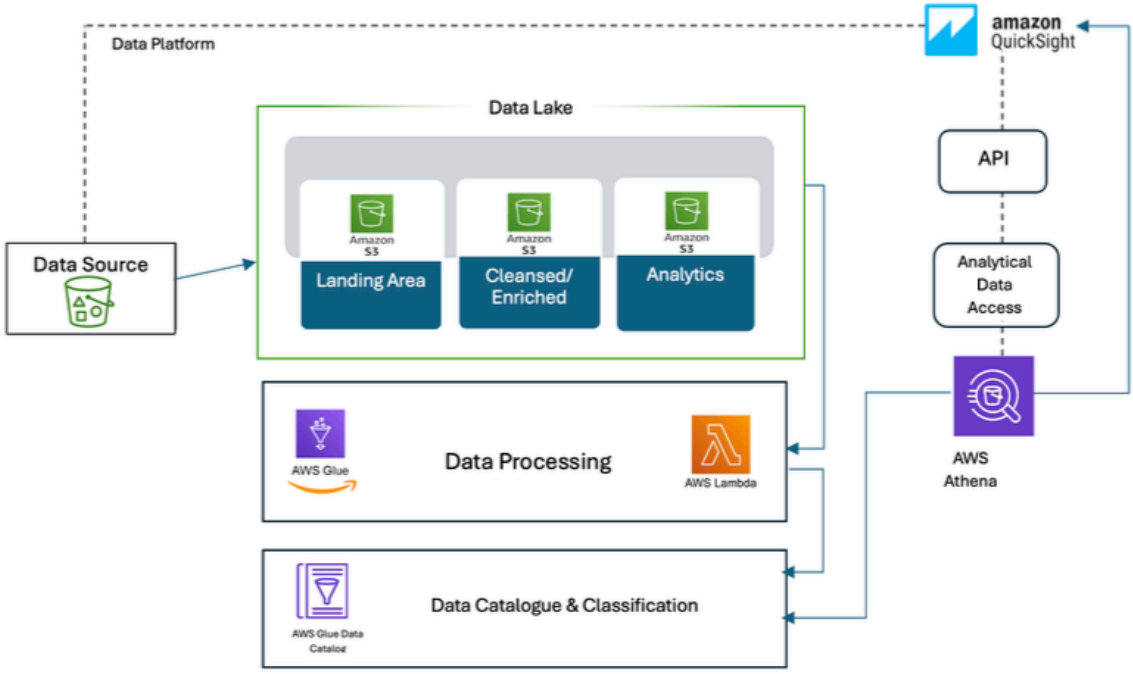
2. INTRODUCTION

In the realm of data-driven decision-making, constructing a resilient ETL (Extract, Transform, Load) pipeline is pivotal for organizations seeking efficient data processing and visualization. This framework serves as the backbone for seamless extraction, transformation, and loading of data, facilitating a streamlined journey from raw datasets to insightful visualizations.

At the core of this pipeline is the orchestration of AWS services, with each contributing to specific stages of the data journey. Beginning with data extraction and storage in Amazon S3, the pipeline traverses through AWS Glue and Lambda functions for data preprocessing. Subsequently, Amazon Athena facilitates SQL queries for querying processed data, and AWS Glue ETL jobs automate the transformation process. The culminating visualization step unfolds on Amazon QuickSight, renowned for its cloud-native business intelligence service, offering interactive dashboards and user-friendly reports.

This introduction sets the stage for a comprehensive exploration of the ETL pipeline, accentuating the synergy of AWS services, and highlighting the unique advantages offered by AWS QuickSight. Furthermore, a comparative analysis with Tableau, another leading visualization tool, will be undertaken to provide insights into the strengths and distinctions of each platform. As organizations strive for agility, scalability, and actionable insights, the integration of AWS services and the ensuing comparison with Tableau emerge as strategic approaches to harness the full potential of big data analytics.

3. ETL ARCHITECTURE



S3 serves as the primary data storage solution. Raw, unprocessed data is commonly stored in an S3 landing zone. AWS Glue automates the process of cleaning, transforming, and preparing data for analysis. AWS Lambda provides serverless compute service for running code without provisioning servers, and the Lambda functions can be triggered by events. After transformation, the cleaned and processed data is stored back in a different S3 bucket. Amazon Athena query service allows SQL-based queries directly on data stored in S3. A fully managed ETL job is executed to further process data if needed before analysis. Amazon QuickSight provides Business analytics service for building visualizations, dashboards, and reports.

4. EXPLORATORY DATA ANALYSIS

Each column in the given list corresponds to specific information in the dataset. Here a description of some of the relevant columns:

'country': Represents the name of the country.

'rank': Indicates the rank of the country based on a certain criterion (e.g., population, area, etc.).

'area': Denotes the total area of the country in square kilometers.

'landAreaKm': Represents the land area of the country in square kilometers.

'cca2' & 'cca3' : Represents country code assigned by ISO.

'netChange': Indicates the net change in population for a specific time period (e.g., yearly net change).

'growthRate': Represents the growth rate of the population, typically expressed as a percentage.

'worldPercentage': Denotes the percentage of the world's population that the country represents.

'pop1980': Represents the population estimate for the year 1980.

'pop2023': Represents the population estimate for the year 2023.

'pop2030': Represents the projected population estimate for the year 2030.

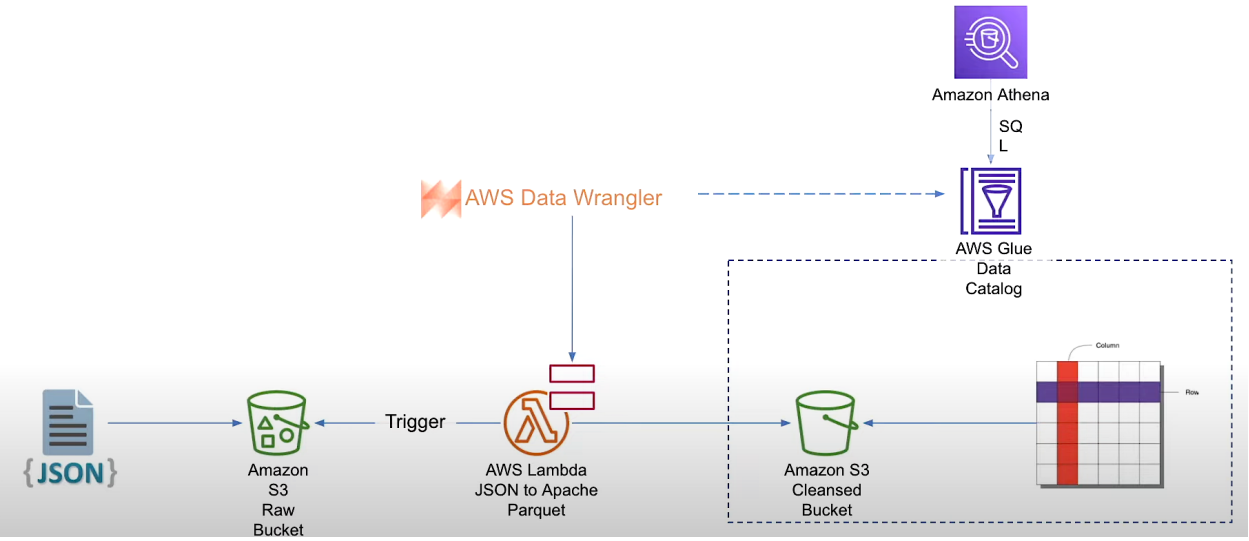
'pop2050': Represents the projected population estimate for the year 2050.

```
import pandas as pd
import numpy as np

data = pd.read_csv("/Users/sarav/Desktop/Study Materials/Fall' 23/Advanced DB/Project/Final data set/world population/countries-table.csv")
data

data = data.dropna()
data.head()

data2 = data.describe().T
data2
```

index	country	rank	area	landAreaKm	cca2	cca3	netChange	growthRate	worldPercentag	density	densityMi	place	pop1980	pop2000	pop2010	pop2022	pop2023
0	India	1	3.28759e+06	2.97319e+06	IN	IND	0.4184	0.0081	0.1785	480.503	1244.5	356	696828385	1059633675	1240613620	1417173173	1428627663
1	China	2	9.70696e+06	9.4247e+06	CN	CHN	-0.0113	-0.0002	0.1781	151.27	391.788	156	982372466	1264099069	1348191368	1425887337	1425671352
2	United States	3	9.37261e+06	9.14742e+06	US	USA	0.0581	0.005	0.0425	37.1686	96.2666	840	223140018	282398554	311182845	338289857	339996563
3	Indonesia	4	1.90457e+06	1.87752e+06	ID	IDN	0.0727	0.0074	0.0347	147.82	382.853	360	148177096	214072421	244016173	275501339	277534122
4	Pakistan	5	881912	770880	PK	PAK	0.1495	0.0198	0.03	311.962	807.983	586	80624057	154369924	194454498	235824862	240485658
5	Nigeria	6	923768	910770	NG	NGA	0.168	0.0241	0.028	245.731	636.444	566	72951439	122851984	160952853	218541212	223804632
6	Brazil	7	8.51577e+06	8.35814e+06	BR	BRA	0.0393	0.0052	0.027	25.8936	67.0645	76	122288383	175073720	196353492	215313498	216422446
7	Bangladesh	8	147570	130170	BD	BGD	0.0557	0.0103	0.0216	1320.68	3441.28	50	83929765	129193327	148391139	171186372	172954319
8	Russia	9	1.70982e+07	1.63769e+07	RU	RUS	-0.0158	-0.0019	0.018	8.82	22.8439	643	138257420	146844839	143242599	144713314	144444359
9	Mexico	10	1.96438e+06	1.94395e+06	MX	MEX	0.0299	0.0075	0.016	66.0797	171.146	484	67705106	97873442	112532401	127504125	128455567
10	Ethiopia	11	1.1043e+06	1.12857e+06	ET	ETH	0.1008	0.0255	0.0158	112.113	290.372	231	34945469	67031867	89237791	123379924	126527060
11	Japan	12	377930	364500	JP	JPN	-0.0209	-0.0053	0.0154	338.257	876.085	392	117624196	126803861	128105431	123951692	123294513
12	Philippines	13	342353	298170	PH	PHL	0.0561	0.0154	0.0147	393.525	1019.23	608	48419546	77958223	94636700	115559009	117337368
13	Egypt	14	1.00245e+06	995450	EG	EGY	0.0551	0.0156	0.0141	113.232	293.27	818	43748556	71371371	87252413	110990103	112716598
14	DR Congo	15	2.34486e+06	2.26705e+06	CD	COD	0.105	0.0329	0.0128	45.1083	116.831	180	26700686	48616317	66391257	99010212	102262808
15	Vietnam	16	331212	313429	VN	VNM	0.0208	0.0068	0.0123	315.411	816.914	704	52968270	79001142	87411012	98186856	98858950
16	Iran	17	1.6482e+06	1.6225e+06	IR	IRN	0.0208	0.007	0.0111	54.9601	142.347	364	38520664	65544383	75373855	88558570	89172767
17	Turkey	18	783562	783562	TR	TUR	0.0143	0.0056	0.0107	109.521	283.658	792	44089869	64113547	73195345	85341241	85816199
18	Germany	19	357114	349390	DE	DEU	-0.0012	-0.0009	0.0104	238.4	617.456	276	77786703	81551677	81325890	83369843	83294633
19	Thailand	20	513120	510890	TH	THA	0.003	0.0015	0.009	140.542	364.003	764	45737753	63066603	68270489	71697030	71801279
20	United Kingdom	21	242900	241930	GB	GBR	0.0072	0.0034	0.0085	279.985	725.162	826	56326328	58850043	62760039	67508936	67736802
21	Tanzania	22	945087	885800	TZ	TZA	0.0622	0.0296	0.0084	76.1324	197.183	834	19297659	34463704	45110527	65497748	67438106
22	France	23	551695	547557	FR	FRA	0.004	0.002	0.0081	118.265	306.305	250	53713830	58665453	62444567	64626628	64756584
23	South Africa	24	1.22104e+06	1.21309e+06	ZA	ZAF	0.0173	0.0087	0.0075	49.8022	128.988	710	29463549	46813266	51784921	59893885	60414495
24	Italy	25	301336	295717	IT	ITA	-0.0054	-0.0028	0.0074	199.078	515.612	380	56329482	56966397	59022450	59037474	58870762
25	Kenya	26	580367	569140	KE	KEN	0.0346	0.0199	0.0069	96.8138	250.748	404	16187124	30851606	41517895	54027407	55100586
26	Myanmar	27	676578	652670	MM	MMR	0.0125	0.0074	0.0068	83.6227	216.583	104	33465781	45538332	49390988	54179306	54577997
27	Colombia	28	1.14175e+06	1.1095e+06	CO	COL	0.008	0.0041	0.0065	46.9447	121.587	170	26176195	39215135	44816108	51874024	52085168
28	South Korea	29	100210	97600	KR	KOR	-0.0012	-0.0006	0.0065	530.574	1374.19	410	38170581	46788591	48813042	51815810	51784059
29	Uganda	30	241550	200520	UG	UGA	0.0423	0.0282	0.0061	242.282	627.51	800	13284026	24020697	32341728	47249585	48582334
30	Sudan	31	1.88607e+06	1.868e+06	SD	SDN	0.0394	0.0263	0.006	25.7543	66.7036	729	16673586	26298773	33739933	46874204	48189806
31	Spain	32	505992	499557	ES	ESP	-0.0014	-0.0008	0.0059	95.1236	246.37	724	37491666	40741651	46572772	47558630	47519628

Index	count	mean	std	min	25%	50%	75%	max
rank	224	112.915	65.3049	1	56.75	112.5	169.25	227
area	224	603662	1.79693e+06	2.02	6106.25	87480.5	446762	1.70982e+07
landAreaKm	224	578248	1.72362e+06	2	5832.5	85497	416370	1.63769e+07
netChange	224	0.0103929	0.0349172	-0.0286	0	0.0009	0.008075	0.4184
growthRate	224	0.00997991	0.0124894	-0.0745	0.002575	0.00835	0.017775	0.0498
worldPercentage	224	0.00448482	0.0175205	0	0.0001	0.0008	0.003075	0.1785
density	224	460.344	2021.32	0.138	42.8044	99.8273	242.497	21402.7
densityMi	224	1192.29	5235.22	0.3574	110.863	258.553	628.068	55433
place	224	434.094	255.71	4	213.5	429	659.25	894
pop1980	224	1.98275e+07	8.34989e+07	6560	322399	3.37943e+06	1.03772e+07	9.82372e+08
pop2000	224	2.74338e+07	1.14036e+08	9638	434857	4.75962e+06	1.63293e+07	1.2641e+09
pop2010	224	3.11679e+07	1.26811e+08	10241	535598	5.4401e+06	2.07814e+07	1.34819e+09
pop2022	224	3.55838e+07	1.39608e+08	11312	624822	6.15604e+06	2.44374e+07	1.42589e+09
pop2023	224	3.5897e+07	1.40239e+08	11396	625673	6.23591e+06	2.44827e+07	1.42863e+09
pop2030	224	3.81314e+07	1.44715e+08	11229	661922	6.69341e+06	2.83299e+07	1.51499e+09
pop2050	224	4.33211e+07	1.51192e+08	11349	768297	8.33673e+06	3.66369e+07	1.67049e+09

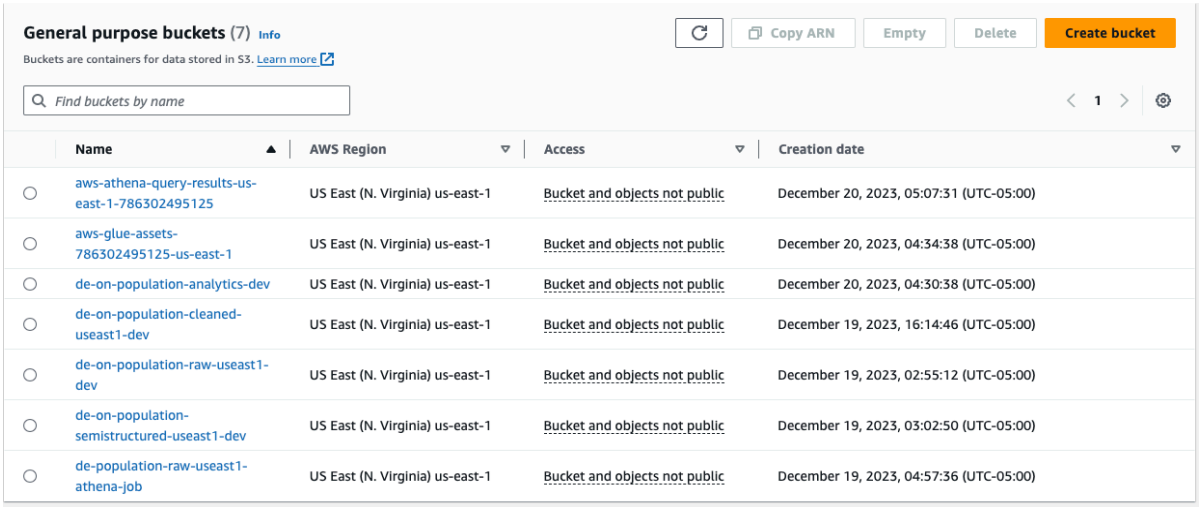
5. METHODOLOGY



This section explains the steps and approach carried out to build the ETL pipeline. ETL is a common data wrangling process that involves extracting data from a source system, transforming it into a usable format, and then loading it into a target system. We will now review each section of the pipeline:

5.1 Amazon S3

S3 serves as the primary data storage solution. Raw, unprocessed data is commonly stored in an S3 landing zone. After transformation, the cleaned and processed data is stored back in S3 or moved to a different S3 bucket. Here is a detailed view of all the S3 buckets that were created and used throughout the pipeline formation and execution.

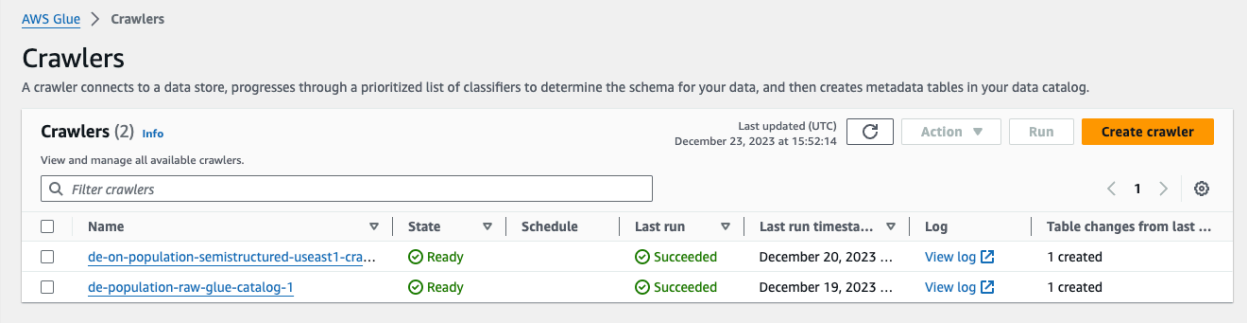


5.2 AWS Glue & Data Catalog

AWS Glue is a fully managed ETL service. It automates the process of cleaning, transforming, and preparing data for analysis. Glue supports visual programming and code-based scripting for data transformation tasks.

We first created a crawler in AWS glue for building the raw data catalog and semi structured data catalog.

Upon running successfully, the crawler adds tables in the database.

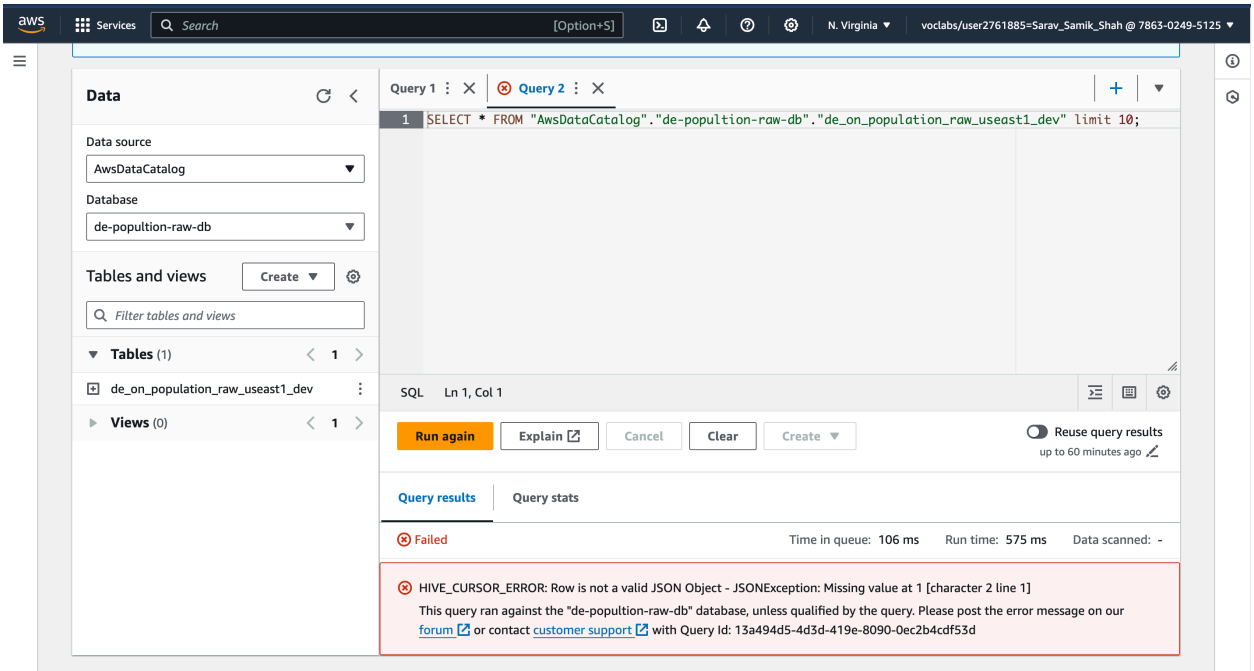


To Query on the data table, we will be redirected to AWS Athena

Upon running the select we get error. It's not able to understand the json data. (array data type).

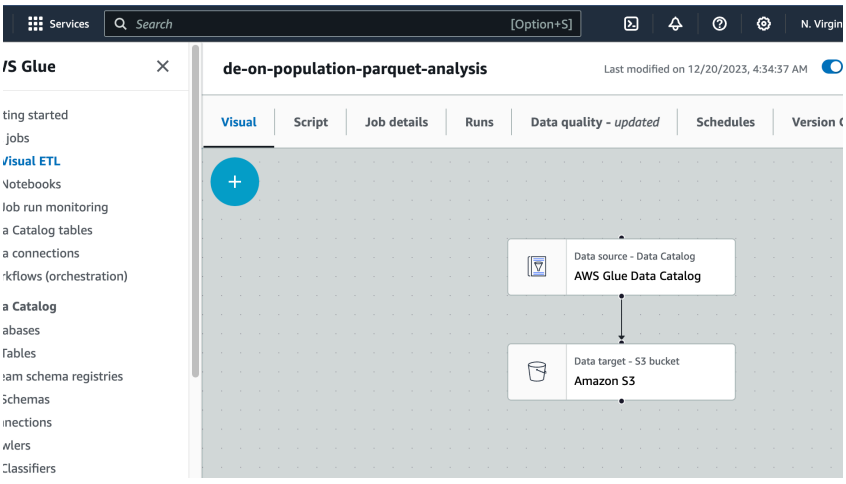
The reason why we are facing this issue because of an issue called SerDe.

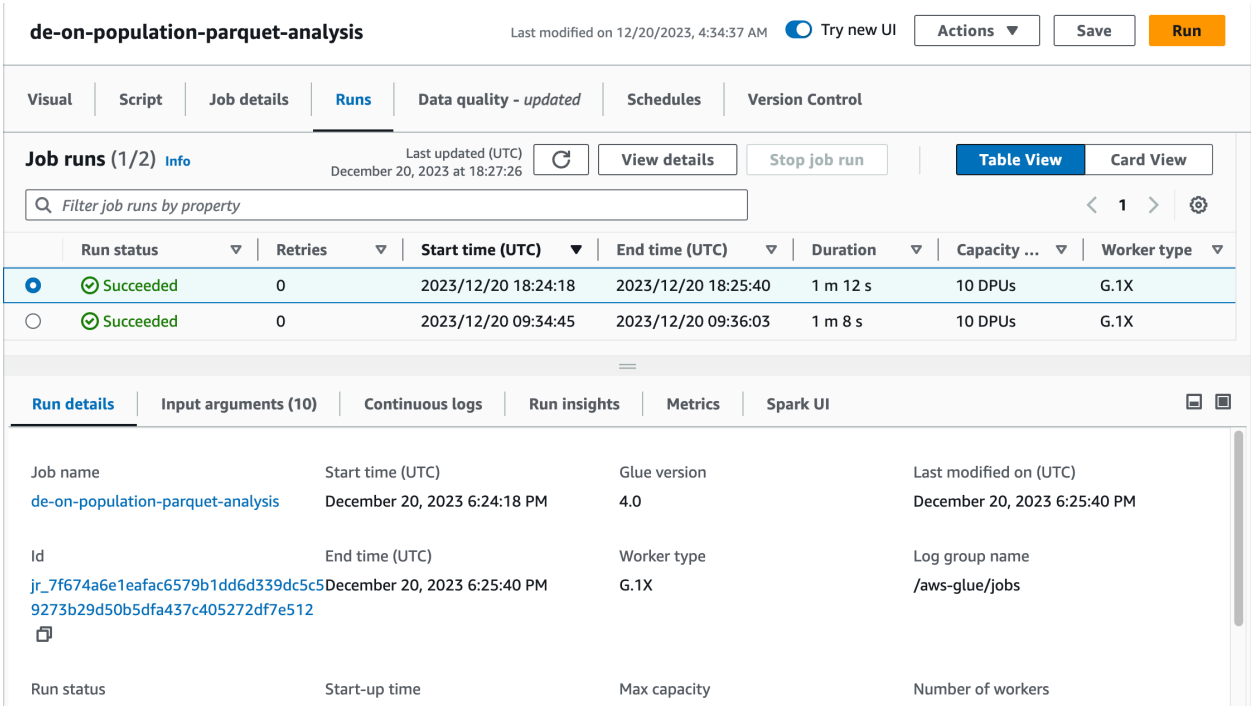
The SerDe expects each JSON document to be on a single line of text with no line termination characters separating the fields in the record. If the JSON text is in pretty print format, you may receive an error message.



AWS Glue ETL job

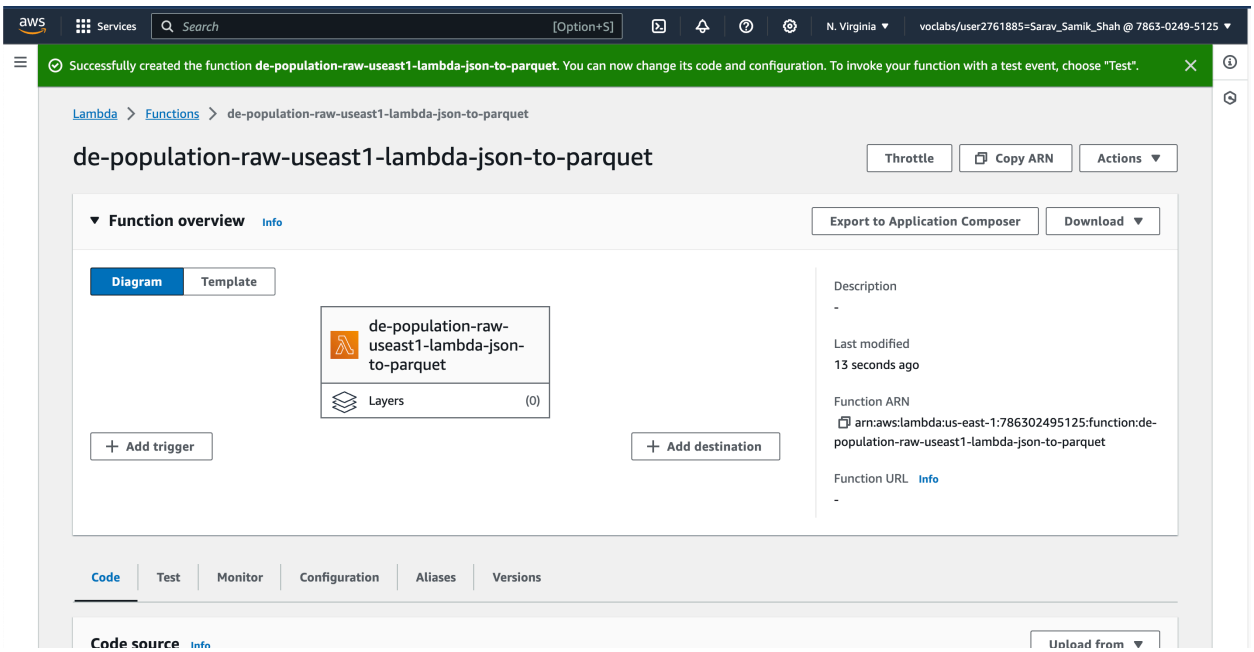
Glue ETL jobs work with a data structure called a DynamicFrame, which is an extension of Apache Spark DataFrames. It provides a flexible and schema-less representation of your data. Glue offers Fully managed ETL service for processing data at scale.
It writes the transformed data to the destination specified.



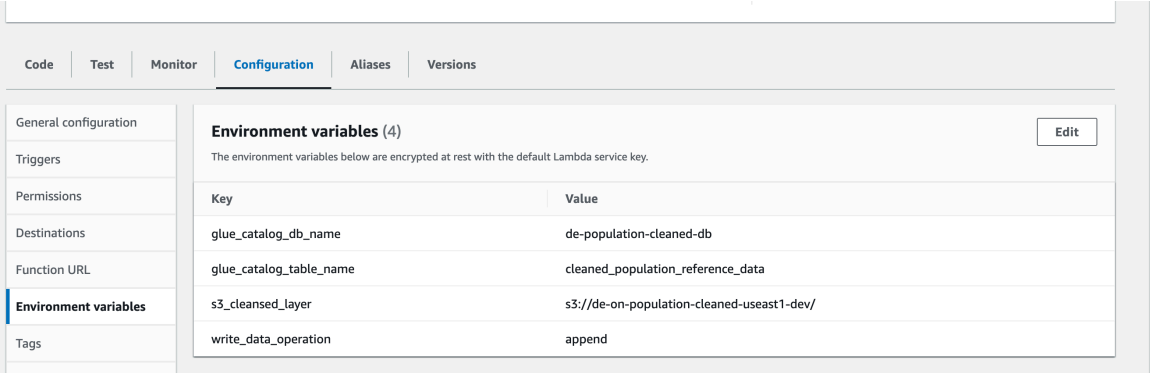

de-on-population-parquet-analysis
Last modified on 12/20/2023, 4:34:37 AM
Try new UI
Actions
Save
Run
Visual
Script
Job details
Runs
Data quality - updated
Schedules
Version Control
Job runs (1/2) Info
Last updated (UTC)
December 20, 2023 at 18:27:26
View details
Stop job run
Table View
Card View
Filter job runs by property
1
Run status
Retries
Start time (UTC)
End time (UTC)
Duration
Capacity ...
Worker type
Succeeded
0
2023/12/20 18:24:18
2023/12/20 18:25:40
1 m 12 s
10 DPUs
G.1X
Succeeded
0
2023/12/20 09:34:45
2023/12/20 09:36:03
1 m 8 s
10 DPUs
G.1X
Run details
Input arguments (10)
Continuous logs
Run insights
Metrics
Spark UI
Job name
de-on-population-parquet-analysis
Start time (UTC)
December 20, 2023 6:24:18 PM
Glue version
4.0
Last modified on (UTC)
December 20, 2023 6:25:40 PM
Id
jr_7f674a6e1eafac6579b1dd6d339dc5c59273b29d50b5dfa437c405272df7e512
End time (UTC)
December 20, 2023 6:25:40 PM
Worker type
G.1X
Log group name
/aws-glue/jobs
Run status
Start-up time
Max capacity
Number of workers

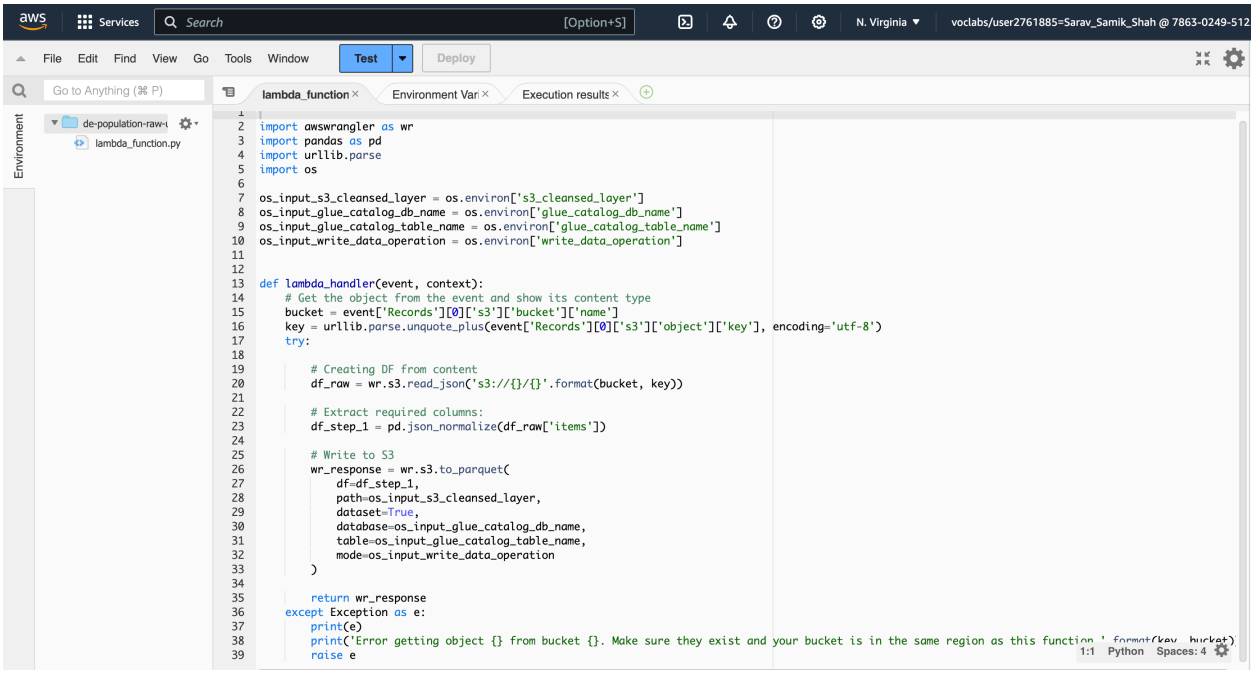
5.3 AWS Lambda

Parquet is a columnar storage format, meaning that it stores data column-wise rather than row-wise.
Parquet files store schema information, which allows for schema evolution. This means that as the schema of your data evolves over time (e.g., new columns are added), Parquet files can handle these changes without requiring modification of the entire dataset. Example: once if you convert the datatype of a column, this format will be saved and all the new files that will be processed be stored with the updated data format.
Hence we convert the JSON file to Parquet file format.

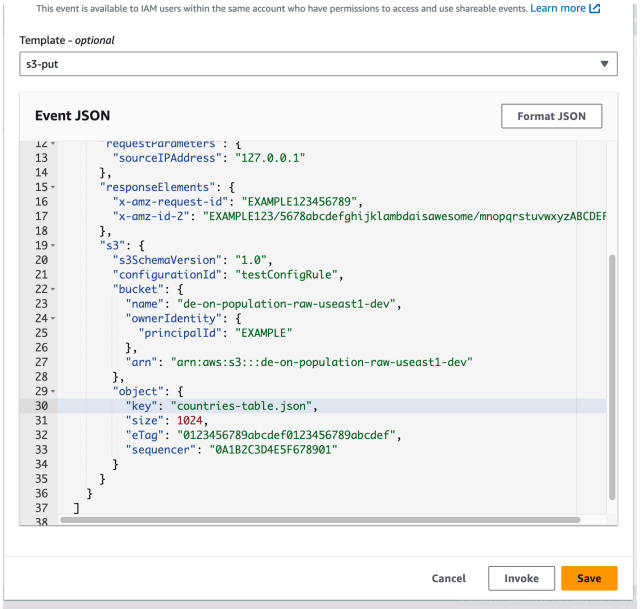


Further we do some data transformation in AWS lambda and stored the cleaned data again in S3 buckets.
Layers enable you to isolate common code and dependencies, making it easier to test and update shared components independently of the function logic.
The code used for data cleaning is given below and we have declared some global variables for better security.

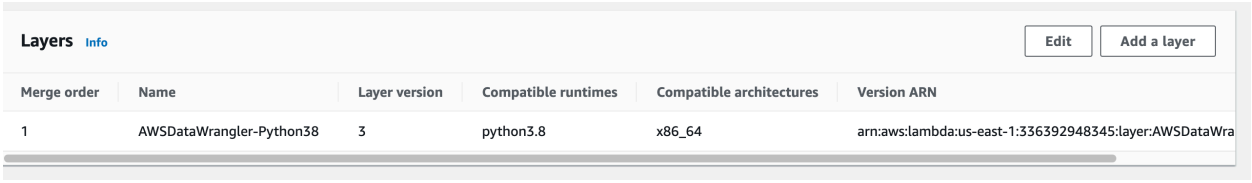




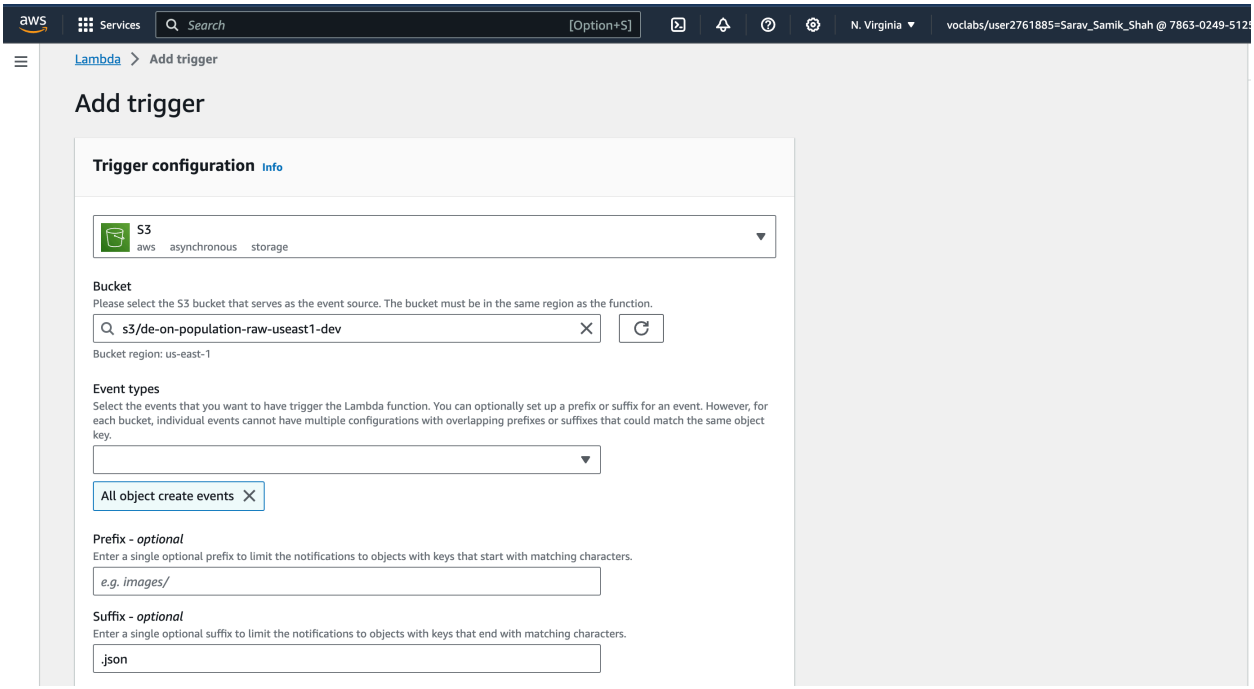
The test function that we used is S3-put:

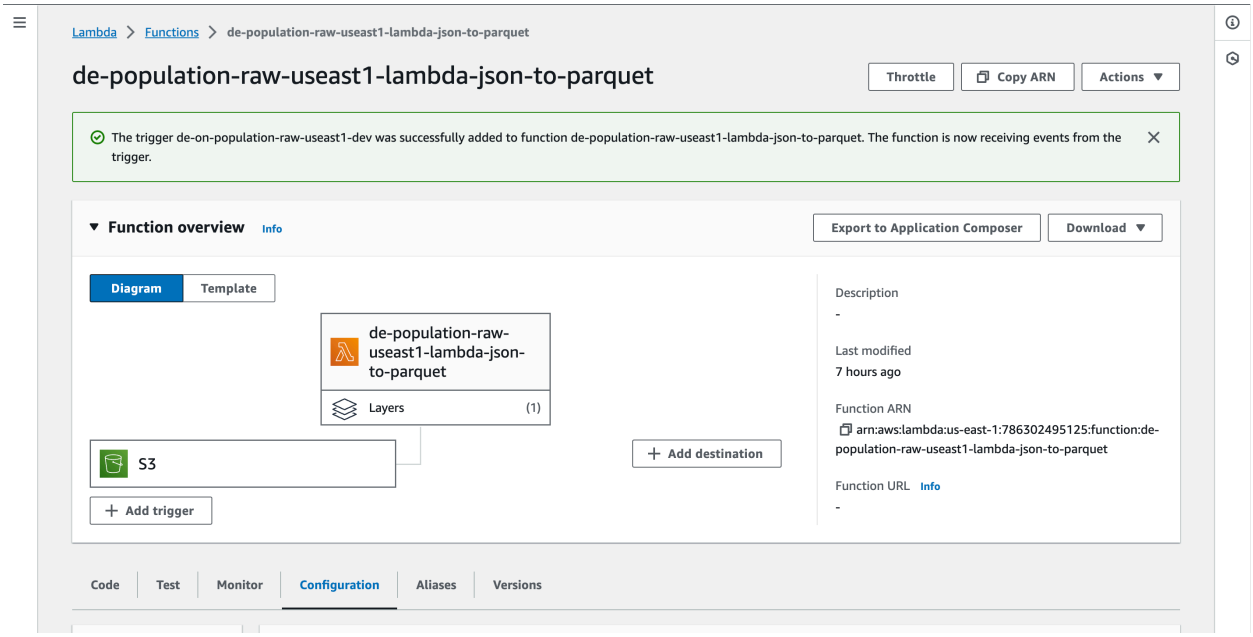


Layers enable you to isolate common code and dependencies, making it easier to test and update shared components independently of the function logic.
Adding the AWS Lambda layer:

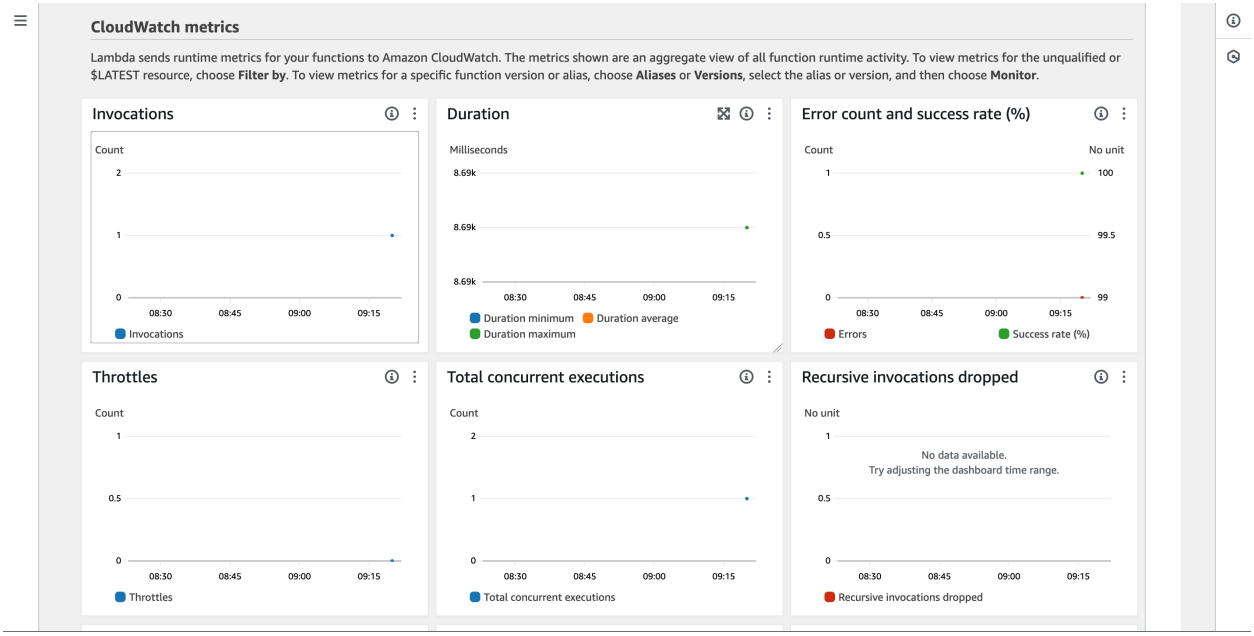


Creating a trigger to automate the Lambda function to clean the data each time a new dataset is uploaded to the S3 bucket:

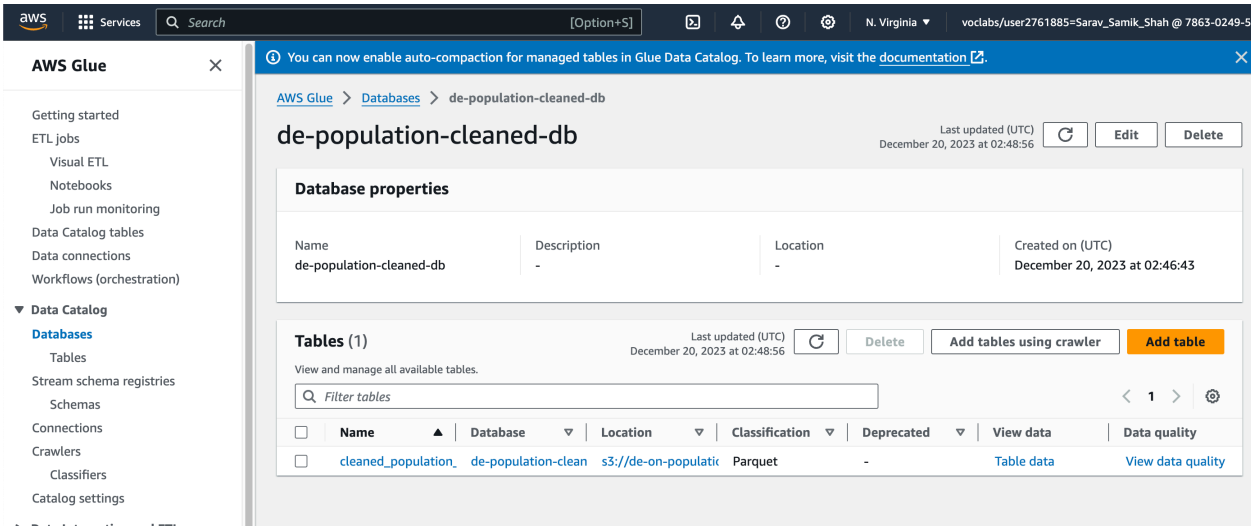




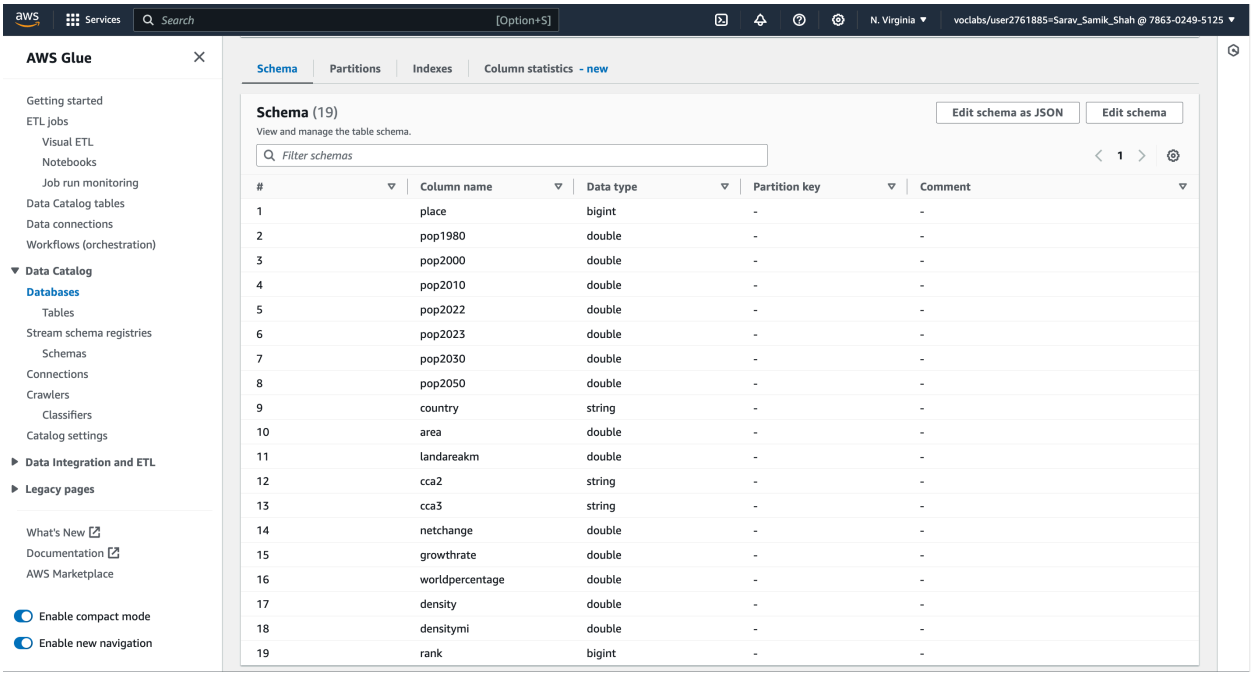
Whenever a new file / dataset is uploaded in the targeted S3 bucket, the Lambda function gets triggered.



The clean version of the data is also now available in AWS Glue -> Data Catalog -> The database that we specified -> Tables.



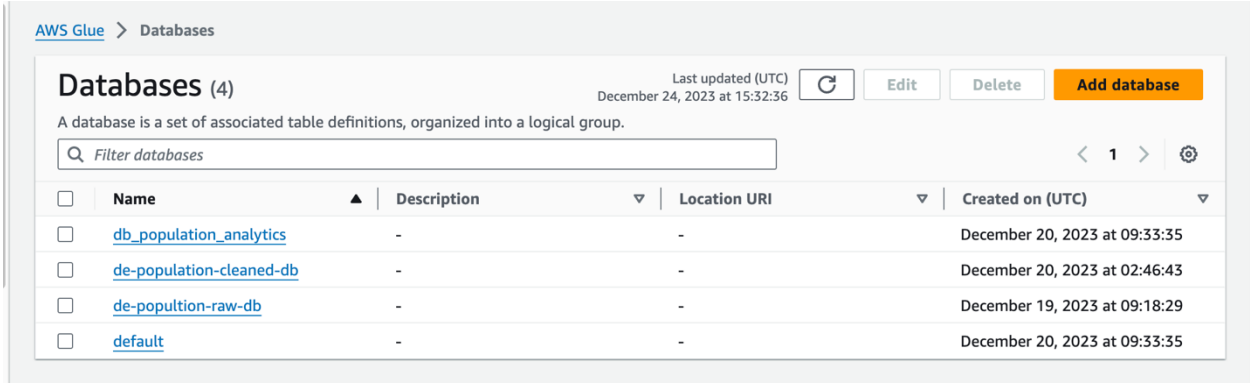
We can see here the structured version of our data is now created:

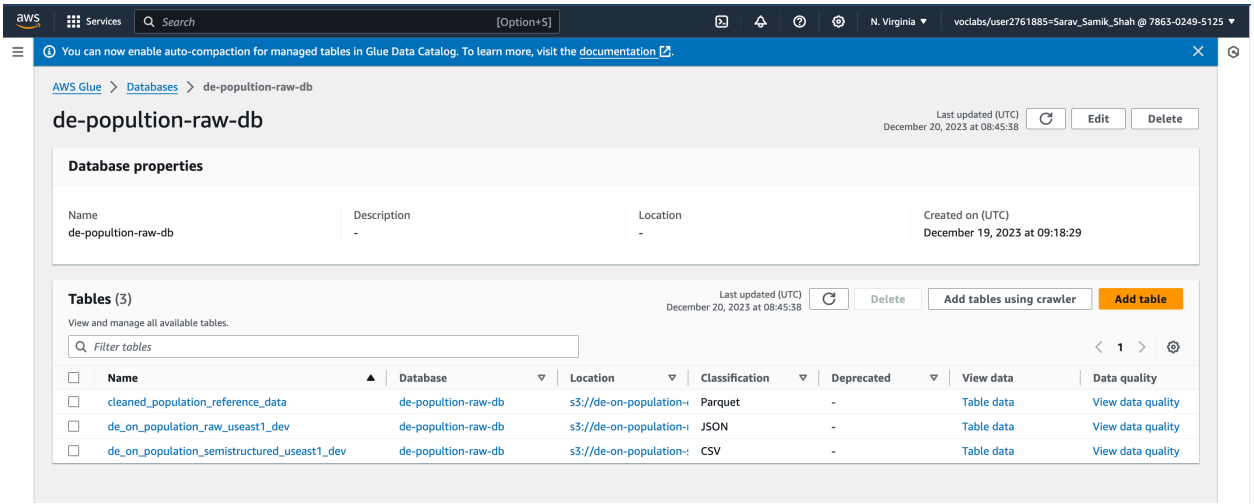


5.4 AWS Athena

Amazon Athena is an interactive query service that enables querying data directly from Amazon S3 using SQL. It is a serverless and fully managed service, allowing users to analyze and derive insights from data stored in S3 without the need to set up and manage complex infrastructure.

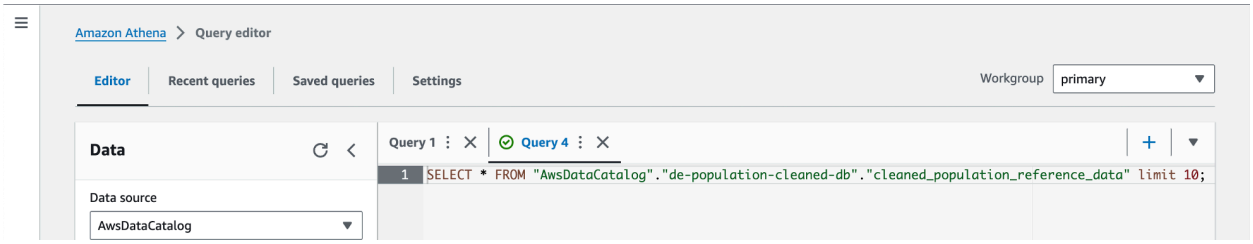
Here's a list of the databases and tables available in AWS glue:



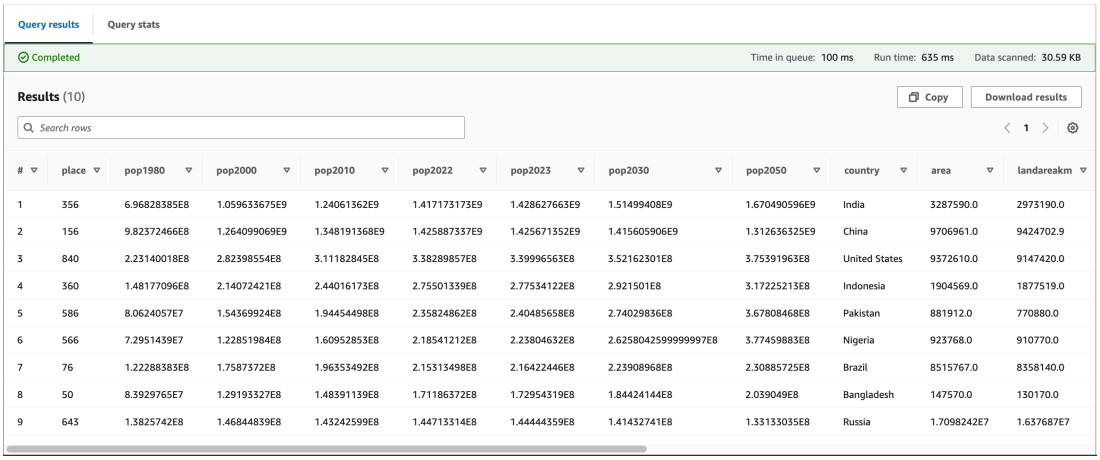


We can now query on the data using Amazon Athena.

Query:

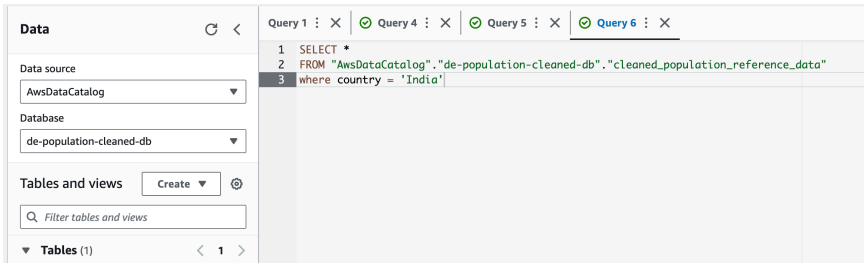


Result:

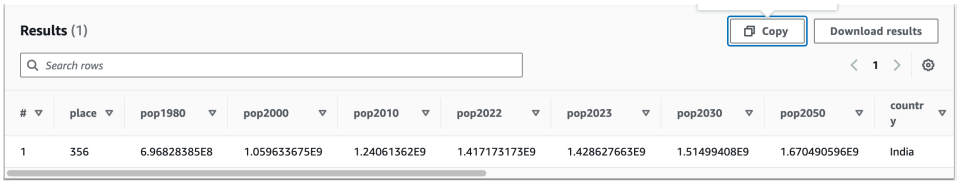


#	place	pop1980	pop2000	pop2010	pop2022	pop2023	pop2030	pop2050	country	area	landareakm
1	356	6.96828385E8	1.059633675E9	1.24061362E9	1.417173173E9	1.428627663E9	1.51499408E9	1.670490596E9	India	3287590.0	2973190.0
2	156	9.82372466E8	1.264099069E9	1.348191368E9	1.425887337E9	1.425671352E9	1.415605906E9	1.312636325E9	China	9706961.0	9424702.9
3	840	2.23140018E8	2.82398554E8	3.11182845E8	3.38289857E8	3.39996563E8	3.52162301E8	3.75391963E8	United States	9372610.0	9147420.0
4	360	1.48177096E8	2.14072421E8	2.44016173E8	2.75501339E8	2.77534122E8	2.921501E8	3.17225213E8	Indonesia	1904569.0	1877519.0
5	586	8.0624057E7	1.54369924E8	1.94454498E8	2.35824862E8	2.40485658E8	2.74029836E8	3.67808468E8	Pakistan	881912.0	770880.0
6	566	7.2951439E7	1.22851984E8	1.60952853E8	2.18541212E8	2.23804632E8	2.6258042599999997E8	3.77459883E8	Nigeria	923768.0	910770.0
7	76	1.22288383E8	1.7587372E8	1.96353492E8	2.15313498E8	2.16422446E8	2.23908968E8	2.30885725E8	Brazil	8515767.0	8358140.0
8	50	8.3929765E7	1.29193327E8	1.48391139E8	1.71186372E8	1.72954319E8	1.84424144E8	2.039049E8	Bangladesh	147570.0	130170.0
9	643	1.3825742E8	1.46844839E8	1.43242599E8	1.44713314E8	1.44444359E8	1.41432741E8	1.33133035E8	Russia	1.7098242E7	1.637687E7

Query:



Result:

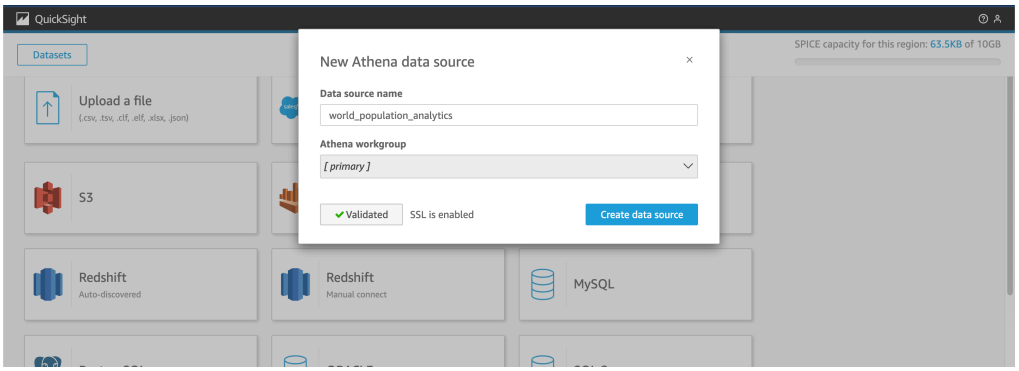


#	place	pop1980	pop2000	pop2010	pop2022	pop2023	pop2030	pop2050	country
1	356	6.96828385E8	1.059633675E9	1.24061362E9	1.417173173E9	1.428627663E9	1.51499408E9	1.670490596E9	India

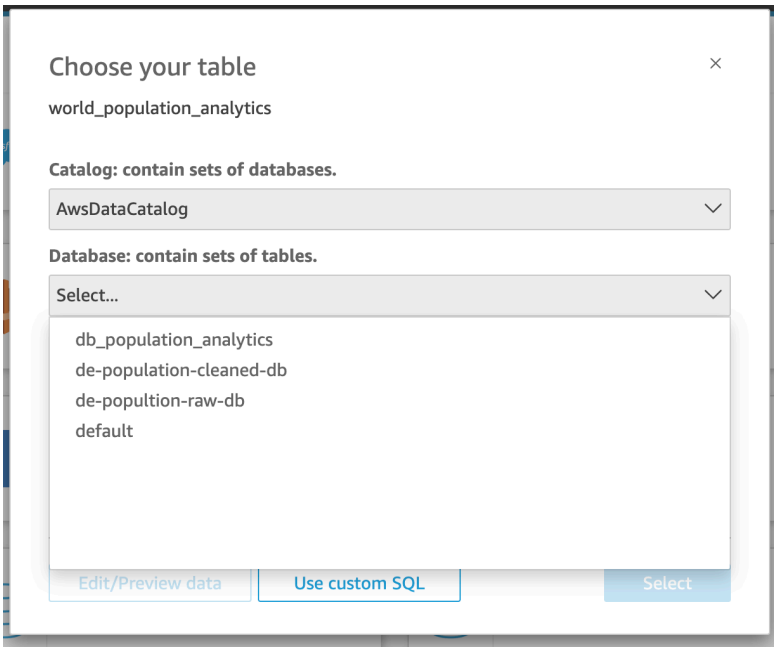
5.5 AWS QuickSight

Athena can be integrated with AWS QuickSight, allowing us to create dashboards and reports based on real-time or historical data stored in Amazon S3.

Integrating Athena as a data source for QuickSight:



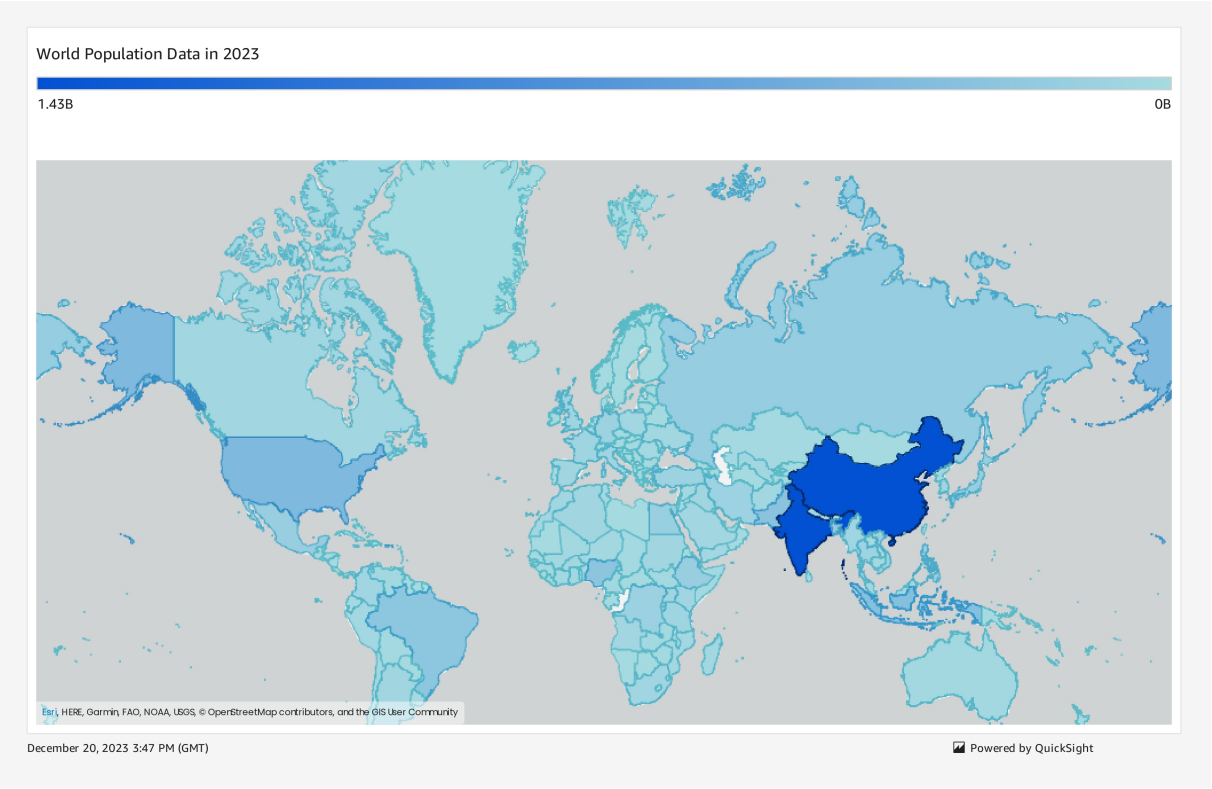
Here we get a list of all the databases and the data tables:

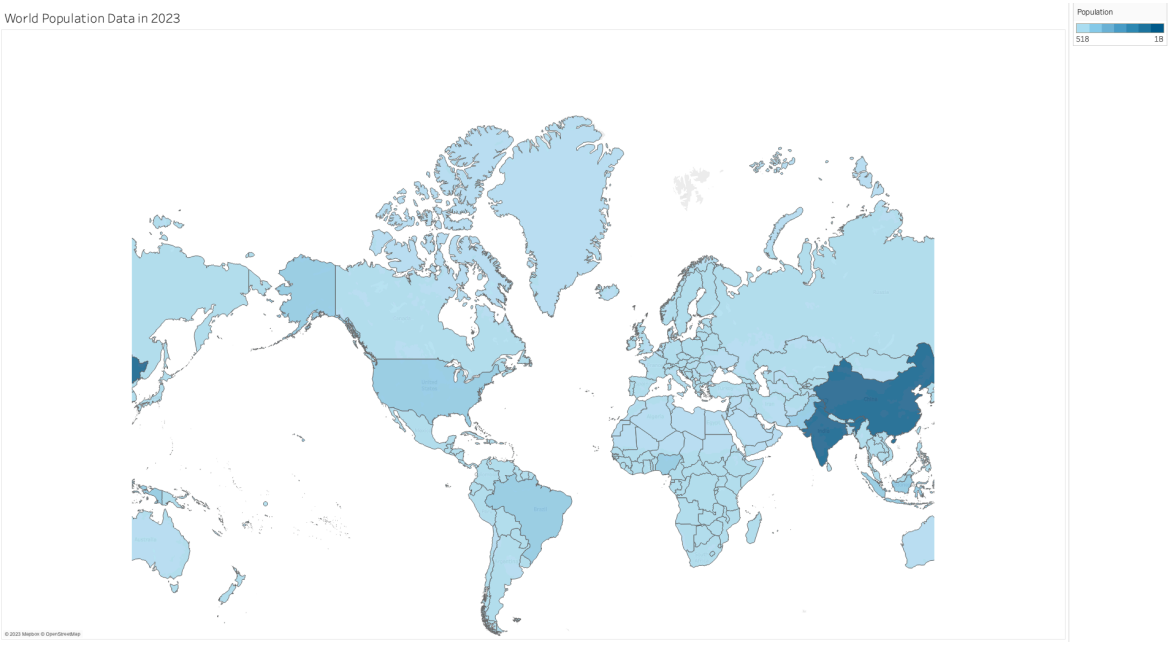


6. RESULTS

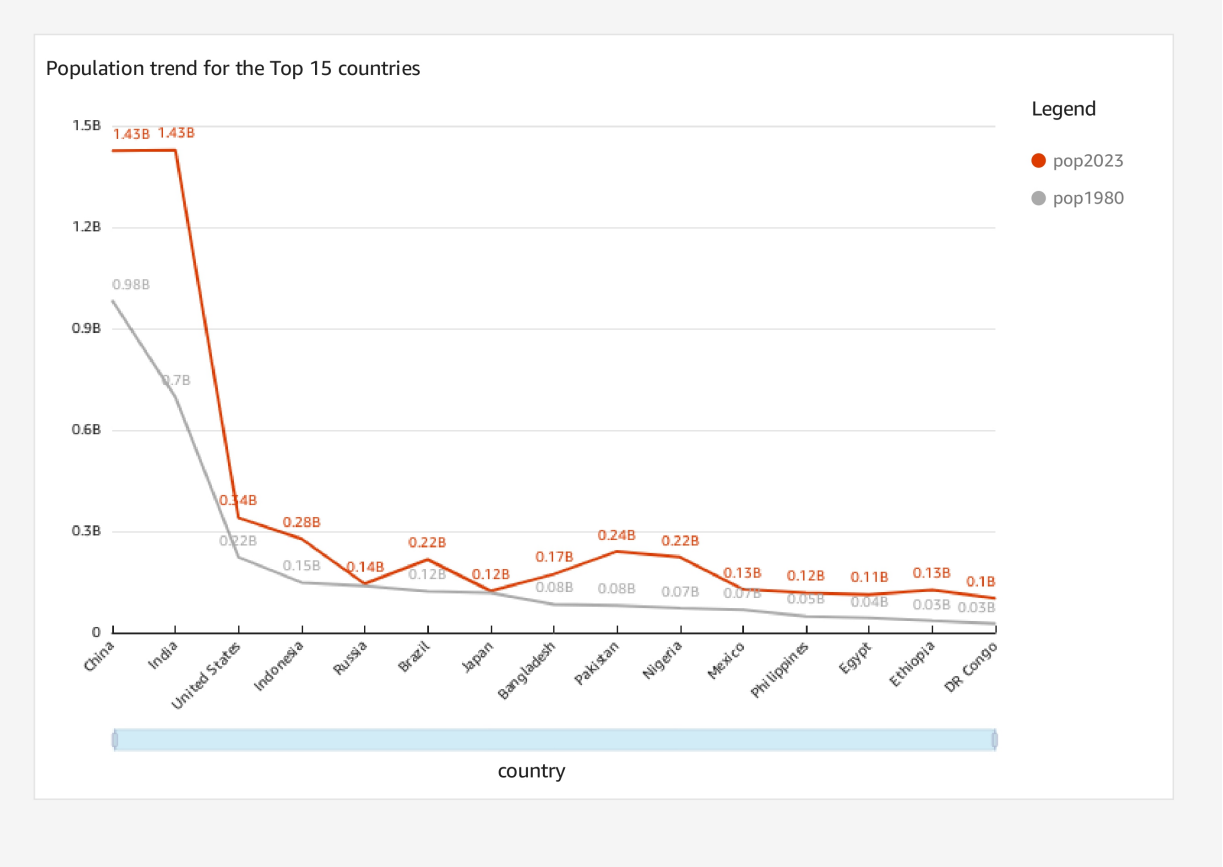
Comparing Visualization in QuickSight vs Tableau

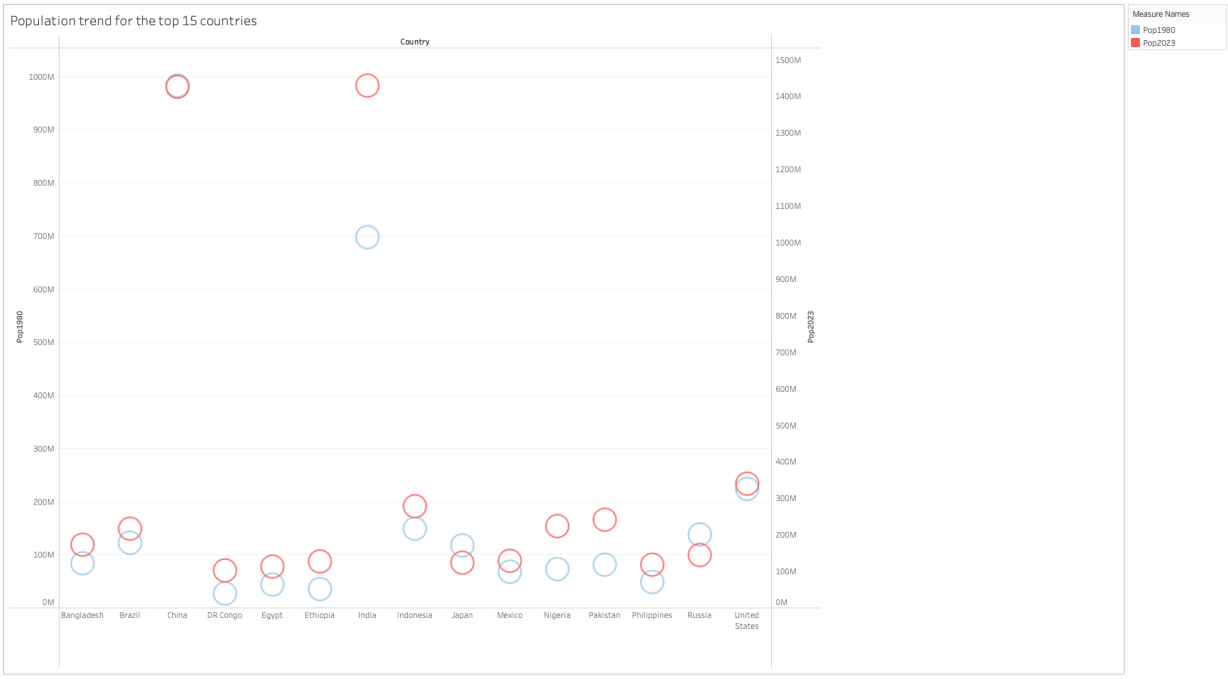
Representation of Population for all the countries in 2023 based on Longitude (generated) and Latitude (generated).



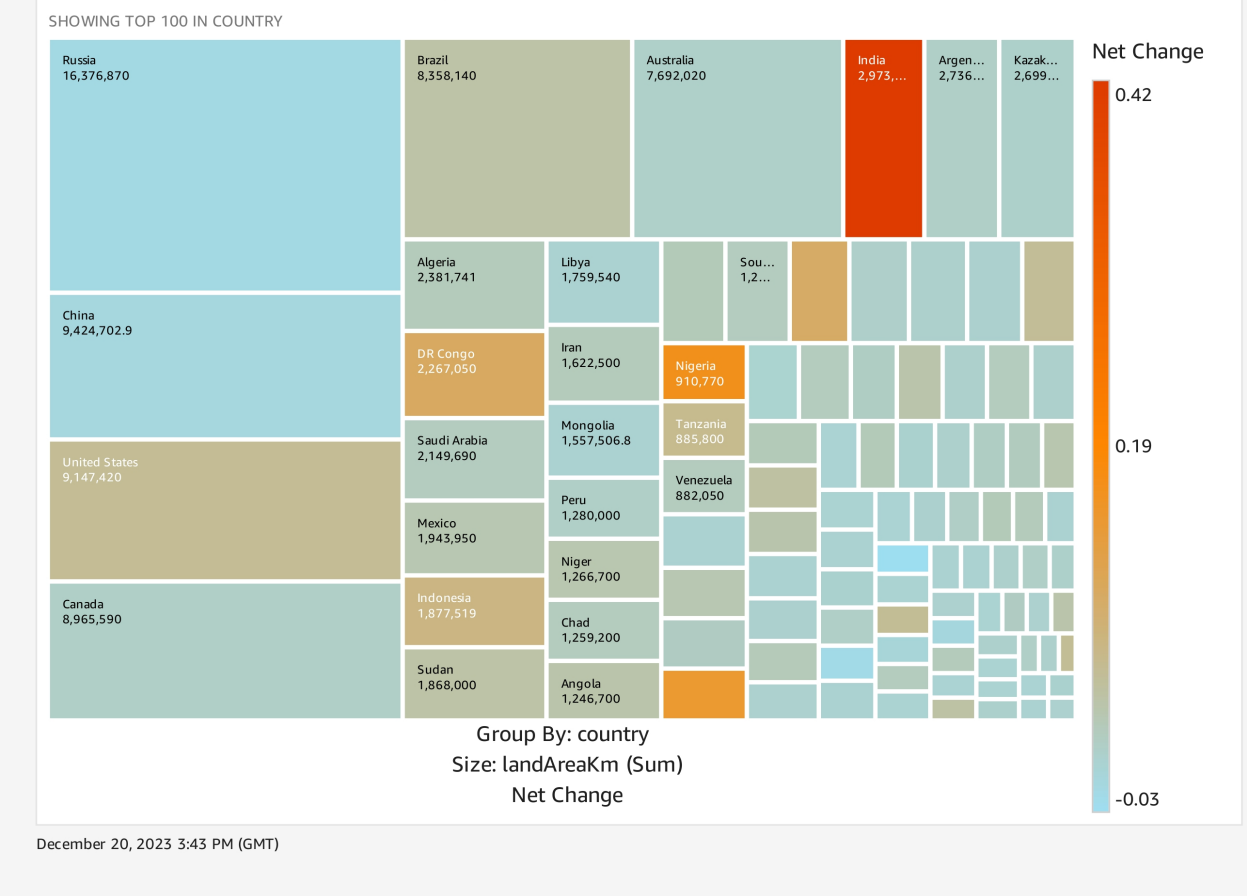


Population trend for the Top 15 countries having the highest population. The graph demonstrates a comparison between the population in 1908 and 2023.





This graph aims to compare the Net change in population for the top 100 countries vs the Land area under the country using AWS QuickSight.



7. CONCLUSION

7.1 ETL Pipeline Performance:
Our evaluation of the ETL pipeline revealed commendable performance in handling diverse data sources and processing volumes. The seamless integration of AWS services, from S3 storage to AWS Glue ETL jobs, contributed to efficient data processing. Athena's SQL-based querying proved invaluable for ad-hoc analyses, demonstrating the agility of the pipeline.

7.2 QuickSight Visualization:
Amazon QuickSight emerged as a powerful tool for data visualization. Its integration with AWS services allowed for the creation of interactive dashboards, providing a user-friendly interface for end-users. The incorporation of machine learning insights, such as anomaly detection and forecasting, added depth to the visualization experience.

The ETL pipeline and QuickSight implementation demonstrated a tangible impact on business decision-making. The accessibility of actionable insights, reduction in data processing times, and the ability to create real-time dashboards contributed to informed decision-making within the organization.

7.3 Comparative Analysis with Tableau:

- QuickSight seamlessly integrates with the broader AWS ecosystem, offering native connectivity to various AWS data sources.

- AWS QuickSight operates on a serverless architecture, eliminating the need for infrastructure management and offers pay-as-you-go pricing.

- QuickSight offers fast query performance even with large datasets. It leverages a cloud architecture, distributed processing, enabling users to analyze and visualize data with low latency.

- QuickSight incorporates machine learning (ML) insights. Hence any user on the business side with the basic knowledge of ML can enhance the depth of analysis without requiring to be ML experts.