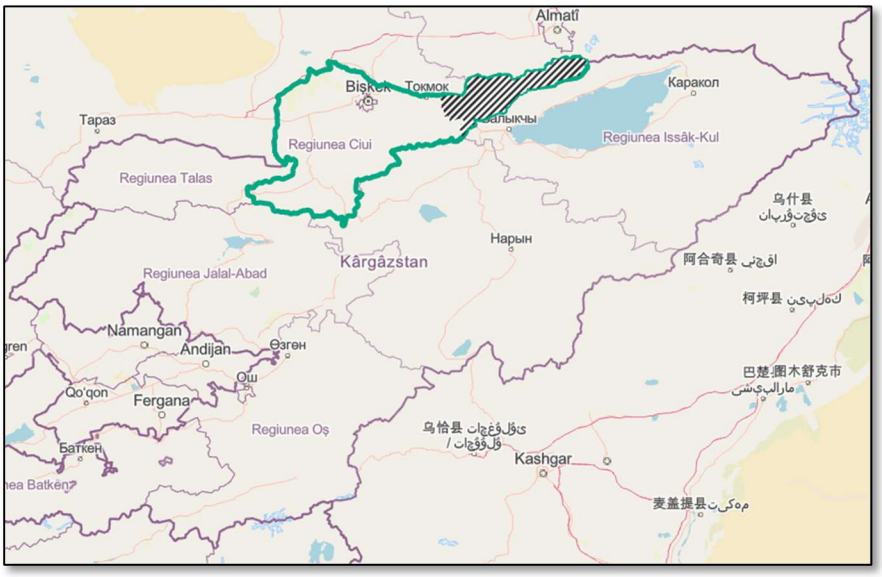
Modeling SDG indicator 9.1.1

Proportion of the rural population who live within 2 km of an all-season road

Author: Elena Hristev

The guide provides step-by-step methodology to estimate SDG indicator 9.1.1 "Proportion of rural population who live within 2 km of all-season road." While this guide utilizes in-country national datasets from **Kyrgyzstan** as a practical case study, the outlined methodology is designed to be universally applicable to any country with access to similar geospatial data. The methodology aims to offer a convenient and automated approach for National Statistics Offices (NSOs) and GIS professionals worldwide to model and report on this crucial SDG indicator. The presented example focuses on a test area (Kemin rayon of Chuy region, Kyrgyzstan), but the model is scalable and applicable to national extents.



Introduction to SDG Indicator 9.1.1

SDG indicator 9.1.1 aligns with **Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation** and specifically **Target 9.1: Develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all.**

This indicator is a key metric for assessing rural connectivity and accessibility, crucial for economic development, access to services, and overall human well-being. The very nature of the indicator suggests two major geospatial data inputs: an **all-season roads dataset** and **rural population statistics.** Both datasets are inherently geospatial, enabling direct spatial modeling of the indicator.

ESCAP
Economic and Social Commission for Asia and the Pacific

Key Data Inputs and Considerations:

1. **All-season Roads Network Data:**

- **Definition:** An all-season road is typically defined as a road that is motorable all year round, implying it remains passable regardless of weather conditions (e.g., heavy rain, snow).
- **Format:** Vector data (lines) representing the road network.
- **Considerations:** National road network data may sometimes lack explicit information on seasonality. In such cases, all represented roads might be used as a proxy for all-season roads, as demonstrated in the Kyrgyzstan case study. Upon availability of precise, topologically correct data with explicit indications of all-seasonality, such data should be prioritized for more accurate modeling.

2. **Rural Population Data:**

- **Definition:** Geocoded population data specifically for rural areas. This could be in point format (e.g., individual buildings with population attributes) or raster format (population grids).
- **Format:** Point shapefile with rural buildings containing population statistics in rural areas.
- **Considerations:** For robust modeling, the most appropriate data is national geocoded geospatial data for "rural" buildings (representing rural population) based on cadastral information or equivalent, with a clear definition of whether buildings are in urban or rural areas. This distinction is critical to ensure only the *rural* population is included in the calculation.

Spatial Reference System

All datasets used in this guide are assumed to have a common spatial reference system (e.g., WGS 1984 UTM Zone 43N for the Kyrgyzstan example). For seamless modeling, please ensure all your input datasets are projected into a consistent and appropriate spatial reference system relevant to your country or region.

Input Geodata Sources (Examples)

The table below provides examples of the input geodata used in this guide. Users are expected to identify and procure equivalent open or national authoritative datasets for their specific region. For the Kyrgyzstan case study, data was sourced from national authoritative bodies.

Geodata	Name of geodata	national/ open data	To be used in analysis	Link
Administrative				
Kemin rayon boundary (for national level to be used: Boundary of Kyrgyzstan)	Kemin_KGZ	national	yes	geospatialSDGs/data/SDG911 at main · ESCAP-SD/geospatialSDGs
Chuy region boundary	Chuy_KGZ	national	no (visual)	geospatialSDGs/data/SDG911 at main · ESCAP-SD/geospatialSDGs
Road network				
All-season roads for Kyrgyzstan	KGZ_allroads	national	yes	geospatialSDGs/data/SDG911 at main · ESCAP-SD/geospatialSDGs
Population in Rural areas				
Buildings in rural areas with population info in Chuy region	Chuy_buildingsUTM43.shp	national	yes	geospatialSDGs/data/SDG911 at main · ESCAP-SD/geospatialSDGs

Upon completion of the guide you can assess your results against Final project with all deliverables and geospatial datasets via this link – geospatialSDGs/data/SDG911/SDG 911 ResultData.zip at main · ESCAP-SD/geospatialSDGs

System Requirements:

Software: *QGIS 3.28.11*

Recommended Hardware for data analytics and processing:

Intel i5/i7, RAM minimum 8 GB/recommended 16 GB, dedicated GPU

Year of analysis: *2017*

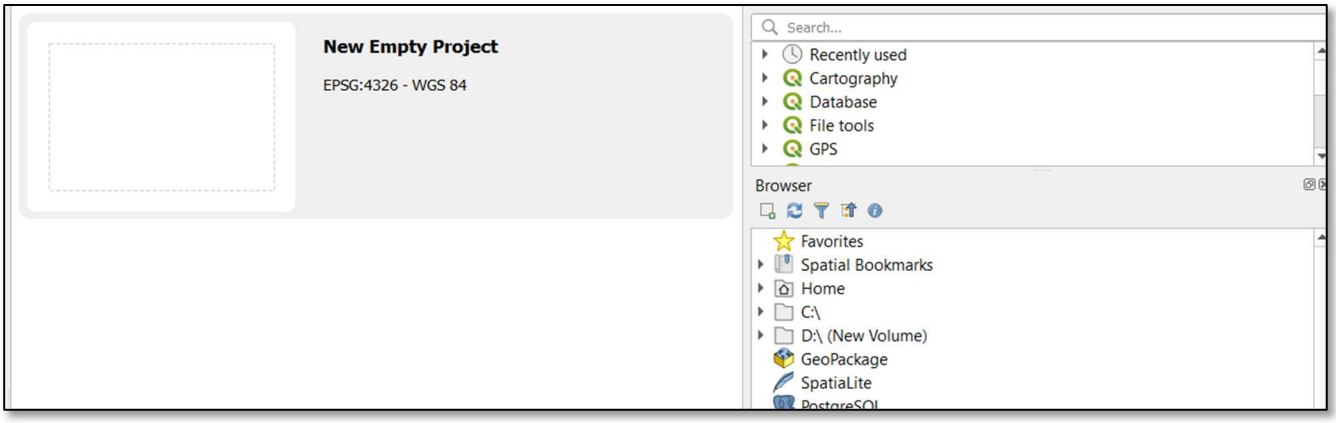
Methodology for obtaining SDG 9.1.1 based on national datasets

The step-by-step methodology below is structured into distinct phases of data processing and analytics, primarily using QGIS.

Step 0: Preparing Geodata

This initial step ensures all necessary data is organized and accessible within your QGIS environment.

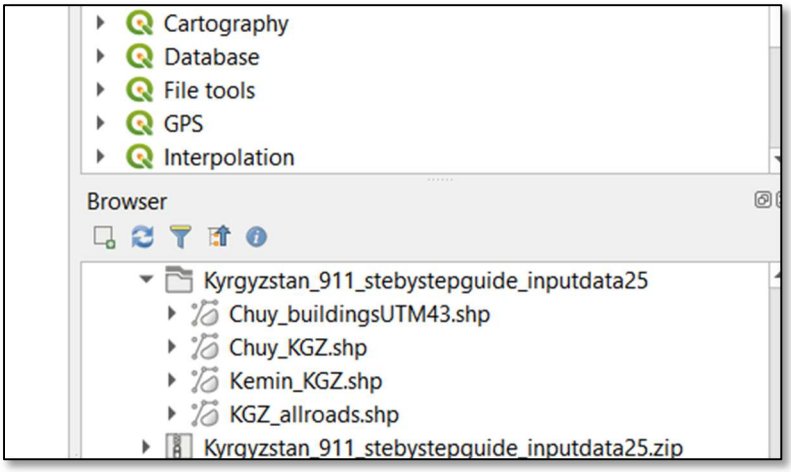
1. **Create a Dedicated Project Folder:** Create a new folder on your local drive (e.g., D:/SDG_911_Project). This folder will house all your input and output data.
2. **Download and Unzip Data:** Download all required spatial datasets (identifying relevant national or open global sources for your area, similar to the examples referenced above). Unzip all downloaded files into the D:/SDG_911_Project folder.
3. **Launch QGIS:** Open the QGIS Desktop application.
4. **Start a New Empty Project:** Choose (double-click) "New Empty Project" from the QGIS initial screen or navigate to Project > New Empty Project.



Step I: Road Network Geodata Processing and Analytics

This section focuses on preparing the road network data for analysis, including clipping to a specific area and creating a buffer zone.

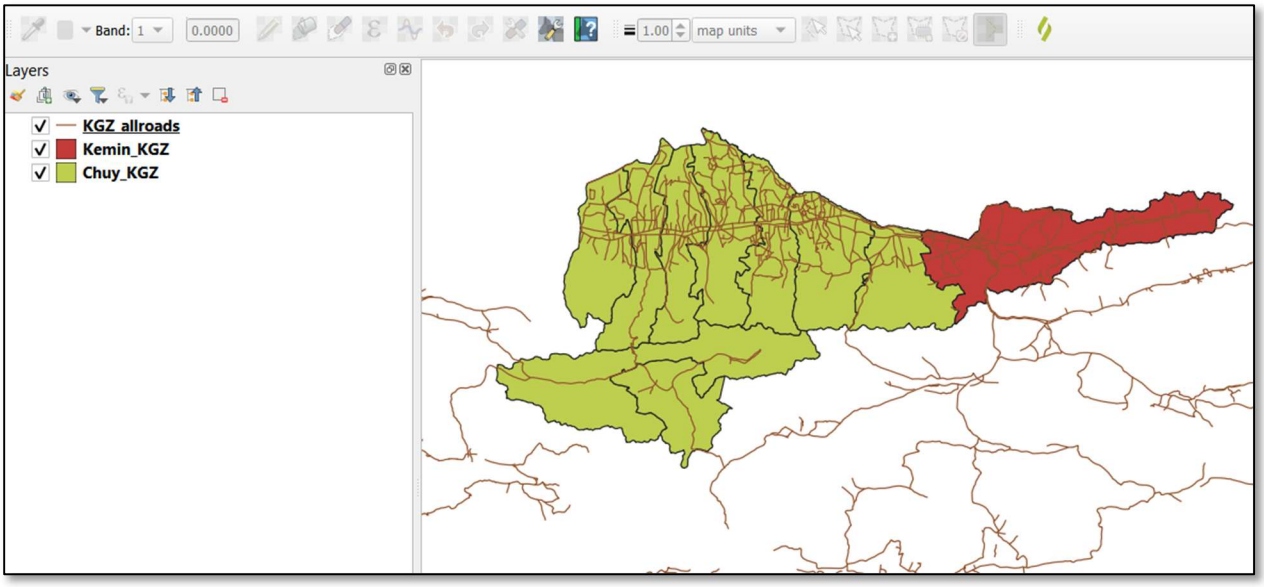
5. **Navigate to Project Folder in QGIS Browser:** In the 'Browser' panel (typically on the left), navigate to your newly created project folder (e.g., D:/SDG_911_Project).
6. **Add Vector Layers to Map**: Select (click) and drag-and-drop the relevant shapefiles from your project folder into the QGIS map canvas. For the Kyrgyzstan example, these would be Chuy_KGZ.shp (Chuy region boundary), Kemin_KGZ.shp (Kemin rayon boundary), and KGZ_allroads.shp (all-season roads).

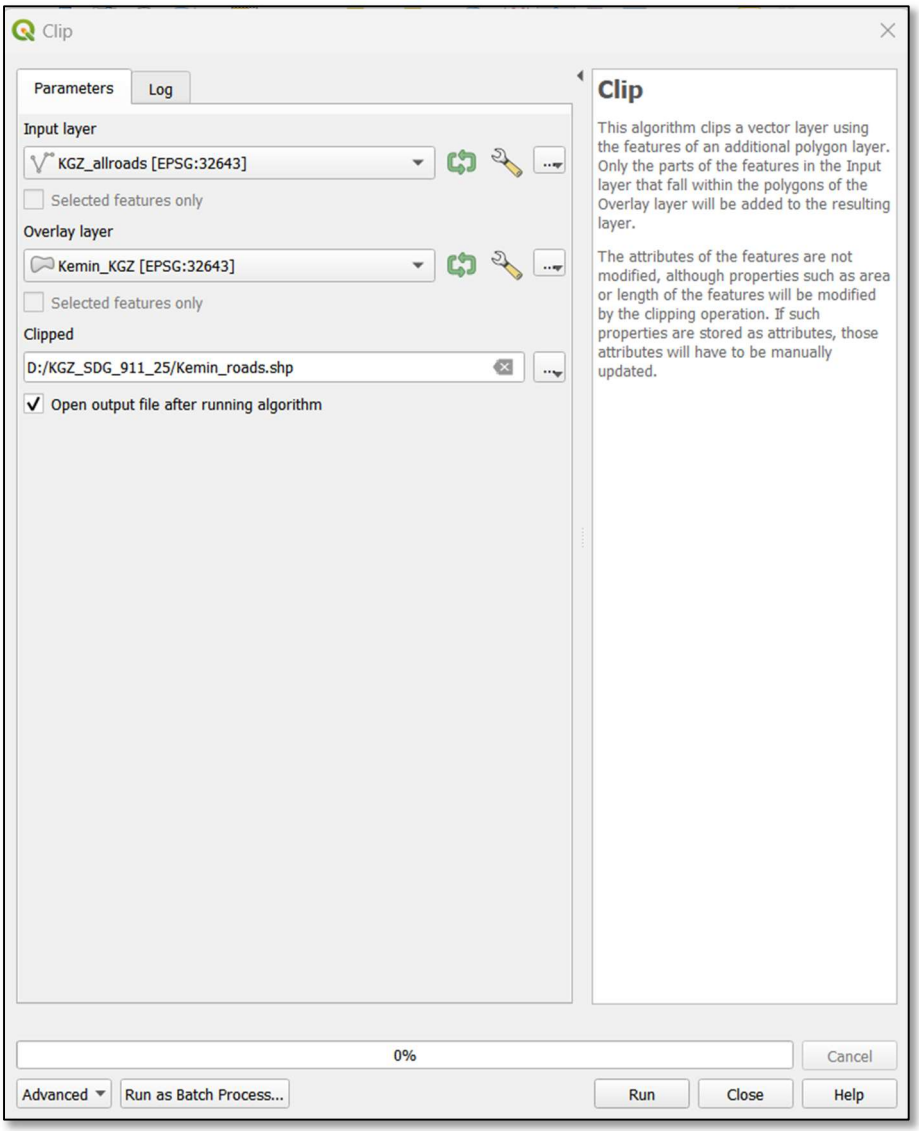


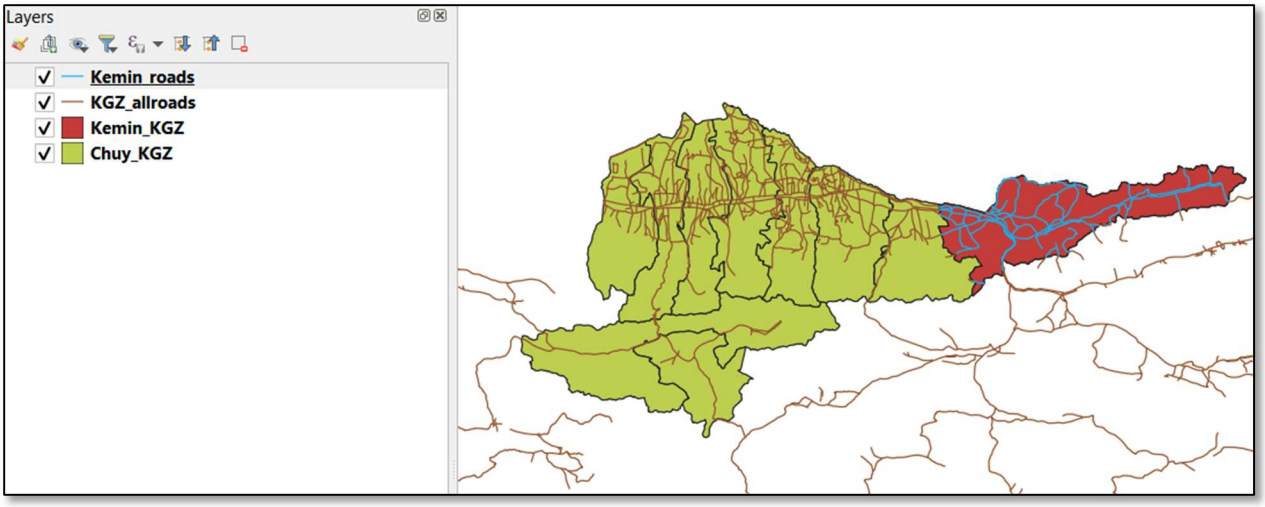
7. **Save QGIS Project:** Save your QGIS project (e.g., as SDG_911_Analysis.qgz) in your project folder (e.g., D:/SDG_911_Project).

8. **Clip Roads to Area of Interest (Optional for National Extent):** To analyze roads within a specific administrative boundary (e.g., Kemin rayon), you will clip the global/national roads layer to that extent.

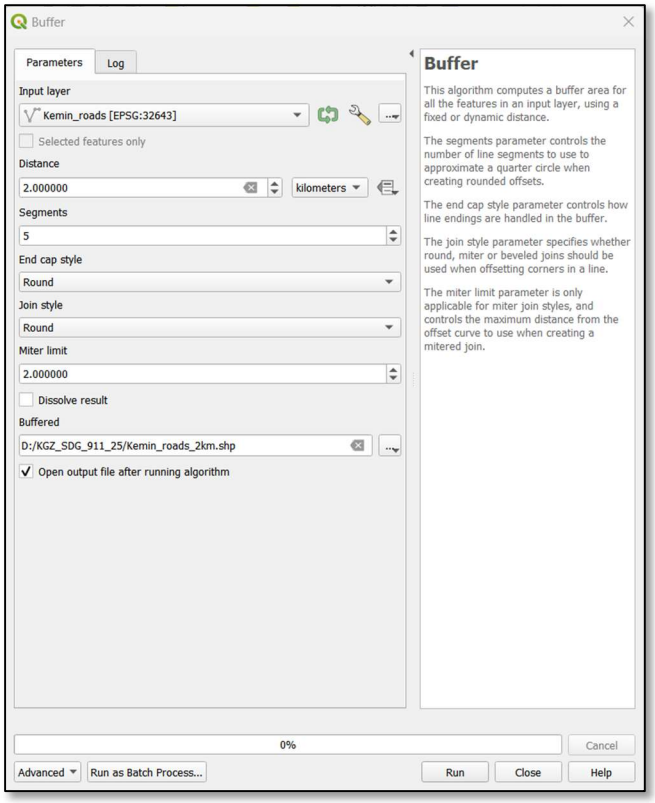
- Choose Vector > Geoprocessing Tools > Clip.
- Set 'Input layer' to your all-season roads layer (e.g., KGZ_allroads).
- Set 'Overlay layer' to your area of interest boundary (e.g., Kemin_KGZ).
- Specify an 'Output layer' path and name (e.g., D:/SDG_911_Project/Kemin_roads.shp).
- Click 'Run'.
- Note: If you intend to produce the indicator at a national extent, you can skip this clipping step and proceed with your national all-season roads dataset.

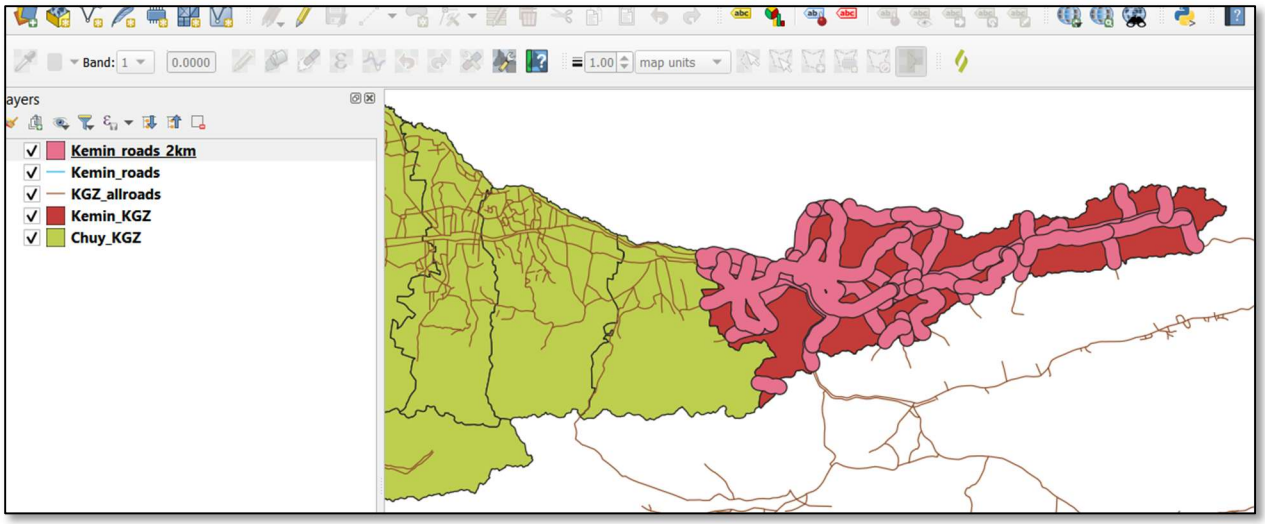



Clip
Parameters
Log
Input layer
KGZ_allroads [EPSG:32643]
Selected features only
Overlay layer
Kemin_KGZ [EPSG:32643]
Selected features only
Clipped
D:/KGZ_SDG_911_25/Kemin_roads.shp
Open output file after running algorithm
Clip
This algorithm clips a vector layer using the features of an additional polygon layer. Only the parts of the features in the Input layer that fall within the polygons of the Overlay layer will be added to the resulting layer.
The attributes of the features are not modified, although properties such as area or length of the features will be modified by the clipping operation. If such properties are stored as attributes, those attributes will have to be manually updated.
0%
Cancel
Advanced
Run as Batch Process...
Run
Close
Help



9. **Buffer Roads with 2 km Area:** Create a 2-kilometer buffer zone around the road network. This buffer represents the area within which rural populations are considered to have access to an all-season road.
   - Choose Vector > Geoprocessing Tools > Buffer.
   - Set 'Input layer' to your clipped roads layer (e.g., Kemin_roads.shp, or your national roads layer if skipping clipping).
   - Set 'Distance' to 2.0 and ensure units are 'kilometers'.
   - Set 'Segments' to 5 for a smoother buffer polygon.
   - Set 'End cap style' and 'Join style' to 'Round' for continuous, rounded buffers.
   - Set 'Miter limit' to 2.0.
   - Check 'Dissolve result' to create a single, continuous buffer polygon.
   - Save the new layer in shapefile format (e.g., D:/SDG_911_Project/Kemin_roads_2km.shp).
   - Click 'Run'.

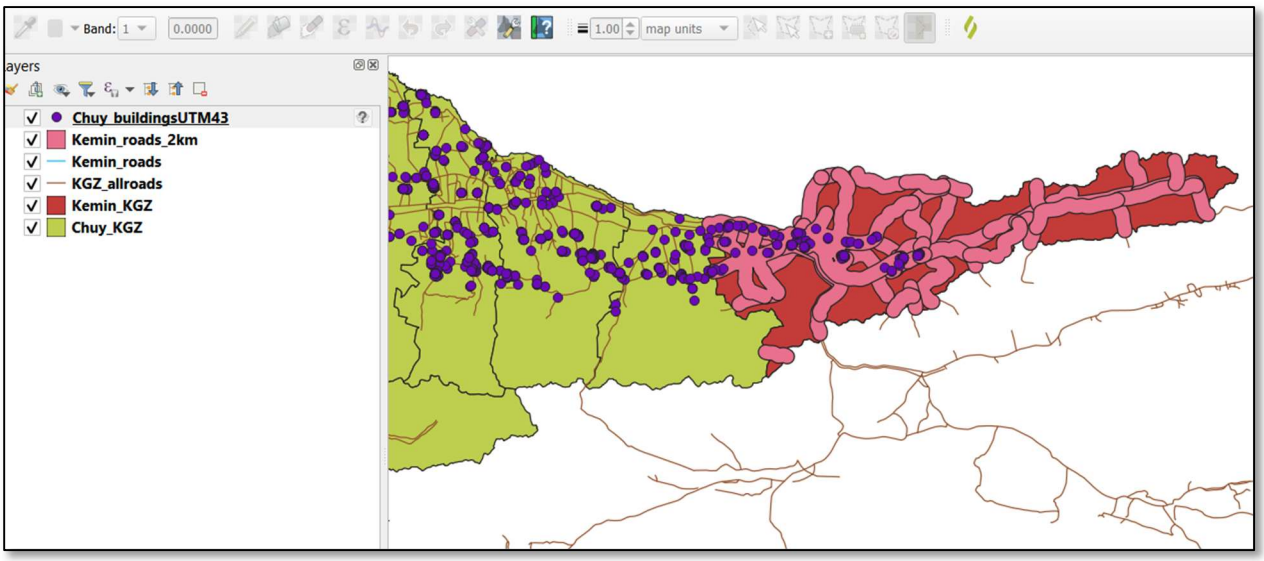

Buffer
Parameters
Log
Input layer
Kemin_roads [EPSG:32643]
Selected features only
Distance
2.000000
kilometers
Segments
5
End cap style
Round
Join style
Round
Miter limit
2.000000
Dissolve result
Buffered
D:/KGZ_SDG_911_25/Kemin_roads_2km.shp
Open output file after running algorithm
Buffer
This algorithm computes a buffer area for all the features in an input layer, using a fixed or dynamic distance.
The segments parameter controls the number of line segments to use to approximate a quarter circle when creating rounded offsets.
The end cap style parameter controls how line endings are handled in the buffer.
The join style parameter specifies whether round, miter or beveled joins should be used when offsetting corners in a line.
The miter limit parameter is only applicable for miter join styles, and controls the maximum distance from the offset curve to use when creating a mitered join.
0%
Cancel
Advanced
Run as Batch Process...
Run
Close
Help


Band: 1
0.0000
1.00
map units
ayers
Kemin_roads_2km
Kemin_roads
KGZ_allroads
Kemin_KGZ
Chuy_KGZ

Step II: Rural Areas Geodata Processing and Analytics

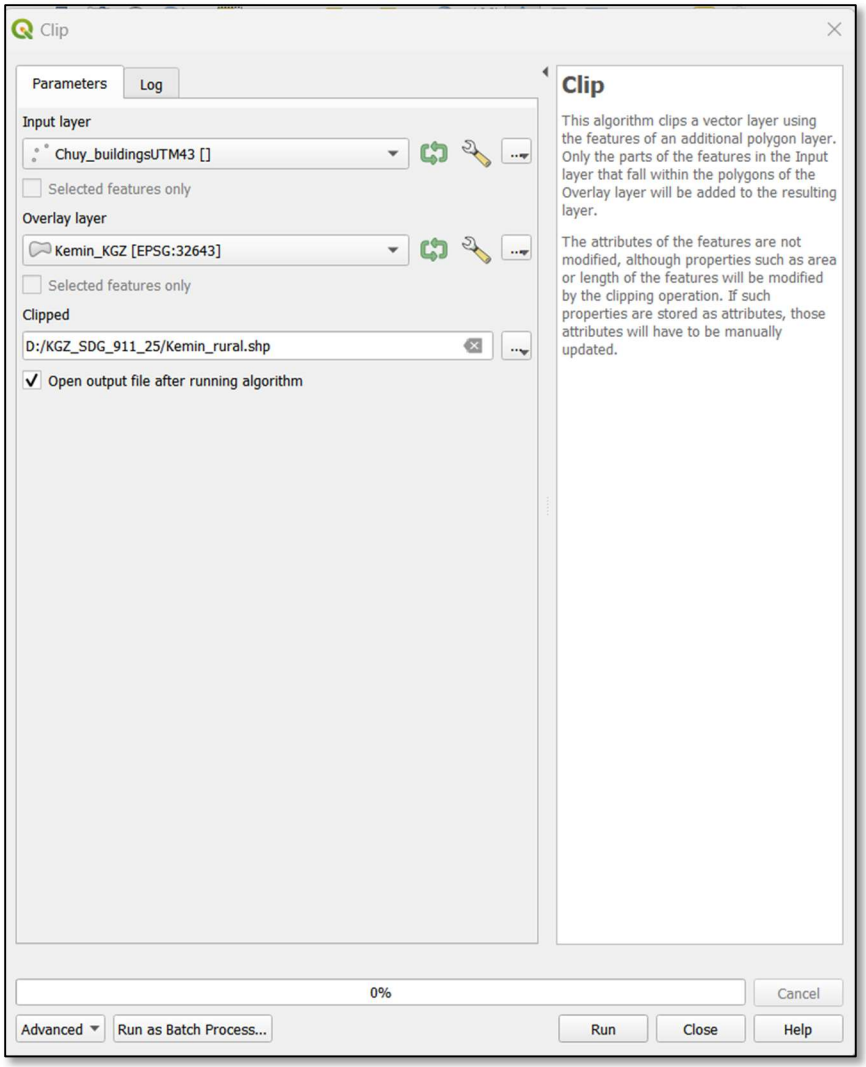
This section focuses on preparing the rural population data and aligning it with your area of interest.

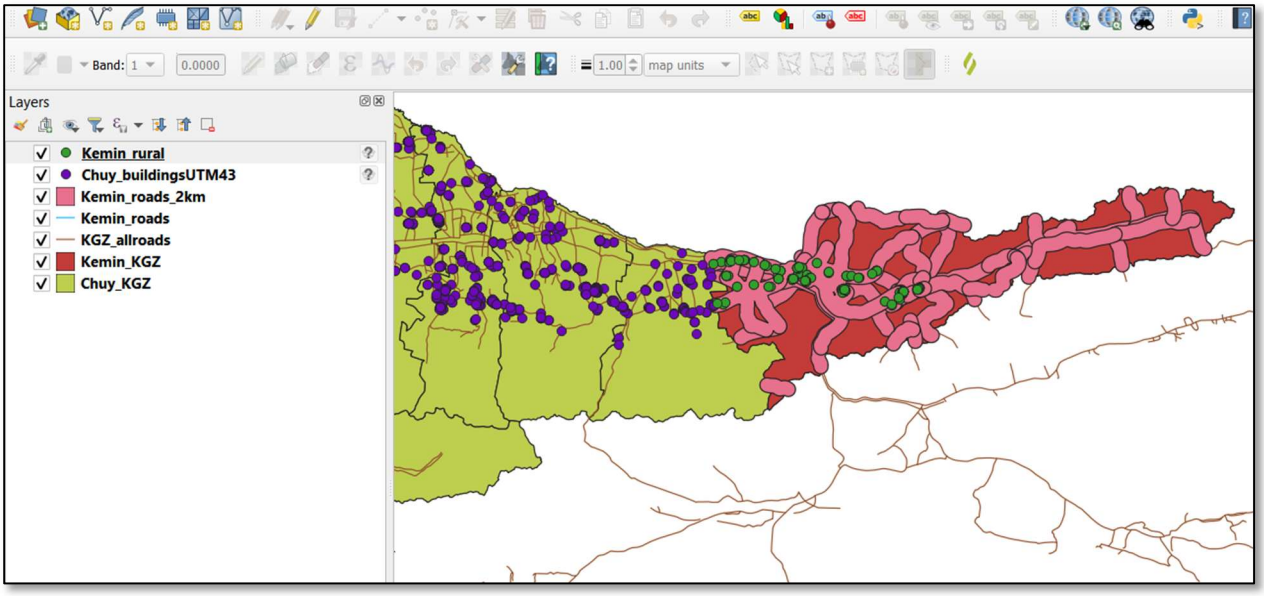
10. **Add Rural Population Data to Map**: Add your vector layer containing information on rural population to the QGIS map canvas (e.g., drag-and-drop Chuy_buildingsUTM43.shp).



11. **Clip Rural Population to Area of Interest (Optional for National Extent):** To obtain rural population points specifically within your chosen analysis area (e.g., Kemin rayon), you need to clip the broader rural population dataset.

- Open Vector > Geoprocessing Tools > Clip.
- Set 'Input layer' to your rural population layer (e.g., Chuy_buildingsUTM43.shp).
- Set 'Overlay layer' to your area of interest boundary (e.g., Kemin_KGZ.shp).
- Specify an 'Output layer' path and name (e.g., D:/SDG_911_Project/Kemin_rural.shp).
- Click 'Run'.
- Note: If producing the indicator at a national extent, skip this clipping step and use your national rural population dataset directly.

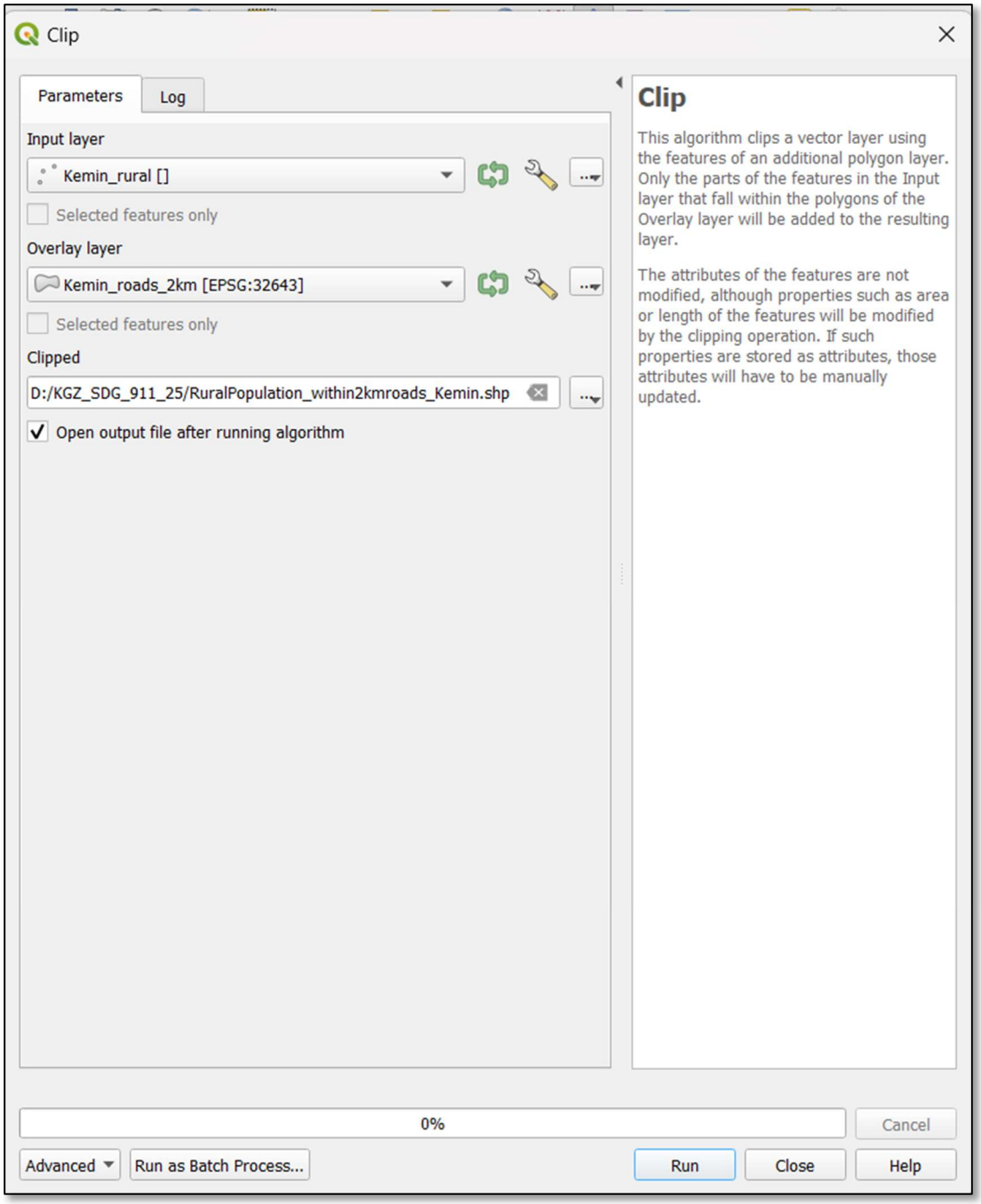

Clip
Parameters
Log
Input layer
Chuy_buildingsUTM43 []
Selected features only
Overlay layer
Kemin_KGZ [EPSG:32643]
Selected features only
Clipped
D:/KGZ_SDG_911_25/Kemin_rural.shp
Open output file after running algorithm
Clip
This algorithm clips a vector layer using the features of an additional polygon layer. Only the parts of the features in the Input layer that fall within the polygons of the Overlay layer will be added to the resulting layer.
The attributes of the features are not modified, although properties such as area or length of the features will be modified by the clipping operation. If such properties are stored as attributes, those attributes will have to be manually updated.
0%
Cancel
Advanced
Run as Batch Process...
Run
Close
Help

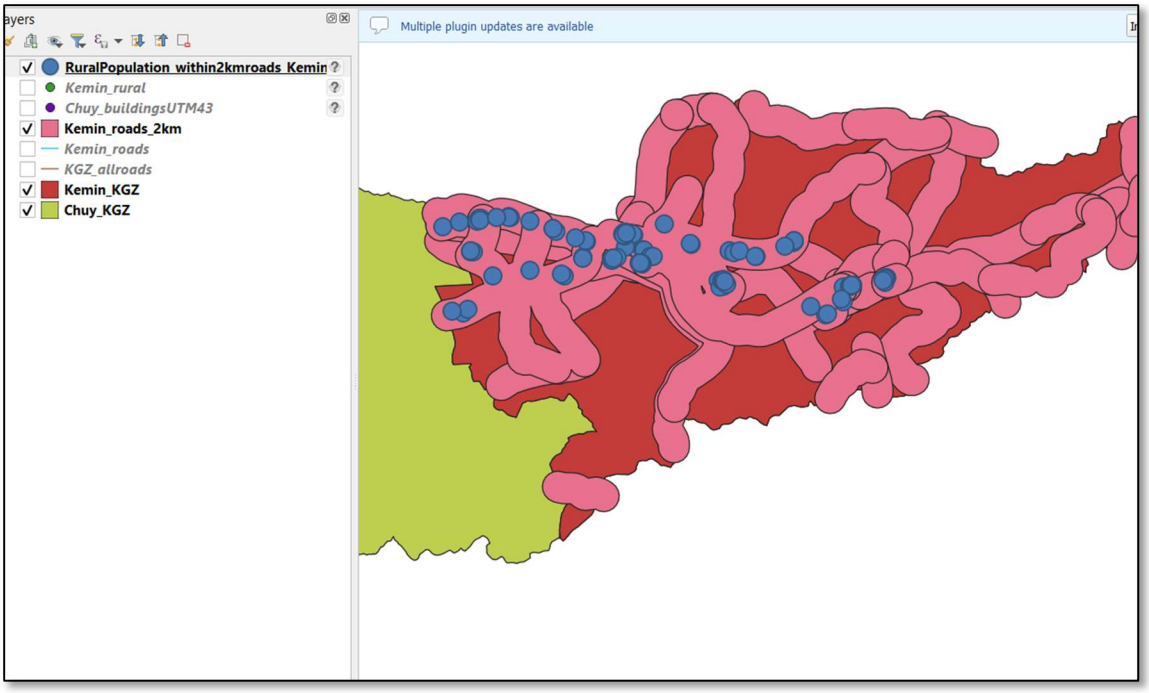


Step III: Modeling Rural Population within 2 km of All-Season Roads

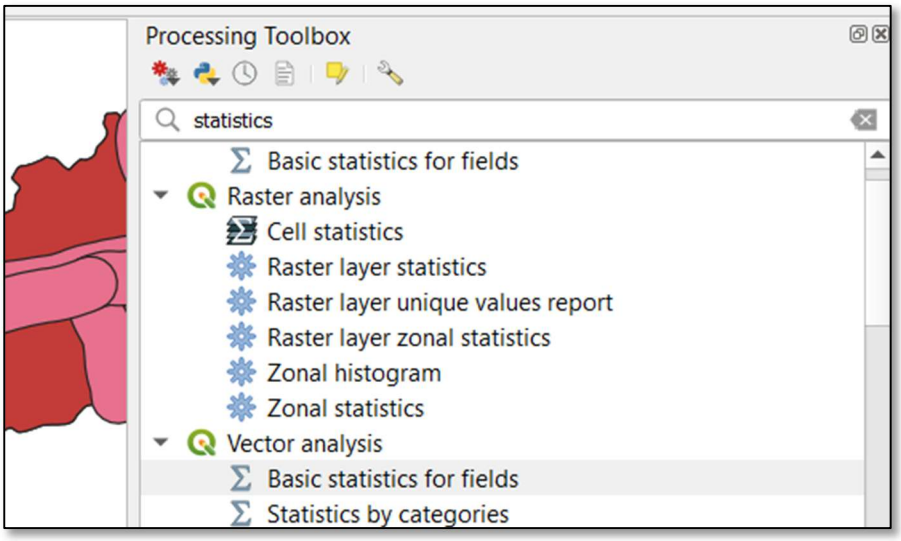
This final step involves identifying the population within the buffered road network and calculating the indicator.

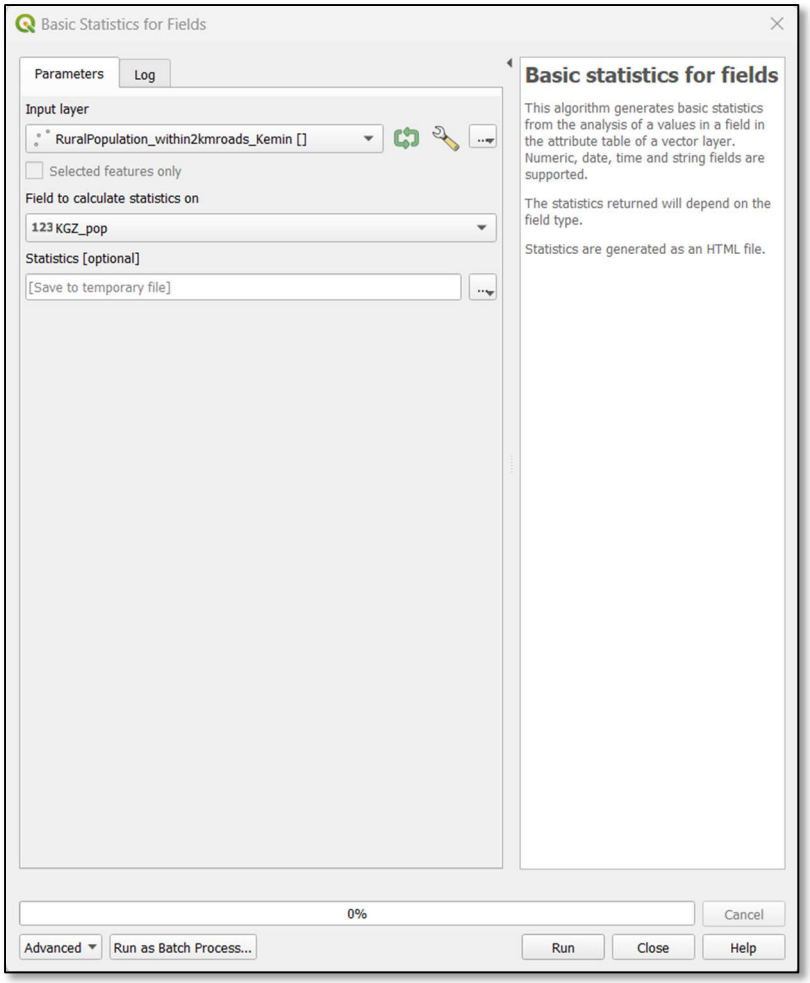
12. **Identify Rural Population within Road Buffer:** To estimate the rural population residing within 2 km of all-season roads, we will again use the Clip tool. This operation will isolate only those rural population points that fall within the buffered road network.
    - Choose Vector > Geoprocessing Tools > Clip.
    - Set 'Input layer' to your rural population layer for the analysis area (e.g., Kemin_rural.shp).
    - Set 'Overlay layer' to your 2 km road buffer layer (e.g., Kemin_roads_2km.shp).
    - Specify an 'Output layer' path and name (e.g., D:/SDG_911_Project/RuralPopulation_within2kmroads_Kemin.shp).
    - Click 'Run'.


Clip
Parameters
Log
Input layer
Kemin_rural []
Selected features only
Overlay layer
Kemin_roads_2km [EPSG:32643]
Selected features only
Clipped
D:/KGZ_SDG_911_25/RuralPopulation_within2kmroads_Kemin.shp
Open output file after running algorithm
Clip
This algorithm clips a vector layer using the features of an additional polygon layer. Only the parts of the features in the Input layer that fall within the polygons of the Overlay layer will be added to the resulting layer.
The attributes of the features are not modified, although properties such as area or length of the features will be modified by the clipping operation. If such properties are stored as attributes, those attributes will have to be manually updated.
0%
Cancel
Advanced
Run as Batch Process...
Run
Close
Help

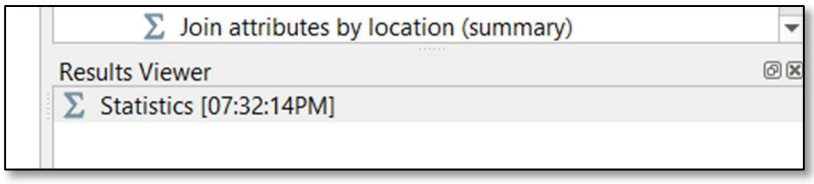


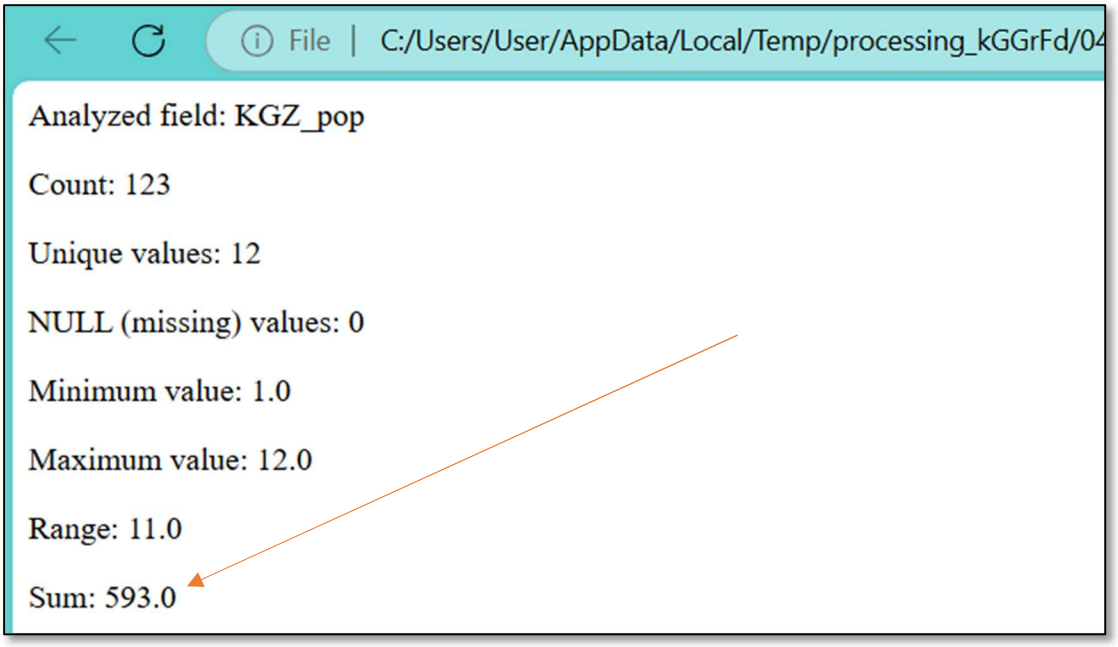
13. **Calculate Basic Statistics for Population (Within Buffer):** To sum the population within the identified 2 km buffer, we will use the "Basic statistics for fields" tool.
- In the 'Processing Toolbox' (accessible via Processing > Toolbox), search for "statistics" and choose Vector analysis > Basic statistics for fields.
- Set 'Input layer' to the layer created in the previous step (e.g., RuralPopulation_within2kmroads_Kemin.shp).
- Set 'Field to calculate statistics on' to your population attribute field (e.g., KGZ_pop).
- Keep 'Statistics (optional)' as default or select desired statistics.
- Click 'Run'.



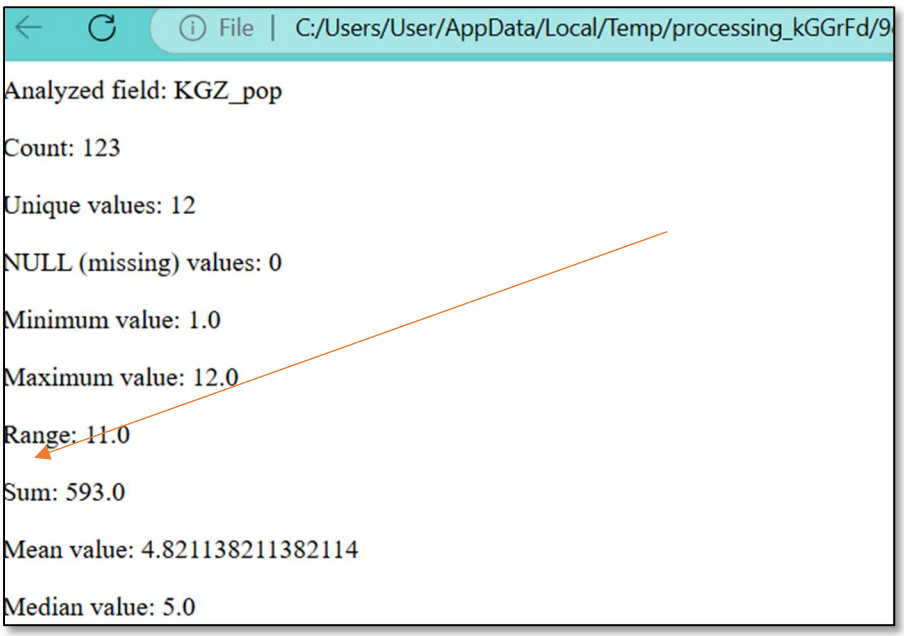


14. **Review Statistics (Population within Buffer):** Open the generated HTML link in the 'Results Viewer' (or locate the temporary HTML file) to review the basic statistics for the population data within the 2 km buffer of all-season roads. Note the 'Sum' value, which represents the total rural population within 2 km of an all-season road.





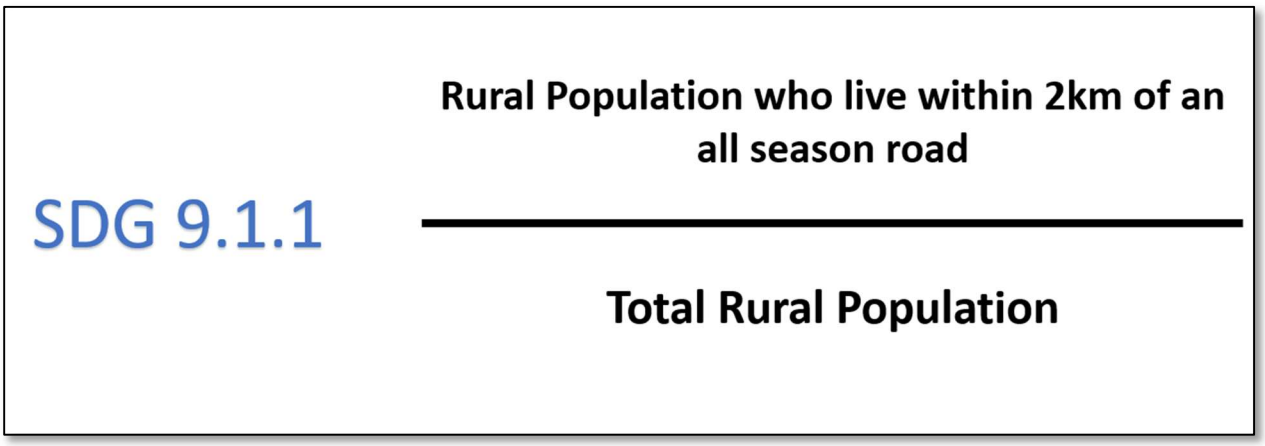
15. **Generate Statistics for Total Rural Population (for Analysis Area):** Next, calculate the total rural population for your entire analysis area (e.g., Kemin rayon) using the same "Basic statistics for fields" tool.
- Set 'Input layer' to your total rural population layer for the analysis area (e.g., Kemin_rural.shp).
- Set 'Field to calculate statistics on' to your population attribute field (e.g., KGZ_pop).
- Click 'Run'.
- Note the 'Sum' value, which represents the total rural population in your defined analysis area.



Calculating SDG Indicator 9.1.1

The SDG Indicator 9.1.1 is calculated as the ratio of the rural population living within 2 km of an all-season road to the total rural population.

Formula for SDG 9.1.1:



16. **Perform Calculation:** Calculate the SDG indicator using the values obtained from the statistics in steps 14 and 15.

- **Example (for Kemin rayon using provided data):**
  - Rural Population within 2km of an all-season road (from Step 14): 593.0
  - Total Rural Population (from Step 15): 593.0
  - SDG 9.1.1=593.0593.0=1 (This indicates that, in this specific example, all rural population in Kemin rayon lives within 2km of an all-season road based on the input data.)

Conclusion and Recommendations

This guide provides a robust and replicable methodology for modeling SDG indicator 9.1.1 using widely available open-source GIS software (QGIS) and national geospatial datasets. By following these steps, National Statistics Offices and GIS professionals can effectively assess rural access to all-season roads within their respective countries.

Key Recommendations for Global Implementation:

- **Data Availability and Quality:** The accuracy of SDG 9.1.1 heavily relies on the quality and availability of disaggregated, geocoded rural population data and accurate, up-to-date all-season road network data. Efforts should focus on acquiring or developing these foundational datasets.
- **Definition of "All-Season Road":** Countries should establish a clear and consistent national definition of "all-season road" that considers local climatic conditions and road engineering standards. If direct seasonality data is unavailable, clear proxies should be documented and consistently applied.
- **Spatial Reference Systems:** Maintain consistency in spatial reference systems across all input datasets to ensure accurate geospatial operations.
- **Scalability:** The methodology described is scalable. While demonstrated for a sub-national area, it can be applied to the entire national extent, provided sufficient computational resources and data are available.
- **Validation:** Regularly validate the derived indicator results against other relevant national statistics or ground truth data to ensure accuracy and reliability.

Additional Information

The guide was developed by Elena Hristev, ESCAP Consultant. For more details, please contact directly at lena.hristev@gmail.com or contact ESCAP-Statistics at stat.unescap@un.org