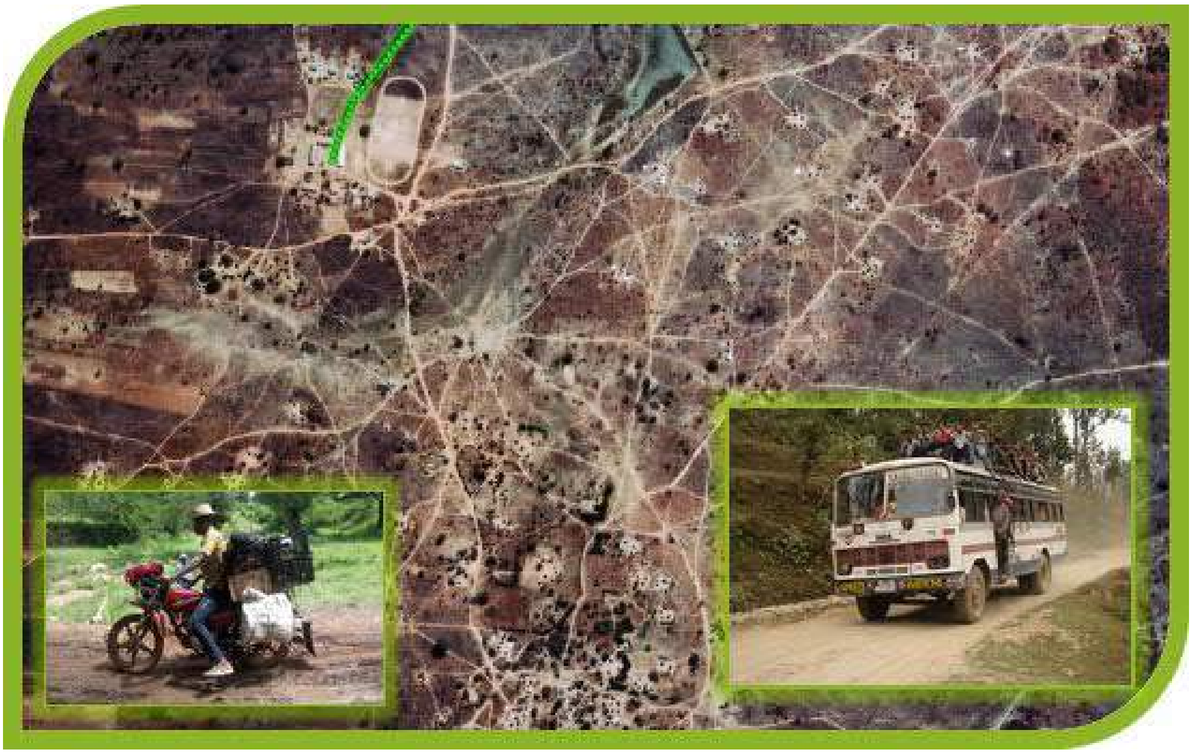
Rural Access Index (RAI)
Supplemental Guidelines

Measuring Rural Access Using New Technologies



TRL Ltd

GEN2033D

December 2019

Preferred citation: Workman, R. & McPherson, K., TRL (2019). Measuring Rural Access Using New Technologies: Supplemental Guidelines. ReCAP GEN2033D. London: ReCAP for DFID.

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Cover photo: Robin Workman-Zambia (satellite image), Robin Workman-Nepal, Andrew Otto- Kenya

Quality assurance and review table

Version	Author(s)	Reviewer(s)	Date
1.0	Robin Workman, Kevin McPherson	Martin Greene (TRL)	13/5/2019
2.0	Robin Workman, Kevin McPherson	Martin Greene (TRL)	30/6/2019
3.0	Robin Workman, Kevin McPherson		15/8/2019
4.0	Robin Workman, Kevin McPherson	Martin Greene (TRL) Annabel Bradbury (ReCAP PMU)	28/9/2019 4/10/2019
5.0	Robin Workman, Kevin McPherson	Martin Greene (TRL)	14/11/2019
6.0	Robin Workman, Kevin McPherson	Martin Greene (TRL)	12/12/2019
7.0	Robin Workman, Kevin McPherson	Martin Greene (TRL)	18/12/2019

ReCAP Database Details: Consolidation, Revision and Pilot Application of the Rural Access Index (RAI)

Reference No:	GEN2033D	Location	Asia and Africa
Source of Proposal	TRL	Procurement Method	Competitive Tender
Theme	Infrastructure	Sub-Theme	Rural Access Index
Lead Implementation Organisation	TRL Ltd	Partner Organisation	N/A
Total Approved Budget	£412,175	Total Used Budget	£305,363
Start Date	28/09/2018	End Date	31/12/2019
Report Due Date	30/09/2019	Date Received	28/09/2019

Contents

Abstract

This document contains supplemental guidelines to the 2016 RAI methodology (World Bank, 2016). These supplemental guidelines contain detailed, step-by-step procedures for calculation, documentation and publication of RAI (SDG 9.1.1) for a country. They follow the key tenets of the 2016 methodology, emphasising the involvement of National Statistical Offices (NSOs) and government agencies in the process, and providing transparency and consistency in how the RAI is calculated.

These guidelines also provide an alternative approach to the 'all-season' aspect of RAI by focusing on the intended purpose of the road network and the changing risks of accessibility to that network, rather than relying on physical measurements of road condition. They also encourage NSOs to engage with new online tools and platforms such as WorldPop, OpenStreetMap and others to improve the accuracy and accessibility of data and statistics for RAI.

Key words

RAI, Rural, Roads, Access, Poverty, Index, SDG, Methodology, Geospatial, OpenStreetMap, WorldPop

Research for Community Access Partnership (ReCAP)

Safe and sustainable transport for rural communities

ReCAP is a research programme, funded by UK Aid, with the aim of promoting safe and sustainable transport for rural communities in Africa and Asia. ReCAP comprises the Africa Community Access Partnership (AfCAP) and the Asia Community Access Partnership (AsCAP). These partnerships support knowledge sharing between participating countries in order to enhance the uptake of low cost, proven solutions for rural access that maximise the use of local resources. The ReCAP programme is managed by Cardno Emerging Markets (UK) Ltd.

www.research4cap.org

Acronyms, Units and Currencies

AfCAP	Africa Community Access Partnership
AI	Artificial Intelligence
AsCAP	Asia Community Access Partnership
DESA	Department of Economic and Social Affairs
DFID	Department for International Development
FAO	Food and Agriculture Organisation
GAUL	Global Administrative Unit Layers
GHSL	Global Human Settlement Layer
GIS	Geographical Information System
GPW	Gridded Population of the World
GRIP	Global Roads Inventory Project
GRUMP	Global Rural Urban Mapping Project
HDI	Human Development Index
IAEG	Inter-Agency Expert Group
IMT	Intermediate Means of Transport
IRI	International Roughness Index
LIC	Low Income Country
LSMS	Living Standards Measurement Study
MDA	Ministries, Departments and Agencies
NASA	National Aeronautics and Space Administration
NSO	National Statistical Office
NSS	National Statistical System
OSM	OpenStreetMap
PCI	Pavement Condition Index
PIARC	World Road Federation
QGIS	Open Source GIS product (previously known as Quantum GIS)
RAI	Rural Access Index
ReCAP	Research for Community Access Partnership
SDG	Sustainable Development Goal
SRTM	Shuttle Radar Topography Mission
SuM4All	Sustainable Mobility for All
TRL	Transport Research Laboratory
UK	United Kingdom (of Great Britain and Northern Ireland)
UKAid	United Kingdom Aid (Department for International Development, UK)
UN	United Nations
UNDG	United Nations Development Group
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNGP	United Nations Global Platform
UNSD	United Nations Statistics Division
UTM	Universal Transverse Mercator

1 Background

The Rural Access Index (RAI) was developed by the World Bank in 2006, and is one of the most important global development indicators in the transport sector. The RAI is defined as the 'proportion of the rural population who live within 2 km of an all-season road'. There is a common understanding that the 2 km threshold is a reasonable extent for people's normal economic and social purposes, and equates to approximately 20-25 minutes walking time.

The 2006 methodology was based on household surveys and had several issues with inconsistency across countries and a lack of sustainable regular updates. In addition, the approach was felt not to be spatially representative and of limited operational usefulness, resulting in weak client ownership.

In 2016, the World Bank partnered with the Department for International Development (DFID) of the United Kingdom and the Research for Community Access Partnership (ReCAP) to develop a new methodology. The 2016 methodology took advantage of geospatial techniques and data collected using innovative technologies. It focused on geospatial analysis of population distribution data, rural-urban definition, road network data and road condition data, rather than household surveys, in order to be more sustainable, consistent, simple, and operationally relevant. The use of innovative technologies referred to the development of high-resolution population distribution datasets using machine-learning and artificial intelligence (AI) techniques, and the use of smartphone applications that can provide an assessment of road roughness more cheaply than via traditional sources. The methodology can be found at:

World Bank. 2016. 'Measuring rural access : using new technologies (English)'. Washington, D.C. : World Bank Group.

The RAI was adopted as Sustainable Development Goal (SDG) Indicator 9.1.1 in 2016, using the geospatial methodology developed in 2016. The above methodology document is referenced in the SDG 9.1.1 metadata.

2 Introduction

This document contains supplemental guidelines to the 2016 RAI methodology. These guidelines have been developed to assist any agency involved in the calculation, quality assurance or publication of the RAI (SDG 9.1.1). They have been developed under the ReCAP programme in coordination with the World Bank.

These supplemental guidelines contain detailed, step-by-step procedures for calculation, documentation and publication of RAI for a country. They follow the key tenets of the 2016 methodology, but also emphasise the involvement of National Statistical Offices (NSOs) and government agencies in the process, and providing transparency and consistency in how the RAI is calculated. They provide a mechanism to document the decision-making processes along the way through the production and quality assurance of metadata. They also explain the role of the custodian in the overall SDG process.

These guidelines also provide an alternative approach to the 'all-season' aspect of RAI by focusing on the intended purpose of the road network and the changing risks of accessibility to that network, rather than relying on physical measurements of road condition.

These guidelines also encourage NSOs to engage with new online tools and platforms such as WorldPop, OpenStreetMap and others to improve the accuracy and accessibility of data and statistics for RAI and other SDG indicators, which over time can reduce the burden of reporting on NSOs. This can also have spin-off benefits for other government agencies in terms of making such fundamental data sets more accurate and available.

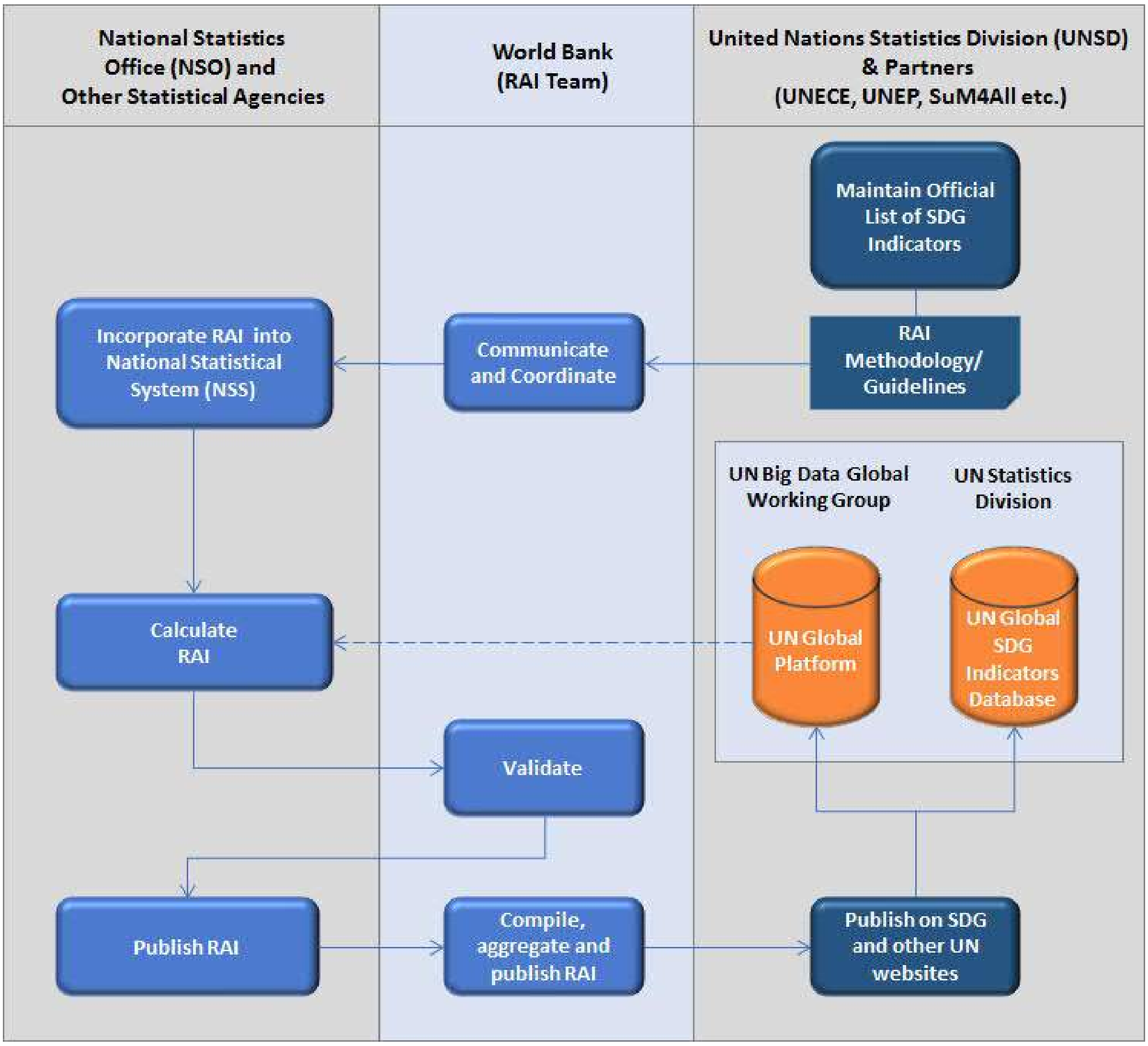
The guidelines are structured as follows:

Section 1	Background
Section 2	Introduction
Section 3	Roles and Responsibilities
Section 4	Detailed Methodology
Section 5	Quality Assuring the RAI
Section 6	Publishing the Results Nationally
Section 7	Publishing the Results Internationally
Section 8	Timetable for Calculation
Section 9	References
Annex A	Developing Accessibility Factors
Annex B	Outline QGIS Guidelines for Calculating RAI
Annex C	Secondary RAI Measurement Options and Methodology. (This annex considers a methodology for a future separate indicator to take into account motorcycle trails and waterways. It is not considered as part of the standard RAI methodology or supplemental guidelines).

3 Roles and Responsibilities

Figure 1 shows the different groups of agencies involved in the definition, calculation, quality assurance and publication of the RAI / SDG 9.1.1.

Figure 1: Overall roles and responsibilities for RAI definition, calculation, quality assurance and publication



3.1 UNSD and Partners

The UN Statistics Division (UNSD) is a division of the United Nations Department of Economic and Social Affairs (DESA). A key responsibility of the UNSD is to assist countries in the development of their National Statistical Systems (NSS), in accordance with the Fundamental Principles of Official Statistics (UN Economic and Social Council, 2013). These fundamental principles include the need for statistical agencies to decide on the definitions, methods and procedures for data collection, processing, storage and presentation of statistical data; and to coordinate among statistical agencies within countries to achieve consistency and efficiency in the statistical system.

UNSD is also responsible for developing and implementing the Sustainable Development Goals (SDGs) which are the indicator framework for 2030 Agenda for Sustainable Development. The UN General Assembly reaffirmed its commitment to the 2030 Agenda in July 2017 (A/RES/71/313).

3.2 World Bank

World Bank is the custodian agency for the RAI. As such, its responsibilities include collecting data from countries under existing mandates and reporting mechanisms, compiling internationally comparable data in the different statistical domains, to support increased adoption and compliance with internationally agreed standards and strengthening national statistical capacity. Other responsibilities of a custodian agency include:

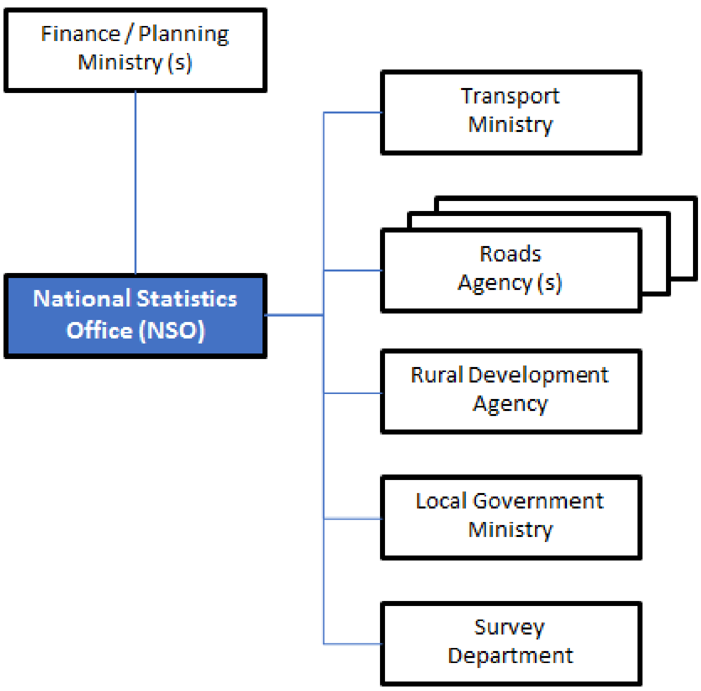
- Communicating and coordinating with national statistical systems in a transparent manner, including on the validation of estimates and data adjustments when these are necessary;
- Compiling the international data series, calculating global and regional aggregates and providing them, along with the metadata, to the UN Statistics Division;
- Preparing the storyline for the annual global progress report; and
- Coordinating on indicator development with the NSS, other international agencies and stakeholders. The Expert Group on SDGs encourages all agencies involved to collaborate on the development of the indicators. (E/CN.3/2017/2).

3.3 National Statistical Offices and Other Statistical Agencies

NSOs are mandated within their country to collect, compile, analyse, abstract and publish statistical information on a wide range of topics. Many other government departments can collect and compile statistics related to their area of expertise, however the NSO typically takes a coordinating role to ensure adherence to fundamental statistical principles across all agencies, and to minimise redundancy and inconsistencies.

Figure 2 shows a generic organisation chart of the national agencies that are typically involved in the decision-making and calculation of the RAI.

Figure 2: National roles and responsibilities for RAI definition, calculation, quality assurance and publication



The NSO in a country should liaise with other statistical agencies (roads agencies, development agencies, mapping agencies etc. as necessary) and incorporate the RAI into its NSS along with the other SDGs. The NSO should send the data to the custodian agency for validation and, once accepted, it should publish the indicator internally on relevant country websites. The custodian agency is responsible for aggregation and publication on the custodian agency websites and on UN websites as appropriate. There are a number of different platforms emerging in this space, including the UN Global Platform as shown in Figure 1.

The RAI should fit into any other reporting process (including national indicator reporting and SDG reporting) that the country already follows. Typically, the Finance or Planning Ministries are responsible for overall definition, reporting and publication of national indicators, and the inclusion of RAI should fit into those reporting processes. In some countries, the NSO may be part of the Finance or Planning Ministry, while in others it may be a separate organisation.

The NSO should agree, document and publish the definitions used for the RAI, the organisations responsible, and the appropriate sources for the key data parameters required for the RAI in their national statistical system to ensure sustainability. These key parameters are summarised in Table 1.

Table 1: Key parameters for the RAI and the responsible national organisations

Key Parameter	Responsible National Organisation
• Population distribution data	Typically, the NSO
• Urban/rural boundaries	Typically, the local government agency or survey department
• Road network mapping	The roads agencies - it should be noted that there is typically more than one roads agency in a country, and so representatives from multiple agencies may need to be involved, along with the relevant transport ministries for oversight and consistency, and potentially the survey department depending on local mandates
• Road condition	The roads agencies as above
• Accessibility factors	For agreement by all agencies. See Section 4.6

4 Detailed Methodology

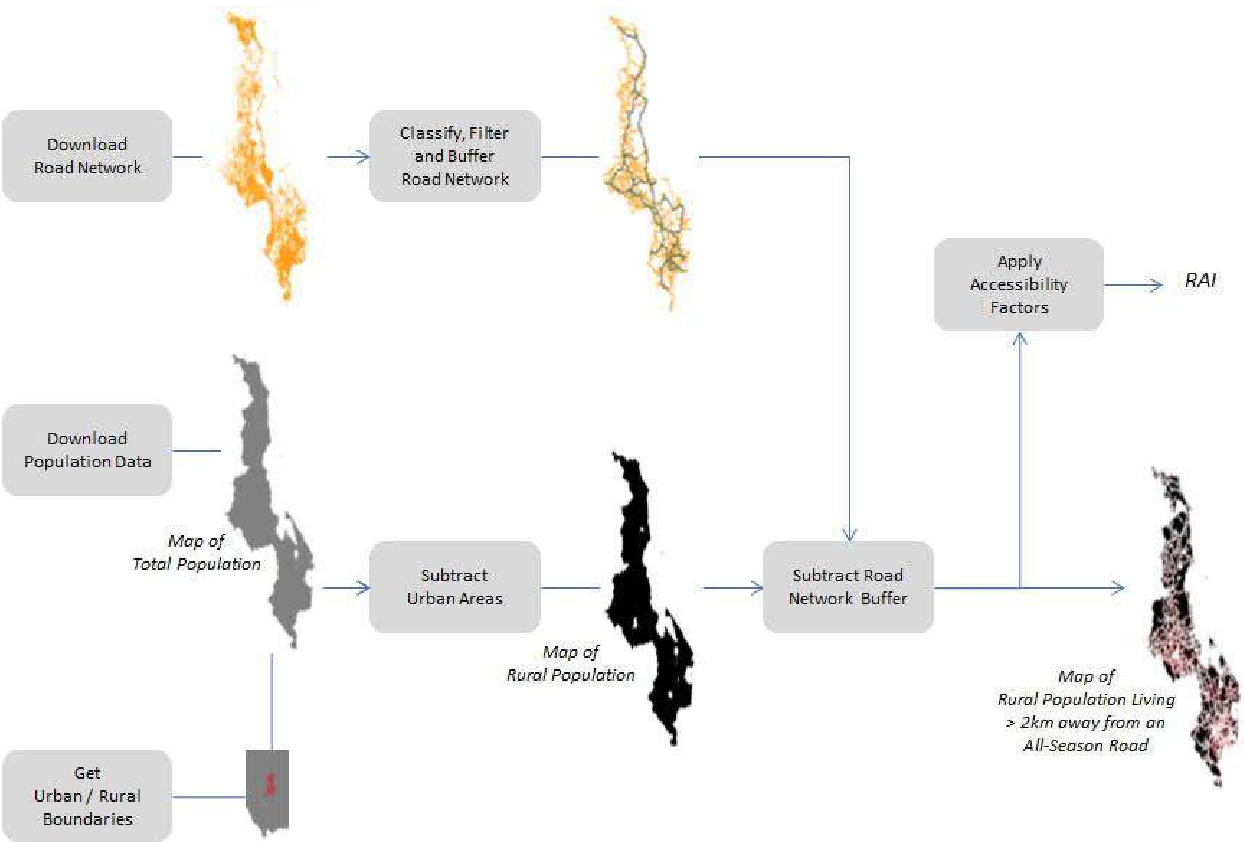
4.1 Framework and Overview

These supplemental guidelines are structured in accordance with the overall framework of the 2016 RAI Methodology, as shown in Figure 3.

Figure 3: Basic methodological framework

Annex B describes step-by-step procedures for calculating RAI in a country using QGIS (formerly, Quantum GIS). QGIS is a widely-used open-source GIS application that can be downloaded from the internet for free, although similar steps can be followed in any desktop GIS package. Figure 4 gives an overview of these steps as described further in Annex B.

Figure 4: Overview of step-by-step GIS procedures



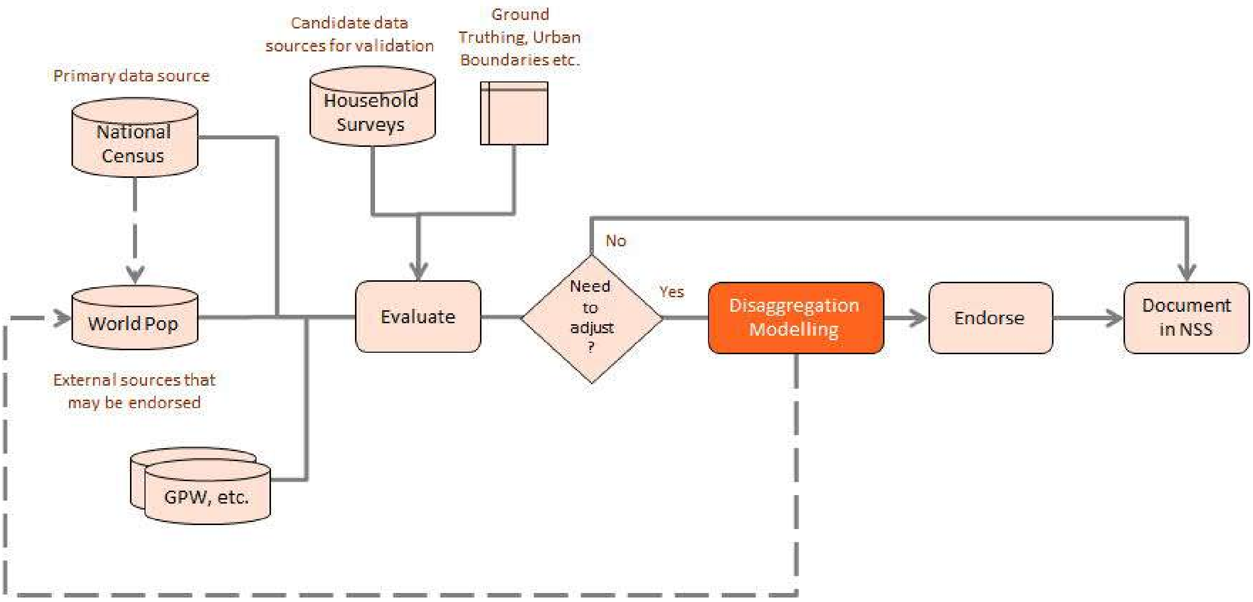
4.2 National Boundaries

The national boundaries of the FAO Global Administrative Unit Layers (GAUL) dataset (FAO, 2015), which correspond to UN Member State recognised boundaries, should be applied.

4.3 Population Distribution Data

UN Statistics Division [Principles and Recommendations for Population and Housing Censuses](#) recognises the population census as the primary source for population data. The essential features of population and housing censuses are individual enumeration, universality within a defined territory, simultaneity, defined periodicity and small-area statistics. It recommends that a national census be taken at least every 10 years. The primacy of the national census as the basis for population data in the RAI is seen in Figure 5.

Figure 5: Defining sources of population data for use in RAI



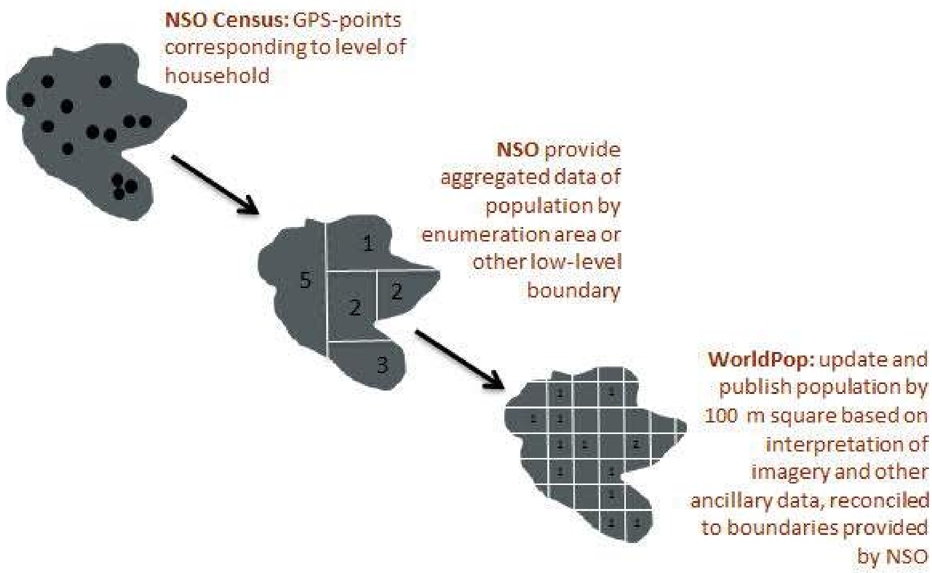
Most countries conduct regular population censuses under the management of the NSO. In many countries, population censuses are geo-referenced, i.e. the coordinates of individual households are recorded as part of the census. It is this geographic element, combined with absolute number of persons registered as living at that location, which is important for RAI. While the NSO has the ability to identify the numbers of people living at a precise location, that data is typically not made available publicly for reasons of privacy and security. The NSO therefore publishes aggregated data at various levels representing areas, but the boundaries are irregular and so these aggregated published data are not amenable to analysis for RAI.

The World Bank RAI 2016 Methodology provides a summary of Global Population Distribution Data Sets. These include WorldPop, Gridded Population of the World (GPW), the Global Rural Urban Mapping Project (GRUMP), LandScan, and UNEP Global Population databases. These data sets will continue to evolve, and new data sets are likely to become available in future (Facebook, for example, is producing high-density population density maps for sharing under its Data for Good programme).

For purposes of RAI calculation, WorldPop is the preferred source for population distribution data. It uses latest national census data, projections and other ancillary data from countries to produce aggregated, 100 metre squares of population data that can be downloaded and used in a local GIS platform. Other services such as the Gridded Population of the World (GPW) exist at a lower resolution, although they may change in future and so can still be evaluated as potential sources of data.

Figure 6 shows the process by which reconciliation and disaggregation may be achieved. While the NSO may retain population census data at the level of the household (first graphic), it may provide boundaries of enumeration areas along with aggregated population of those areas to WorldPop (second graphic), so that WorldPop can re-run its population models to ensure that its data match those of the NSO at the level of enumeration area (third graphic).

Figure 6: Reconciling and disaggregating WorldPop data



Such refinement will be useful not only for RAI, but for all indicators (SDG and non-SDG, national and international) that use WorldPop data. It also promotes the use of WorldPop data among other agencies. Greater engagement and endorsement of WorldPop as a legitimate source of data for RAI and other indicators will be of great benefit in improving the accuracy of indicators, and will lead to better planning in future.

Unless there has been direct cooperation with the NSO in disaggregating the WorldPop datasets further, then any data available from the WorldPop website is reconciled with the latest population census at the sub-national level (i.e. administrative boundary level 1), extrapolated / interpolated from the latest two national censuses. It is recommended that the NSOs work with WorldPop to reconcile their data to any latest national census and projections, and to disaggregate the WorldPop data to greater degrees of granularity where possible.

4.4 Rural-Urban Definition

At present there is no globally agreed definition of what is a rural area and what is an urban area. The UN Statistics Division (UNSD) advises that because of national characteristics which distinguish urban from rural, each country should decide which areas are to be classified as urban and which as rural, in accordance with their own circumstances.

The 2016 RAI methodology relied on the Global Rural Urban Mapping Project (GRUMP) v1 Urban Extent Polygons from 1995.

Other more recent options are available, including the MODIS 500-m map of global urban extent from the Nelson Institute Center for Sustainability and the Global Environment, updated in 2008.

The UN Expert Group on Statistical Methodology for Delineating Cities and Rural Areas recently proposed a new approach called the DegUrba Methodology. This approach has been developed by the European Commission Global Human Settlement Layer (GHSL) project, and is designed to instil some consistency into the definitions based on population density on a 1 km grid, but adjusted for local situations. This may be recommended in future, but at present the boundaries defined by the NSO in each country take precedence for RAI.

In many countries, the local government agencies publish their urban/rural boundaries on their website, and this same definition is used for all statistics in the country that depend on an urban/rural breakdown.

Many indicators (national, as well as SDGs) are dependent on the urban/rural boundary, either in their definition or in any disaggregation of the indicator. Consistency of that definition across the various indicators is important. This is especially true in situations where correlation analysis is being performed (e.g. between RAI and poverty, or RAI and availability of health facilities).

It is recommended, therefore, that:

- If the spatial definition of the urban/rural boundaries in any country are not well defined, or if there is no agency mandated to publish them and keep them up-to-date, or if they are likely to change frequently within a country, then the GRUMP Urban Extent Polygons should be used.
- If the NSO in any country can define their urban/rural boundaries clearly and accurately, then it should publish these geospatially on the NSO website and/or on any national geonodes, and cite them clearly as the authoritative source of this information. The NSO should also ensure that these same boundary definitions are used for all statistics and indicators that are published or disaggregated at the urban/rural level. In these circumstances, then the NSO can decide to use these boundaries as the basis for calculation of the RAI.
- NSOs should also monitor the outputs and decisions of the UN Expert Group on Statistical Methodology for Delineating Cities and Rural Areas for possible future consideration.

4.5 Road Network Data

The 2016 RAI Methodology recommends that data from the government agencies responsible for the road networks is used in order to define the road network.

Planning and management of roads in a country is usually divided among separate national and local agencies. Often there is no one agency responsible for collation of all road network data in a country, and so responsibility for data and mapping of the road network can be distributed among multiple agencies.

Mapping should be regularly updated, but resource and capacity constraints in the various agencies sometimes limit this activity. Most national roads agencies have good electronic mapping available for their network through GPS surveys, and have clear policies and guidelines in place for keeping the mapping of the network up-to-date as new roads are constructed or existing roads are re-classified. However, local roads agencies are typically less rigorous in keeping their maps up-to-date.

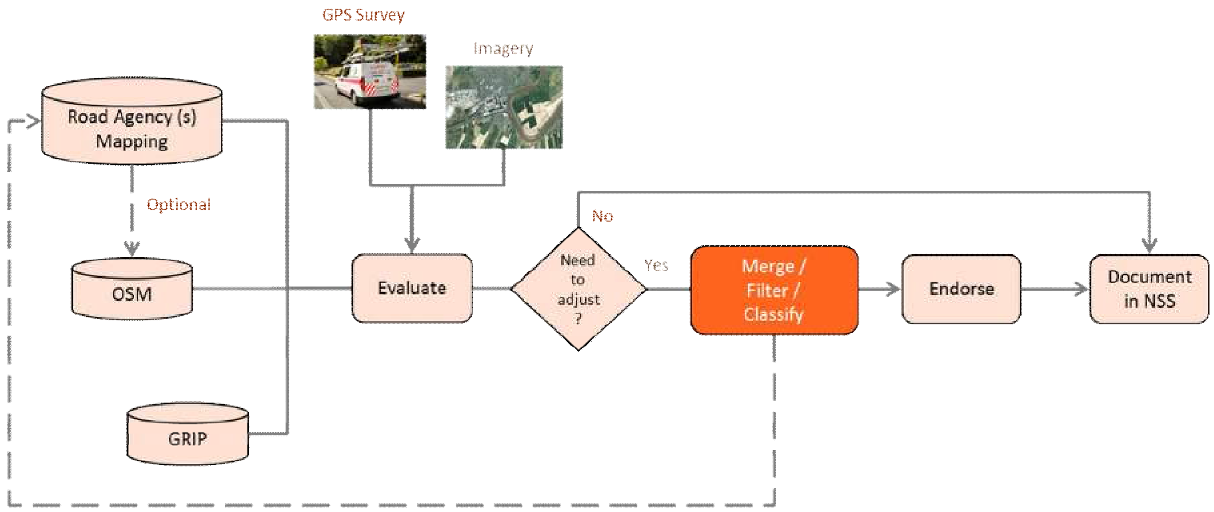
In some countries, there is also a large and less well-defined unclassified network, which nevertheless provides an important level of access to local communities. Unclassified roads should be included in the RAI measurement if they can legitimately be shown to serve a purpose of linking villages or hamlets to the classified network, or if they provide connectivity between farms and markets, or even if they provide access to individual dwellings.

The NSO should agree with the agency or agencies involved to define the extent of the road network for purposes of RAI calculation. It should assess the currency and accuracy of existing mapping in the road agencies, through comparison with online sources and/or available imagery. The length and classification of the road network to be included should be clearly documented, and a decision must be made whether to include any unclassified roads in that network. See Figure 7.

There are many freely available sources of road mapping data. OpenStreetMap (OSM) is a collaborative project to create a free editable map of the world, and has almost become a de facto standard for crowd-sourced mapping not only for roads but for health services, education services, etc. Other major online mapping platforms and GIS tools often link to live OSM map services for background mapping.

In OSM, the main roads and urban roads tend to be better recorded than rural roads. However that is changing as more and more countries become accustomed to working with online data sets, and as universities and humanitarian agencies work to improve online mapping of road networks, especially for purposes of disaster planning and disaster relief. A definitive online map of the road network in any country provides a wealth of benefits to national and international, government and non-government agencies, to local businesses, and to the general public.

Figure 7: Defining sources of road network data for use in RAI



Other online data sources, such as the Global Roads Inventory Project (GRIP) exist (see Figure 7), although at present GRIP does not appear to be as widely recognised as OSM. However, that may change in future and so it should still be evaluated as a potential source of road network data. Other map services may also be consulted, including Google Maps and Bing.

- Definitive online mapping of the road network in any country provides a wealth of benefits to national and international, government and non-government agencies, to local businesses, and to the general public.
- Roads agencies in a country should publish their road network mapping, including basic inventory parameters such as classification and surface type, geospatially on their website and/or on any national geonodes.
- OSM is almost a de facto standard for crowd-sourced mapping. Countries should work towards ensuring that their road network data collected by the respective roads agencies is published on OSM where possible, although it is recognised that some countries regard this as sensitive data not for open publication. Local OSM community groups should liaise with roads agencies to promote coordination of activities and sharing of data, and to share experiences on data quality assurance, OSM editing tools, etc. To learn more about the OSM community, see the user diaries, community blogs, and the OSM Foundation website.

4.6 All-Season Roads

The original 2006 definition of 'all-season' is as follows:

> **All-season original definition**
>
> An 'all-season road' is a road that is motorable all year round by the prevailing means of rural transport (often a pick-up or a truck which does not have four-wheel-drive). Predictable interruptions of short duration during inclement weather (e.g. heavy rainfall) are accepted, particularly on low volume roads. (Roberts et al, 2006).

These supplemental guidelines add the following to the above definition for clarity:

> **All-season definition update**
>
> A road that it is likely to be impassable to the prevailing means of rural transport for a total of 7 days or more per year is not regarded as all-season.
>
> Note that some roads agencies use the term 'all-weather' to describe their roads, however 'all-weather' typically means 'paved' and should not be confused with 'all-season'.

The 2016 RAI Methodology recognises the challenge of defining the 'all-season' aspect of the RAI, and uses road condition data as a proxy for 'all-season'. Road condition remains a valid way of identifying 'all-season' roads, but it tends to be resource hungry for local roads organisations, and it can be unreliable if measurements such as roughness are used, especially on unpaved roads. Also the condition of unpaved roads can change very quickly, and so a survey conducted one week might produce very different results to one conducted on the following week.

Therefore these supplemental guidelines allow alternative ways of defining the all-season aspect of the road network, using Accessibility Factors to estimate the likelihood of a road being impassable, for use where condition data is not reliable or does not give full network coverage.

4.6.1 Road condition data

The 2016 RAI Methodology uses the following interpretation to identify all-season roads based on condition data:

- Paved road with International Roughness Index (IRI) less than 6 metres/km and unpaved road with IRI less than 13 metres/km, when IRI data are available
- Paved road in excellent, good, or fair condition and unpaved road in excellent or good condition, when IRI data are not available but other road condition data, such as the Pavement Condition Index (PCI) or visual assessment by class value, are available.

> These values should only be used where there is reliable road condition data available. The parameters should be calibrated to the local conditions, i.e. checks should be made to determine that paved roads in poor condition are largely not all-season, and that unpaved roads in fair or poor condition are largely not all-season. The parameters can be adjusted accordingly to the local conditions, based on a systematic and documented study.

4.6.2 Accessibility Factors

Accessibility factors provide an alternative means to road condition for identifying 'all-season' roads. This alternative approach is broader based, more sustainable and should facilitate international comparison. It does not require ground measurements of road condition to be made.

Accessibility factors determine the likelihood of a road being all-season, or the risk of a road being inaccessible. This is closely aligned with the intent of the original 2006 study, i.e. 'accessible all year with the prevailing mode of transport', and '… may be temporarily unavailable during inclement weather'.

This Section describes the general concept of accessibility factors and looks at how they can be applied to produce a final RAI calculation. Annex A provides detailed instructions for developing accessibility factors for a country. It includes desktop review of road types and construction, climate and terrain; determination of climatic zones; selection of trial areas; and desktop review and ground-truthing in trial areas in order to compile accessibility factors for a country.

Characteristics which can affect accessibility factors

There are a number of characteristics of a country and its roads that will have a bearing on the accessibility factors, including:

- Road surface type: The road network can be divided into paved roads and unpaved roads. Unpaved roads are more vulnerable to being impassable to traffic than paved roads. They therefore have a higher risk of reduced accessibility, and hence a lower accessibility factor would be applied.
- Climate: Each country is unique in its climate impacts on roads. Climate change is exacerbating the risks of impassability through extreme weather events. Individual events should not affect the ability of a road to be all-season, because individual washouts and damage can be repaired, but the risk to a network will affect the accessibility. Countries with a benign climate will experience a lower level of road closures due to weather and should therefore apply a higher accessibility factor, whereas countries with tropical or monsoonal rains will experience a higher risk of road closure due to weather and should apply a lower accessibility factor.
- Terrain: Gradient of roads has an effect on their durability and their ability to withstand heavy rainfall. Steep roads are more vulnerable to scour, washout and slipperiness, especially when unpaved. Therefore countries with mountainous areas or flood plains should apply a lower accessibility factor to those areas, and countries with flat or rolling terrain should apply a higher accessibility factor.

Figure 8 shows sample accessibility factors for paved and unpaved networks in a country, based on a combination of climate and terrain zones.

Figure 8: Sample accessibility factors for paved (left) and unpaved (right) road networks

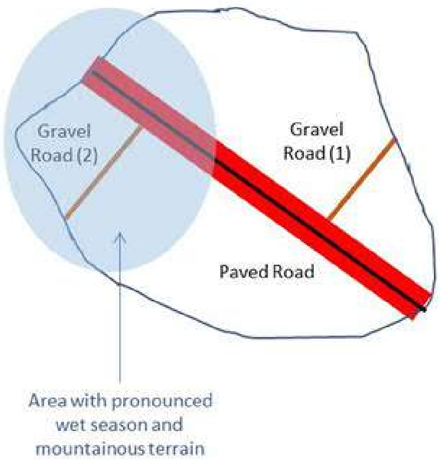
		Terrain	
		Low Risk (e.g. Flat, Rolling)	High Risk (e.g. Mountainous, Flood plains)
Climate	Low Risk (e.g. Benign Climate)	1	1
	High Risk (e.g. Tropical or Monsoonal Rains)	1	0.95

		Terrain	
		Low Risk (e.g. Flat, Rolling)	High Risk (e.g. Mountainous, Flood plains)
Climate	Low Risk (e.g. Benign Climate)	1	0.95
	High Risk (e.g. Tropical or Monsoonal Rains)	0.95	0.90

Application of accessibility factors

Figure 9 shows how RAI would be defined and calculated for a simple area with 3 roads.

Figure 9: Applying accessibility factors to RAI



Rural Population: 18 million

RAI calculation:

Paved Road pop (dry area) within 2 km: 3 million * 1.0 = 3.0 million
Paved Road pop (wet area) within 2km: 2 million * 0.95 = 1.9 million

Gravel Road (1) pop within 2 km: 2 million * 1.0 = 2.0 million
Gravel Road (2) pop within 2 km: 1 million * 0.9 = 0.9 million

Total Rural Pop within 2 km = 7.8 million

RAI = 7.8 million / 18 million = 43.3%

(If Accessibility Factors not applied, then RAI = 44.4%)

The above fictitious example is not very sensitive to the factors. If it is assumed that all roads are all-season (i.e. all factors are 1), then the RAI would be 44.4; while if the accessibility factors are applied, then the RAI becomes 43.3. The sensitivity of RAI to accessibility factors and other parameters will vary by country.

Other considerations

Classification of roads means different things in different countries. Typically, roads are classified as trunk roads, urban roads, feeder roads, etc. and different agencies are responsible for planning and maintenance of that high-level classification. Some countries also have a significant 'unclassified' network which has grown up informally and where there is no clear organisational responsibility for their maintenance, which makes those networks more vulnerable to weather events. However, in practice, local arrangements are often made whereby government funds are used to keep rural roads open even if they are not classified. Good knowledge of the country is therefore required to assess the applicability of factors.

Also, how well a road network is maintained is important. Simple tasks such as drain clearing and vegetation control can affect the condition of a road. In extreme cases this can affect whether a road is classed as all-season or not. Thus, accessibility factors may be enhanced if improved maintenance practices are introduced, and/or if maintenance funding is increased. A major increase in maintenance funding could be a reason, for example, for a country to agree a change to accessibility factors.

Accessibility factors should therefore not be changed frequently, and only in response to a significant change in funding, policies, or standards. The rationale for defining those factors should be documented in RAI metadata as described in Section 4.8.

4.7 Calculating and Presenting the RAI

The RAI can be calculated with GIS software, using layers of population data, urban/rural boundaries, road network mapping, and road condition and/or accessibility factors. Outline procedures for calculating RAI in a country using QGIS (formerly, Quantum GIS) software can be found in Annex B. QGIS is a widely-used open-source GIS application that can be downloaded from the internet for free.

Note that there are two important by-products of calculating the RAI using GIS as described here:

4.7.1 Accessibility as absolute numbers

The first by-product is the calculation of absolute numbers of rural population that do not have access to an all-season road. There are a number of reasons why it is useful to present this figure separately from the RAI, and hence why the metadata in Section 4.8 includes the field 'rural population not within 2 km of an all-season road'.

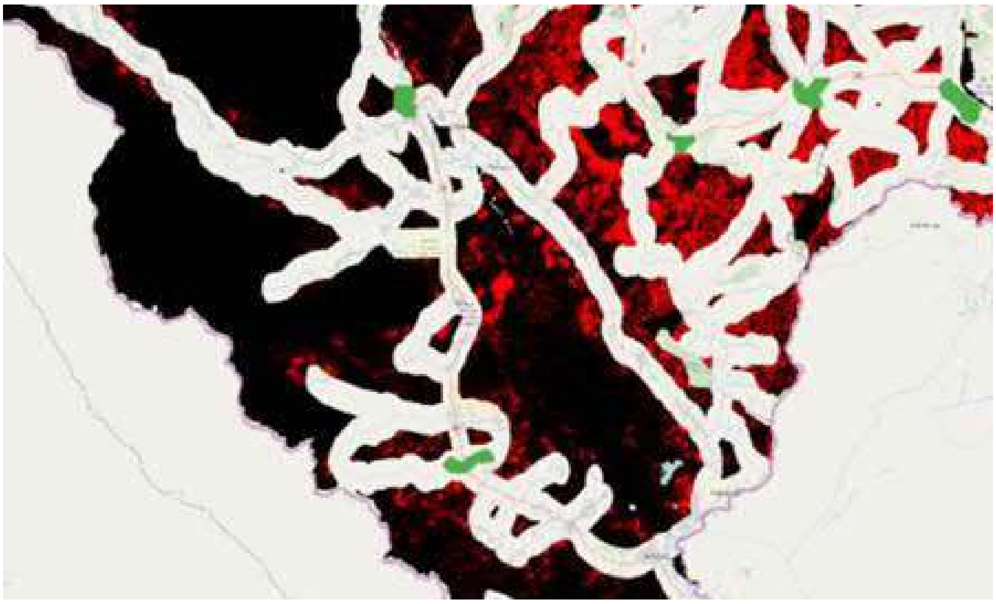
1. It is more relevant to 'no person left behind' rural access policies
2. The immediate impact of a statement such as '20 million people in the country do not have access to an all-season road' is much more powerful than 'the country has an RAI of 53%'
3. It is more easily scalable to regional or global level
4. It is easier to visualise the impact of road projects e.g. 'the project will give access to 20,000 people', rather than say, 'the project will improve RAI by 1%'
5. Absolute numbers are important over time. There are scenarios in which RAI might increase, but absolute numbers without access might also increase (e.g. due to differential population growth, or differential patterns of urbanisation) indicating that different or additional policies or programmes may be required.

4.7.2 Mapping of rural populations with limited access

The second by-product is mapping which identifies actual locations and populations that have limited rural access (see Figure 10).

Such mapping can be combined with other mapping layers showing locations of health services, education services, transport services etc. to feed into wider rural development plans and to help ensure that basic accessibility issues are addressed during planning and programming.

Figure 10: Mapping of populations with limited rural access



When planning and programming projects it is easy to use the RAI methodology to identify on maps the actual locations that currently have limited rural access, and to quantify the numbers of people that would be impacted by individual road construction or maintenance projects. As projects are completed, it will be easier to demonstrate the impact of those projects through absolute reduction in the number of people without access, rather than an increase in RAI.

4.8 Metadata

Table 2 lists the metadata that shall be recorded for each calculation of RAI, using a fictitious example for the values. This metadata is used to help ensure consistency of calculation, and to provide a basis for quality assurance. It lists the data sources used, and any assumptions made. It also lists the mapping projection used in order to calculate distances.

If RAI is calculated at sub-national levels, then the metadata shall also be produced at sub-national levels.

Table 2: Example metadata

Metadata Tag	Value
Rural Access Index	
RAI Value:	45.2
Rural population not within 2 km of an all-season road:	5,500,140
Level:	National
Date:	July 2019
Administrative Boundary	
Source:	FAO Global Administrative Unit Layers (GAUL) dataset
Date:	2015
Total Area (km^2):	119,000
Population	
Source:	WorldPop
Date:	2019
Total population:	17,300,000
Notes:	WorldPop 2019 projection derived from 2015 national census disaggregated to level of enumeration area
Urban / Rural Boundary	
Source:	Department of Surveys
Date:	March 2015
No of Urban Areas:	30
Total Urban Area (km^2):	985
Total Rural Area (km^2):	118,015
Notes:	No changes made to urban/rural boundaries since 2015
Road Network	
Source(s):	OpenStreetMap (OSM)
Date:	Downloaded February 20th 2019
Total Length (km):	Total: 49,000
Classification:	Primary: 7,000 Secondary: 12,000 Tertiary: 30,000
Surface Type:	Paved: 5,000 Unpaved: 44,000
Notes:	• Based on Roads Authority data for classified network only
Accessibility Factors	
Notes:	• Paved roads: o All paved roads assumed to be accessible all-year round • Unpaved roads: o Flat/rolling areas factor 0.95 (length affected 42,528 km) o Mountainous areas factor 0.8 (length affected 472 km)
Changes with justification:	The factor for unpaved roads in flat/rolling areas was changed from 1.0 to 0.95 in 2018 to reflect seasonal flooding experience.
Mapping Projection	
Projection:	Universal Transverse Mercator (UTM) zone

5 Quality Assuring the RAI

World Bank is the custodian agency for the RAI. Responsibilities of custodian agencies are given in the Report of the Inter-Agency and Expert Group on Sustainable Development Goal Indicators. These responsibilities include validation of estimates and data adjustments.

With regards to the regular calculation of RAI, this quality assurance role includes:

- Review of the metadata entry for the calculation of RAI (see Section 4.8)
- Comparison with historical data for the area under consideration

RAI is not expected to change significantly on an annual basis, it would be surprising if the RAI for any country changed more than 1% per annum. Any change of more than 1% per annum should be justified in the metadata (e.g. by a significant redefinition of the urban/rural boundary, or by inclusion of previously undefined roads). It is unlikely that a change in the Accessibility Factors would by themselves cause a change of more than 1% per annum.

6 Publishing the Results Nationally

The NSO should publish the RAI headline figures in local publications and on their national website, when they have been verified and approved by the custodian. The metadata should also be published so that the source and methods used for the calculation are clear.

It is important that provision for measuring and publishing SDG 9.1.1 is included in the National Statistical System of a country, which dictates the publication of statistical data by the NSO. The OECD paper designed to strengthen national statistical systems is a useful document to help countries apply national statistics to international indicators and goals.

7 Publishing the Results Internationally

7.1 World Bank Data Catalogue

The final stage of the SDG 9.1.1 process is to publish the data internationally. World Bank has established a Data Catalogue where SDG indicator data results and metadata can be published and disseminated. World Bank, as custodian of the RAI, will publish data from a country to this catalogue once it has been quality assured.

As custodian, World Bank is also responsible for producing inputs into the SDG Global Progress Report, and producing National SDG reports including lessons learned, which will feed into review and improvement of the methodology in future along with potentially new data sources and methodologies (such as mobile phone network data, machine learning etc.).

These data, reports and analyses are fed onto the UN Statistics Division for publication as described below.

7.2 UN sites and resources

The UN Global SDG Database provides access to data compiled through the UN System in preparation for the Secretary-General's annual report on "Progress towards the Sustainable Development Goals".

The SDG Metadata Repository is part of the Global SDG Database. It reflects the latest reference metadata information provided by the UN System and other international organizations on data and statistics for the Tier I and II indicators in the global indicator framework.

The UN Global Platform (UNGP) provides a platform for learning about trusted data, projects, applications, services and partners. It is hoped that eventually it will provide data, tools and services with which to calculate SDGs and other indicators (including RAI). It currently contains tools and services to make imagery, mobile phone network data, and social media data, available for statistical practitioners.

Further details on reporting of the SDGs are contained in the UNDG publication Guidelines to Support Country Reporting on the Sustainable Development Goals. This is a useful guideline which takes the reader through the steps necessary to produce an SDG report, including examples and a checklist. This document is aimed primarily at data custodians.

8 Timetable for Calculation

SDG indicators are in general measured annually. In most cases this would not be appropriate for the RAI, simply because road networks and populations do not change that quickly. Additional burden should not be put on a country to measure RAI when the result is unlikely to be different from the previous measurement. For example some high income countries are likely to have an RAI approaching 100%, so unless there has been a significant change in their road network or population, there is little value in re-measuring on an annual basis.

The timescale for calculation of RAI may be different between countries. The reporting entity in each country may seek advice from the custodian to establish a realistic timetable that is within the resources of the country to achieve, and will reflect reasonable changes in the RAI.

Significant events that could trigger a re-measurement of RAI would be:

- Major road construction or rehabilitation programme
- Major movement of populations, for example through urbanisation or long-term conflict
- Major neglect of road maintenance, possibly as a result of conflict or economic disaster
- Natural disasters that affect the road network

Climate change is unlikely to cause rapid enough change in the all-season status of the network to warrant more frequent RAI assessment. Table 3 gives recommended frequencies for calculation of RAI.

Table 3: Recommended frequencies for calculation of RAI

Situation	Frequency of measurement	Comments
Countries with major road construction or rehabilitation programmes	Annually	Until programmes are complete
Countries with rapid urbanisation	Every 2 years	Until rates of urbanisation normalise
Countries where maintenance has been neglected, through long-term conflict or economic disaster	Every 2 years	Until full recovery
Countries who have experienced natural disasters such as earthquake or flood	Every 2 years	Until rehabilitation is complete
Countries with RAI of 95% or more	Every 5 years	Unless there are good reasons to measure otherwise
All other countries	Every 3 years	

The availability of data may also have a bearing on the frequency with which the RAI will be measured, as may the development of electronic tools and use of open source data and platforms.

9 References

Roberts, P., Shyam K.C. and Rastogi, C., (2006) 'Rural Access Index: A Key Development Indicator', Transport Paper TP-10. World Bank, Washington DC.

UN Development Group. 'Guidelines to Support Country Reporting on the Sustainable Development Goals' (2017).

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UN Expert Group Meeting on Statistical Methodology for Delineating Cities and Rural Areas. 'Conclusions and Recommendations on DegUrba Methodology'. (January 2019).

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UN Statistics Division. 'Principles and Recommendations for Population and Housing Censuses' (Revision 3, 2017).

World Bank. 2016. 'Measuring rural access: using new technologies (English)'. Washington, D.C. : World Bank Group.

ANNEX A: Developing Accessibility Factors

This annex is designed to provide instruction in how to develop accessibility factor values for a particular country. It should be read in reference to the core document 'Supplemental Guidelines'

A.1. Accessibility Factors

This Annex describes the process to define accessibility factors for a country, using Myanmar by way of an example. Accessibility factors represent the likelihood of a road being passable all-year round.

The process involves the following steps:

Step 1: Review road types and construction

Step 2: Review climate details

Step 3: Review terrain details

Step 4: Determine zones

Step 5: Select trial areas

Step 6: Conduct desktop study of trial areas

Step 7: Conduct ground truthing in trial areas

Step 8: Compile accessibility factors for each road type

Step 1: Review road types and construction

Accessibility factors will vary by road surface type.

The following shows the characteristics of paved and unpaved roads and highlights the difference between them in terms of how the all-season status could be affected.

Paved roads:

- Usually have lined side drains, culverts and bridges. The paved surface and drainage system prevents penetration of moisture into the structure of the road. Excluding water from the road structure is the key issue in road asset preservation. Paved roads have a significant advantage over unpaved roads because the pavement and lined drains keep the road structure dry, preventing weakening through saturation.
- Have a harder and more durable wearing surface. This surface prevents erosion of the road through traffic and the action of water (typically heavy rainfall, which can cause scour).
- Offer more protection in steep and unstable areas, although it may be necessary to apply more durable surfaces than bituminous, for example concrete or stone soling.
- Paved roads are generally much less vulnerable to the environment. This assumes that the road is maintained to a reasonable level and the integrity of the structure is retained.

Unpaved roads:

- Are constructed from gravel or earth, which forms the wearing surface of the road. Normally this material is sourced locally, so the local geology can provide some clues as to the type of materials that are likely to be used for the road.
- Usually have earthen side drains. This leaves the road structure vulnerable to water ingress through the un-lined drains as well as through the road surface. Wet and saturated gravel or earth loses strength rapidly, and as a result becomes vulnerable to the action of traffic.
- Are very vulnerable to the environment. The condition of unpaved roads can change rapidly during wet periods, almost on a weekly basis, especially if the surface is not well compacted and the drainage is poor. Deterioration can be rapid and major damage can occur during periods of intense rainfall.

- Can be more durable if appropriate construction and regular maintenance are applied. This will mitigate deterioration, so this needs to be taken into account in the development of accessibility factors.

Figure A.1 shows typical examples of paved and unpaved roads.

Figure A.1: Examples of typical paved and unpaved rural roads

Thus, for purposes of determining accessibility factors, roads will be divided into two groups, Paved and Unpaved.

- Paved: Asphalt concrete, bituminous overlay or surface dressing, concrete
- Unpaved: Gravel, water bound macadam, earth, laterite, marl, etc.

  Note: Where short steep sections are treated with stone soling, concrete or cobblestones, the predominant surface type of the road should be used.

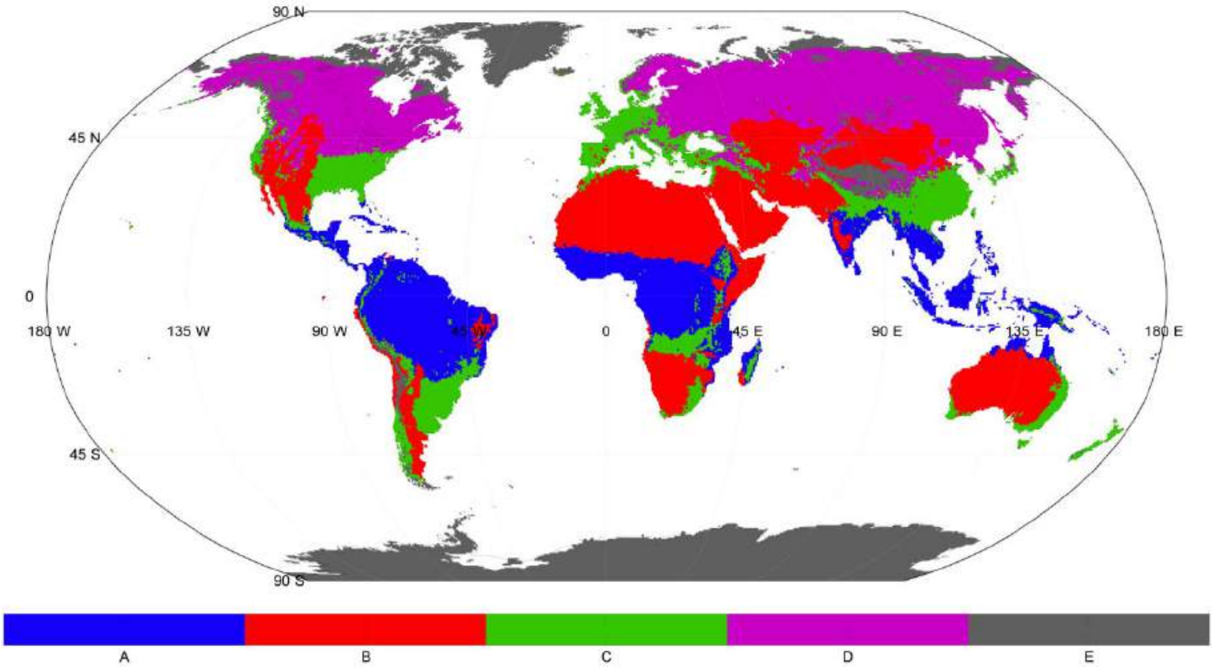
Using this information the primary surface types in a country should be logically grouped into Paved and Unpaved. The data for roads should be checked to ensure that these surface types are indicated accurately.

Step 2: Review Climate details

Review country information and maps to determine significantly different areas of climate. This would involve identifying areas as High Risk or Low Risk in terms of the potential that accessibility will be restricted.

Information on climate can normally be obtained from the meteorological department in a country. There are also several online sources of climate information. One of the most widespread and used is the Koppen climate classification system, which was first established in 1884 and has over a century of information to base its classification on. The world map of Koppen climate classification can be seen in Figure A.2.

Figure A.2: World Map of major Koppen climate classification types



There are five main groups in the Koppen system:

- A: Tropical
- B: Dry
- C: Temperate
- D: Continental
- E: Polar

Groups A and B could be established as High and Low risk respectively, but groups C and D could be variable, depending on the environment in the country and the intensity of rainfall. Rainfall intensity has also been recognised as a key factor in developing passability criteria for unpaved roads (Paige-Green, 1984). Data for rainfall intensity should be available from government meteorological departments and can be used to further refine the climate category for the accessibility factor of a country by identifying the areas of highest and most intense rainfall and assigning a lower accessibility factor to these in accordance with the risk.

For the purposes of RAI group E is very unlikely to be needed as it covers Arctic tundra and ice-cap, where there are very few roads, apart from Iceland, Greenland, parts of northern Russia and Canada, and high altitude areas in the Himalayas, all of which would be high risk.

The remaining four groups can be used to distinguish between high and low risk areas. These can be further subdivided at country level into 29 specific climatic conditions.

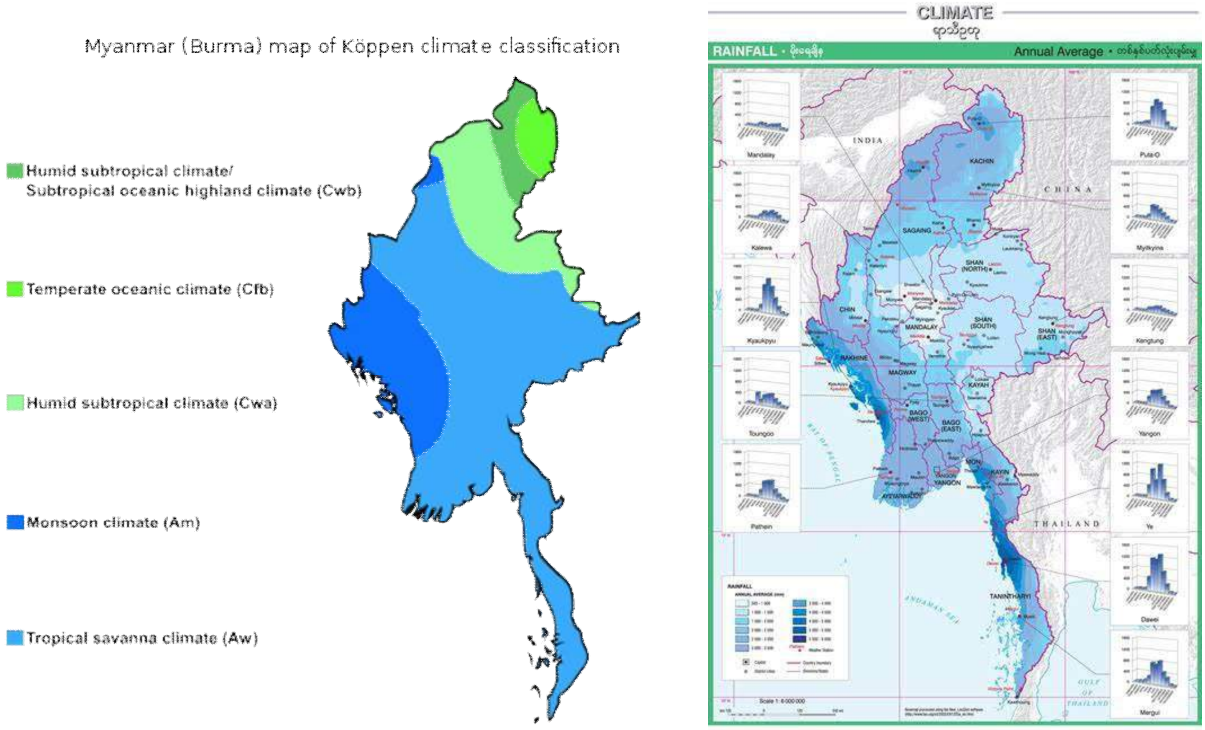
Following on from the above, High Risk and Low Risk for climate zones could be defined as follows:

> High Risk = Tropical or Temperate climate. Significant wet season, intense precipitation, monsoonal rains, heavy storms are common. Significant risk of landslides that could cause road closures for long periods, muddy or slippery surfaces that restrict access. This could be exacerbated by secondary effects, for example in earthquake prone areas even small tremors can exacerbate landslides in the wet season.

> Low Risk = Dry or Continental climate. Long dry season, medium to low rainfall, short wet seasons with less intense rainfall. Landslides not common, road remain passable even during the wet season.

From the maps of Myanmar in Figure A.3 the areas of monsoonal and tropical savannah climate are likely to have a higher risk of preventing roads from being all-season. This should be confirmed by ground truthing in selected areas (see Step 6).

Figure A.3: Climate / rainfall maps of Myanmar



Step 3: Review Terrain details

Review the country to determine significantly different areas of terrain. This would involve identifying areas as High risk or Low risk in terms of the potential that accessibility will be restricted.

Information on terrain can normally be obtained from the geological or survey departments in a country. There are also several online sources of terrain information, including Google Earth, and the Shuttle Radar Topography Mission (SRTM) maps are available free of charge at 30m resolution from the National Aeronautics and Space Administration (NASA). Similar data is also available via WorldPop at 100m resolution, based on the same source.

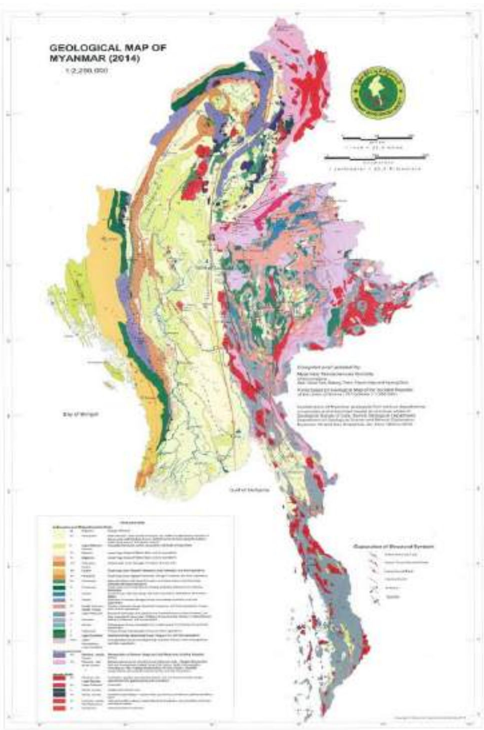
High Risk and Low Risk for terrain zones could be defined as follows:

> High Risk = Hilly or mountainous terrain, unstable or slippery materials, medium to high risk of landslides. Also difficult terrain which could include low-lying areas close to the sea or flood plains of lakes/rivers, with high risk of erosion, but this would only be applied if it affects a large area such as a district or county.
>
> Low Risk = Flat or rolling terrain, road materials with medium to low plasticity, small risk of landslides.

Sample geological and topographic maps for Myanmar are shown in Figure A.4. These maps show that in this case there is a clear coincidence with the geology and the topography, as could be expected where there is a dramatic variety in terrain. The flat and low areas that run north to south through the country, clearly have a different geology to the mountainous areas that border the northern half of the country.

If this distinction is not clear in any given country, then the two maps would need to be assessed to inform an accessibility factor for each area.

Figure A.4: Geological and topographical maps of Myanmar



Step 4: Determine Zones

Decide which overlapping areas apply to the country in question and define which areas of the country are likely to fall into each area, based on climate and terrain data. Table A.1 shows a typical example for a country.

There are four different potential zones for paved roads and four for unpaved roads, as shown in Table A.1.

Table A.1: Accessibility Zones

Zone	Surface Type	Climate Risk	Terrain Risk	Accessibility Factor
A	Paved	Low risk climate	Low risk terrain	1.0
B		High risk climate	Low risk terrain	to be determined
C		Low risk climate	High risk terrain	to be determined
D		High risk climate	High risk terrain	to be determined
E	Unpaved	Low risk climate	Low risk terrain	1.0
F		High risk climate	Low risk terrain	to be determined
G		Low risk climate	High risk terrain	to be determined
H		High risk climate	High risk terrain	to be determined

A factor of 1.0 represents full accessibility; for example all roads of a particular surface type are expected to remain open all year round, apart from minimal disruption due to excessive events of less than 7 days per year.

Typically an area with low risk for climate and low risk for terrain would have a factor of 1.0. This is expected to be the case for both paved and unpaved roads. This is shown as Zone A and Zone E in Table A.1.

The Accessibility Factors are measured and compiled as shown in Figure A.5.

Figure A.5: Typical accessibility factor tables for paved (left) and unpaved (right) roads

		Terrain	
		Low Risk (e.g. Flat, Rolling)	High Risk (e.g. Mountainous, Flood plains)
Climate	Low Risk (e.g. Benign Climate)	1	1
	High Risk (e.g. Tropical or Monsoonal Rains)	1	0.95

		Terrain	
		Low Risk (e.g. Flat, Rolling)	High Risk (e.g. Mountainous, Flood plains)
Climate	Low Risk (e.g. Benign Climate)	1	0.95
	High Risk (e.g. Tropical or Monsoonal Rains)	0.95	0.90

Step 5: Select Trial Areas

Select a trial area for each Zone, so that the accessibility factor can be determined. The trial area should be representative of the Zone and should include a variety of different roads, including paved and unpaved roads. A typical trial area would include approximately 100 km of roads.

This selection should be carried out in association with the relevant roads authority. Where there exists more than one roads authority or department, for example strategic and rural roads, then both should be consulted in order to ensure a representative sample.

Step 6: Conduct Desktop Study of Trial Areas

This step involves determining the 'all-season' status of the roads within the trial area. This is called ground truthing and can be carried out initially in a workshop environment.

It is recommended that this involves local engineers who are familiar with the network. It is also advisable to include local technicians, supervisors, and possibly transport operators, who know the local network very well. The local engineers and other experts will be asked to judge the all-season status of all roads within the trial area, based on the prevailing description of an all-season road:

Firstly define the network in the trial area by paved and unpaved roads. A separate assessment will be necessary for each. Produce a network map and display on a computer or in hard copy so that all participants are able to see it clearly.

It is important to first ensure that the local engineer and other local experts understand fully the definition of an all-season road:

> **All-season definition**
>
> An 'all-season road' is a road that is motorable all year round by the prevailing means of rural transport (often a pick-up or a truck which does not have four-wheel-drive).
>
> Predictable interruptions of short duration during inclement weather (e.g. heavy rainfall) are accepted, particularly on low volume roads. (Roberts et al, 2006).
>
> A road that it is likely to be impassable to the prevailing means of rural transport for a total of 7 days or more per year is not regarded as all-season.
>
> Note that some roads agencies use the term 'all-weather' to describe their roads, however 'all-weather' typically means 'paved' and should not be confused with 'all-season'.

The local experts will then be asked to identify those roads on the map that are all-season, as per the prevailing definition.

When they have completed their judgement the total of all-season paved roads and all-season unpaved roads should be calculated. This should then be provided as a percentage of the total sample size for each surface type.

For example:

Paved roads

- For paved roads in a particular zone (i.e. High risk climate / High risk terrain)
- Total length of paved roads = 150 km
- Total length of all-season paved roads = 135 km
- Therefore 90% of paved roads are all-season, and the accessibility factor would be 0.9.

Unpaved roads

- For unpaved roads in a particular zone (i.e. High risk climate / High risk terrain)
- Total length of paved roads = 200 km
- Total length of all-season paved roads = 160 km
- Therefore 80% of paved roads are all-season, and the accessibility factor would be 0.8.

Step 7: Ground Truthing of Trial Areas

The desktop assessment should then be 'ground-truthed' by visiting the roads, inspecting their condition and talking to local people to ascertain how long the road may be closed due to climate or terrain issues. Roads should be classified as all-season or not, and any roads that are impassable should also be noted. Then the results of the ground truthing should be compared to the desktop assessment, and used to refine the accessibility factors as necessary. Georeferenced photographs should be taken to enable review. See Figure A.6.

Figure A.6: Unpaved Roads - not all-season and all-season

Step 8: Compile Accessibility factors for each road type

Figure A.7 shows how the climate and terrain details would be translated into high and low risk areas on a map for Myanmar.

For each road type there will be four options for accessibility factors, with the default of Low risk climate and Low risk terrain being 1, as shown in Figure A.8.

Figure A.7: Risk areas for climate and terrain in Myanmar

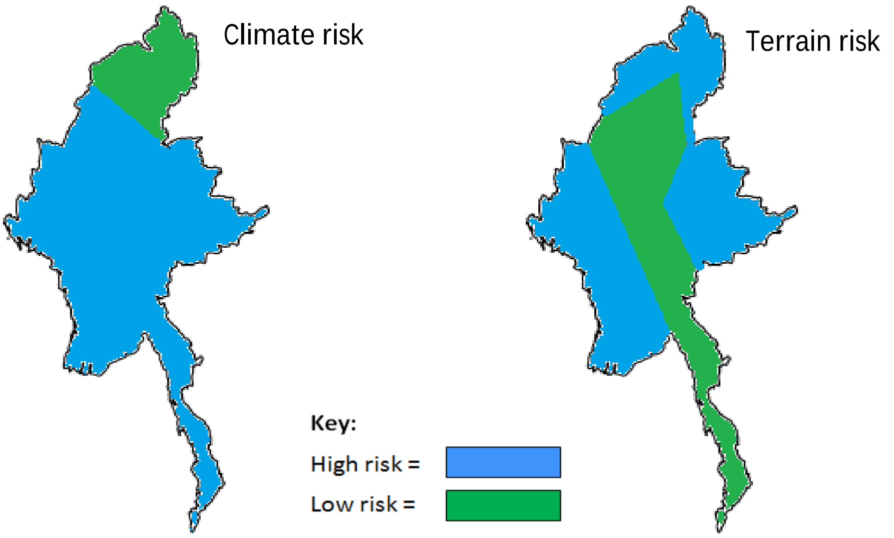
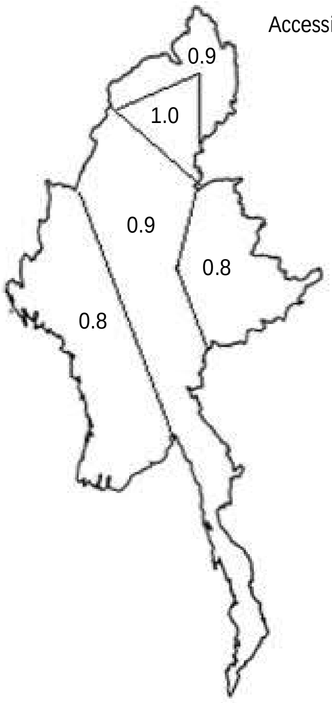


Figure A.8: Accessibility Factors for Unpaved Roads Myanmar



		Terrain	
		Low Risk (e.g. Flat, Rolling)	High Risk (e.g Mountainous)
Climate	Low Risk (e.g. Dry Season)	1	0.9
	High Risk (e.g. Wet Season)	0.9	0.8

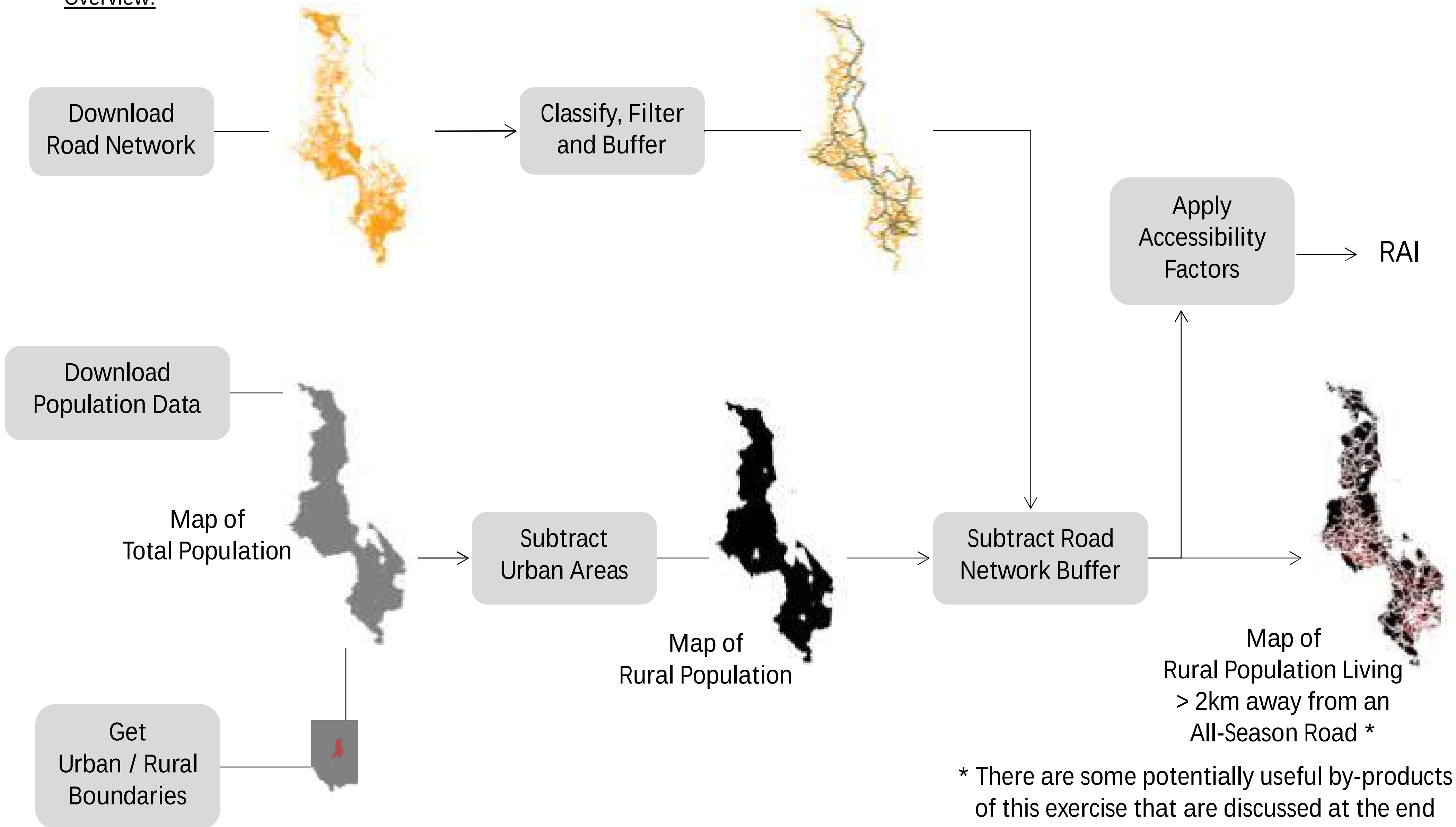
ANNEX B: Outline QGIS Guidelines for Calculating RAI

This annex is designed to provide guidance on calculating RAI using QGIS (formerly, Quantum GIS). It should be read in reference to the core document ‘Supplemental Guidelines’. Working knowledge of QGIS is required.

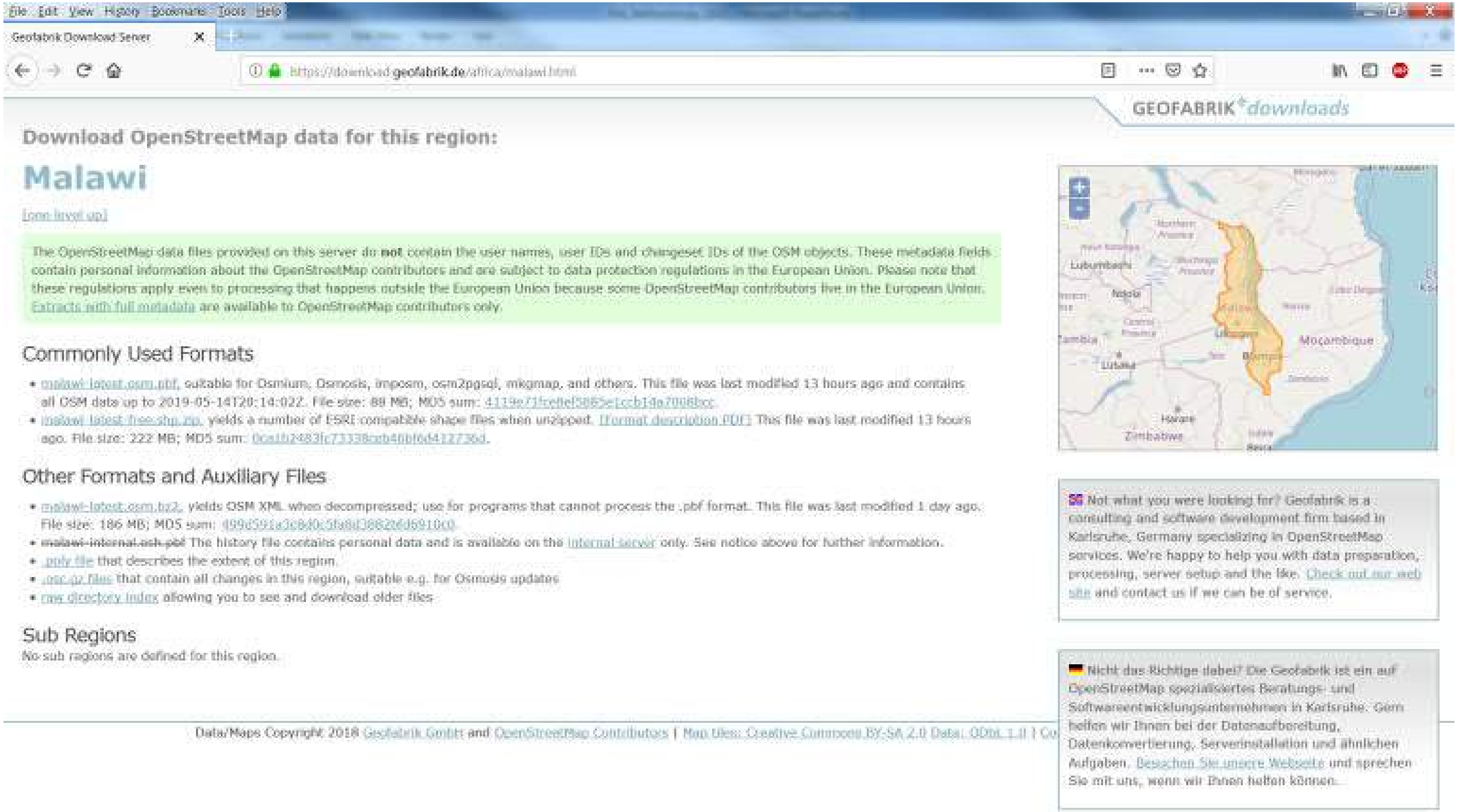
Disclaimer: All examples here are for illustrative purposes only to show overview procedures in QGIS, using sample data from Malawi.

They do not represent official RAI calculations for Malawi.

Overview:


Download
Road Network
Classify, Filter
and Buffer
Apply
Accessibility
Factors
RAI
Download
Population Data
Map of
Total Population
Subtract
Urban Areas
Map of
Rural Population
Subtract Road
Network Buffer
Map of
Rural Population Living
> 2km away from an
All-Season Road *
Get
Urban / Rural
Boundaries
* There are some potentially useful by-products
of this exercise that are discussed at the end

Step 1: Download OSM data.

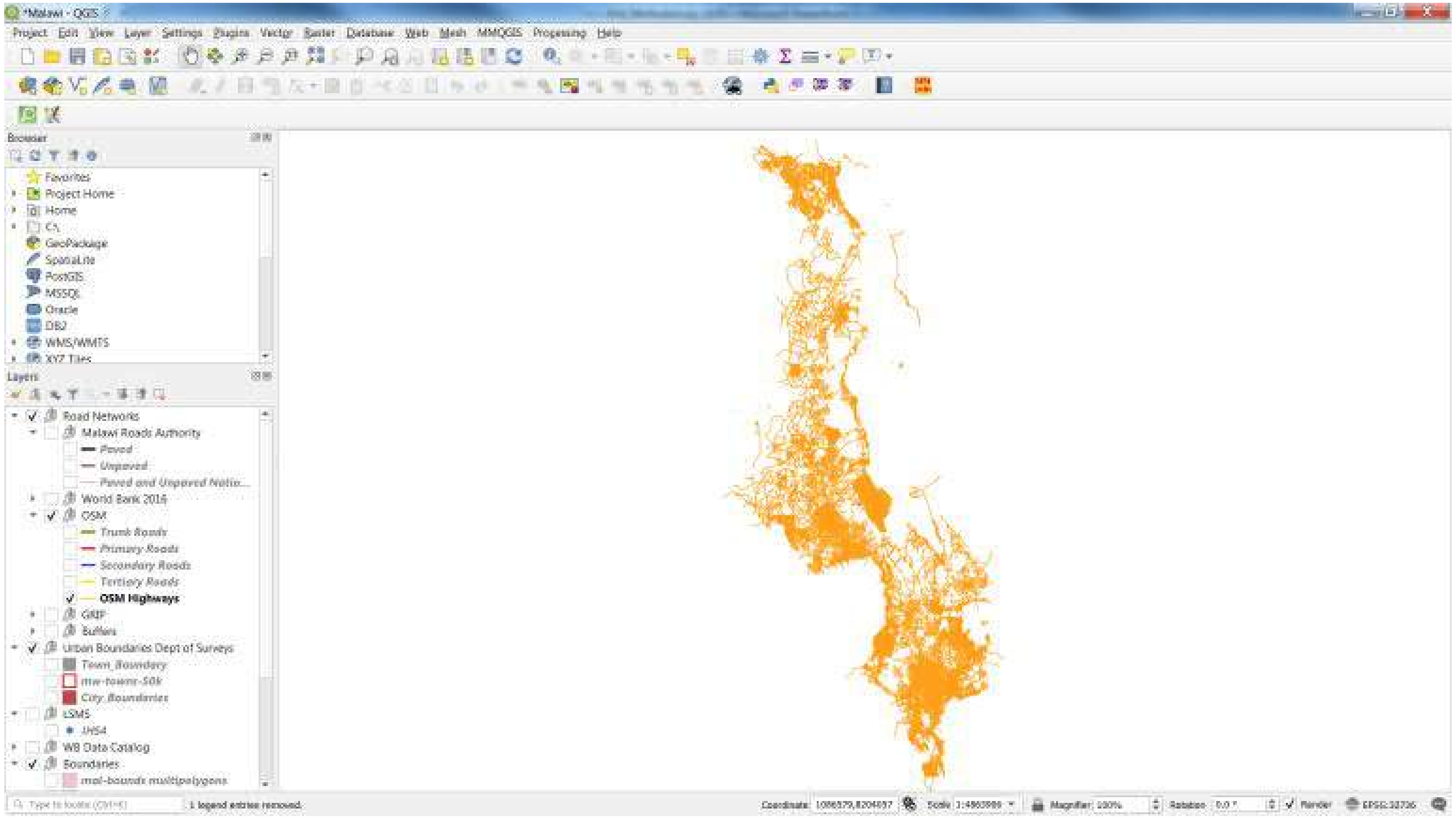


Step 2: Filter OSM data.

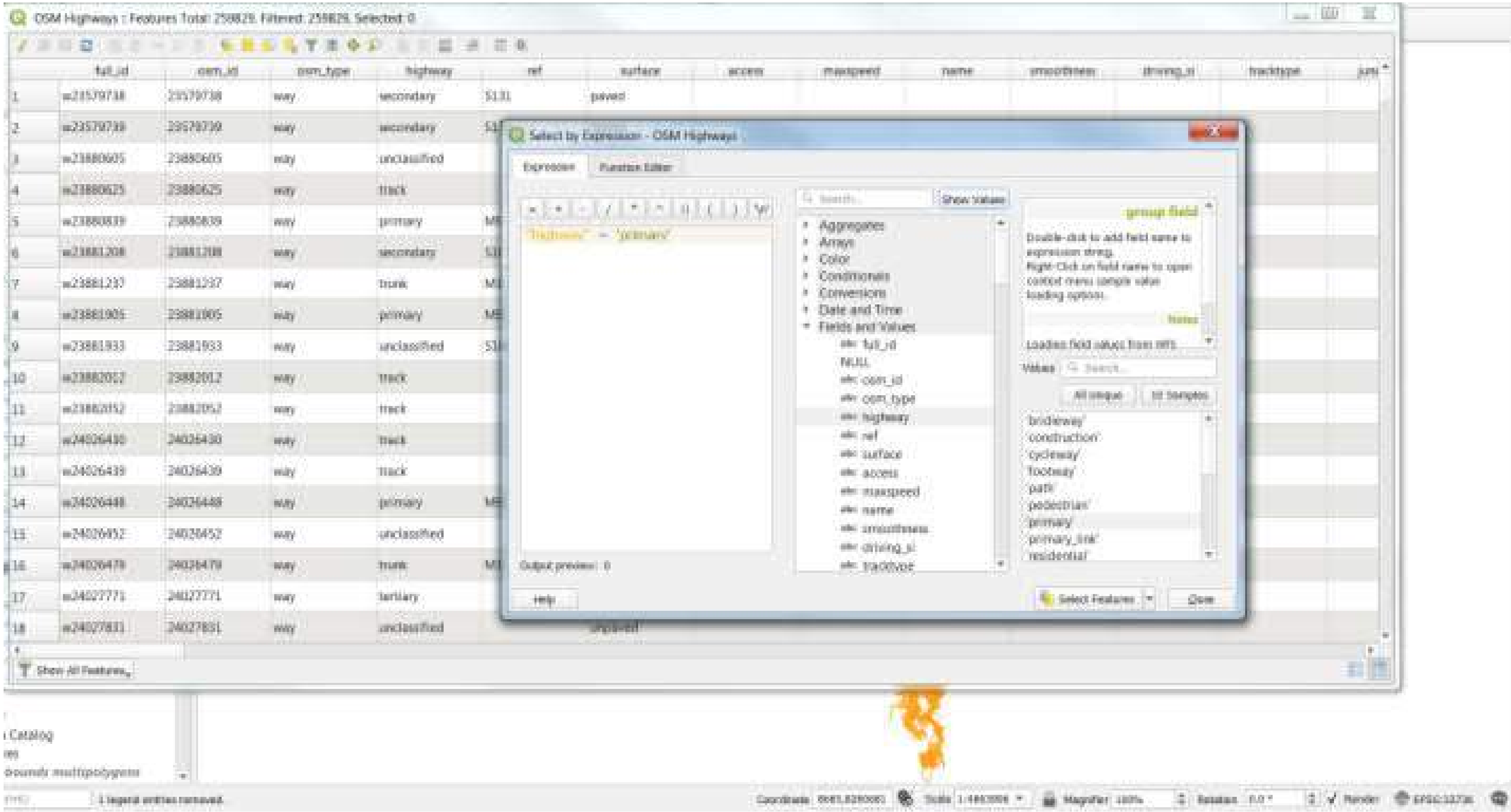
This filter can be downloaded from https://wiki.openstreetmap.org/wiki/Osmfilter

> Filtering of an OSM map to extract relevant features.
> The command line below extracts all highways:
>
> ./osmfilter <input_file> --keep="highway"

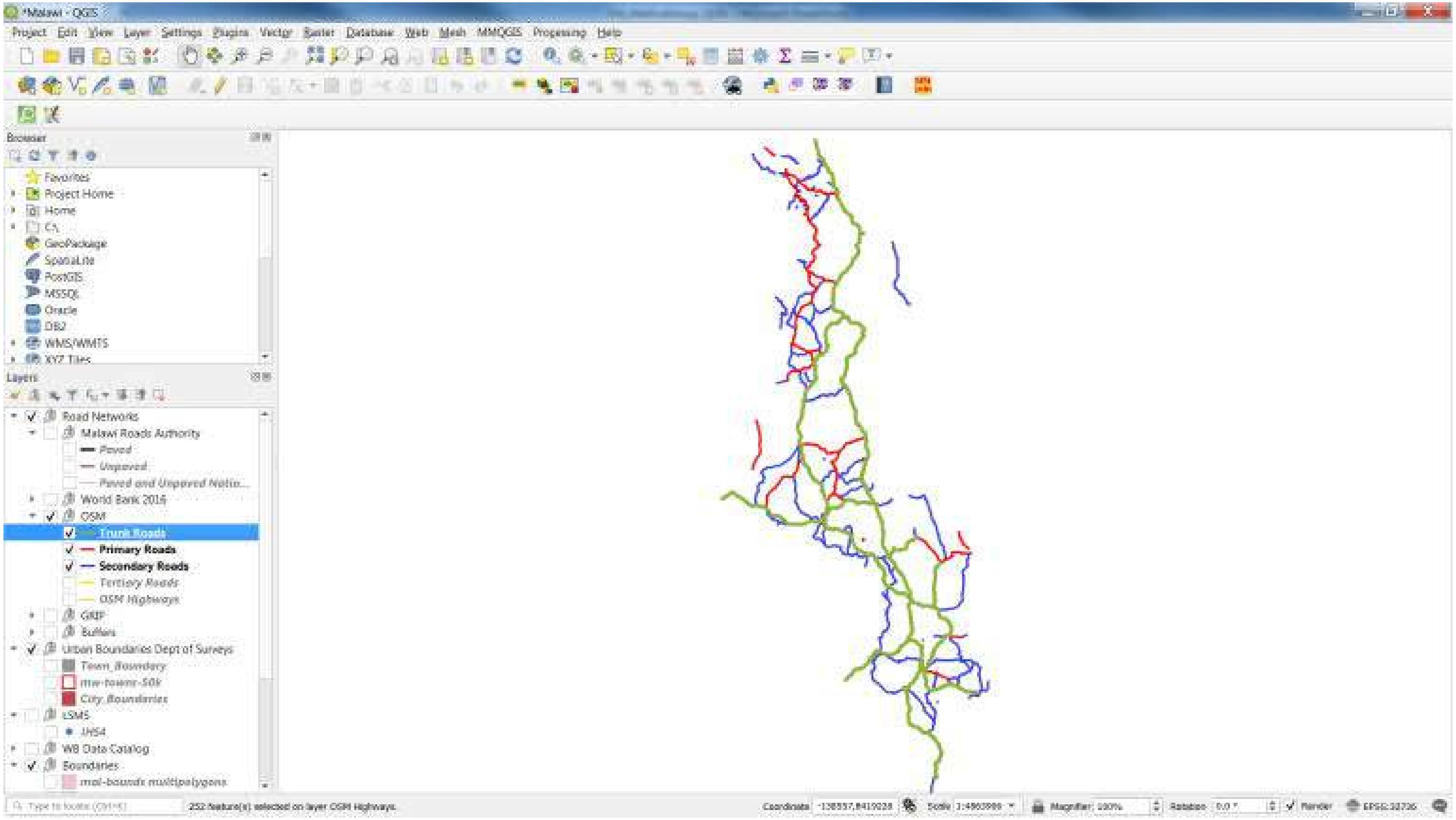
Step 3: Load Highways into QGIS.



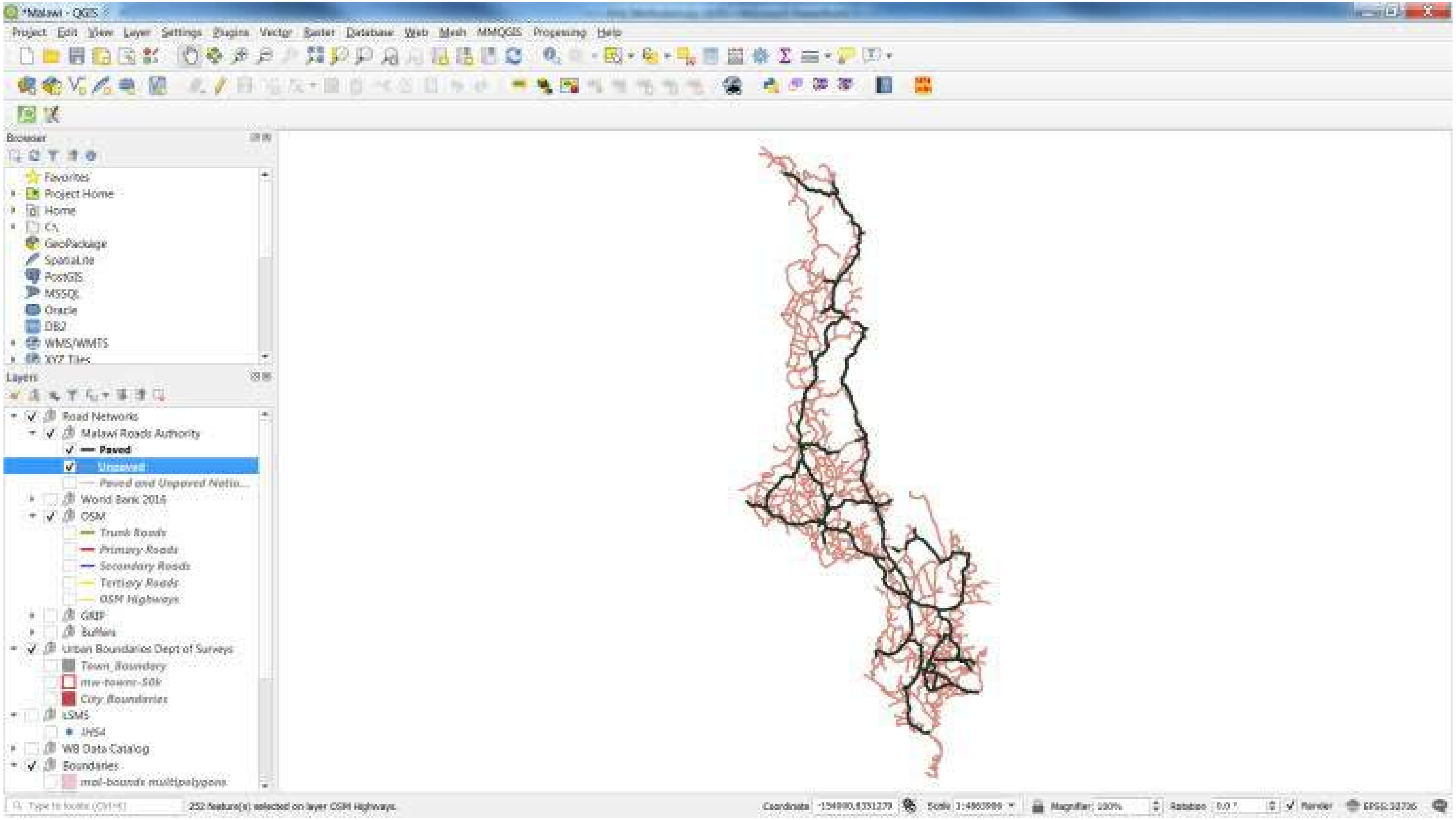
Step 4: Filter Highways in QGIS.



Step 5: Save the required classifications as separate layers (confirm length with official stats)



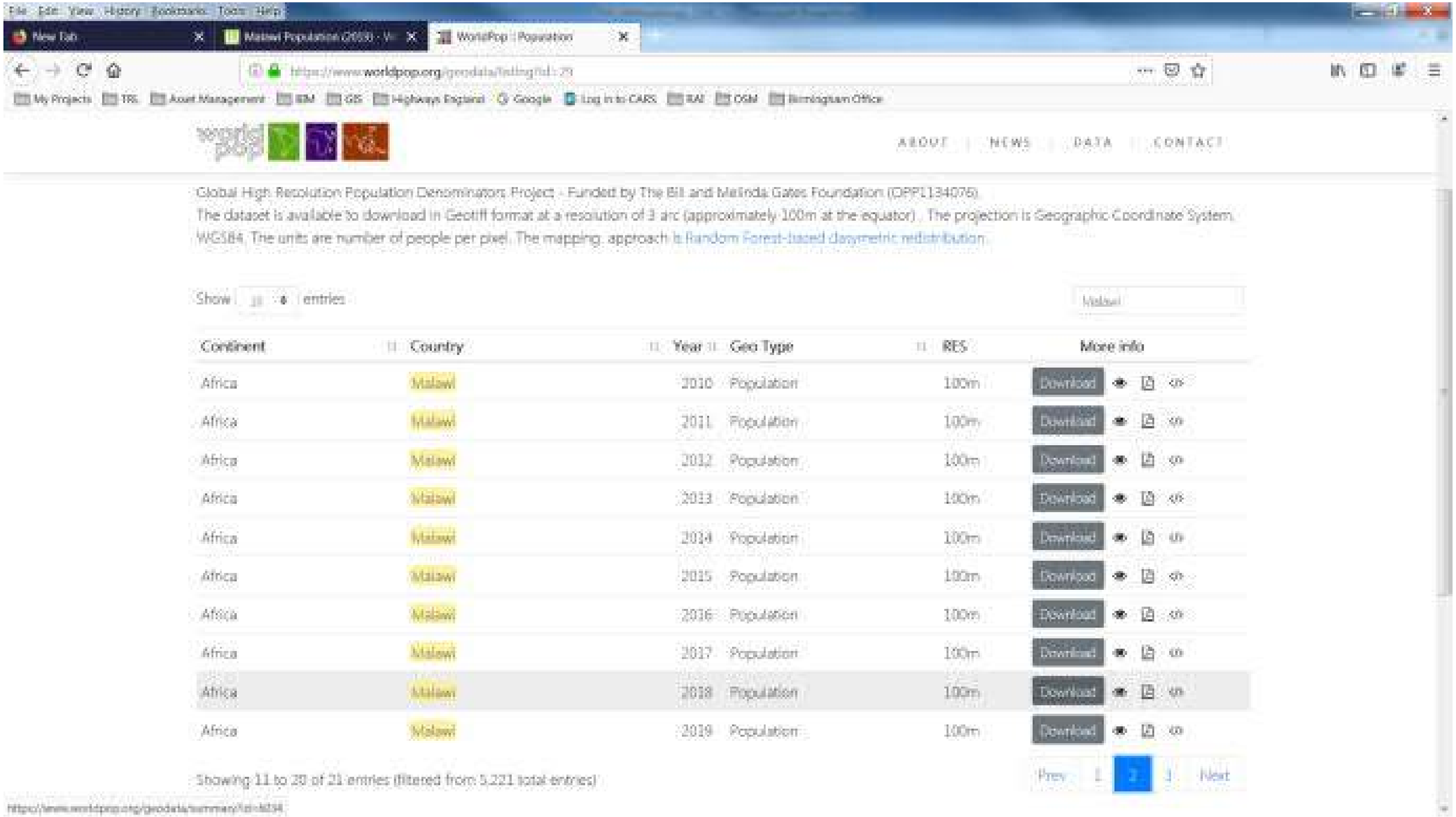
Step 6: Separate out the Paved and Unpaved Roads



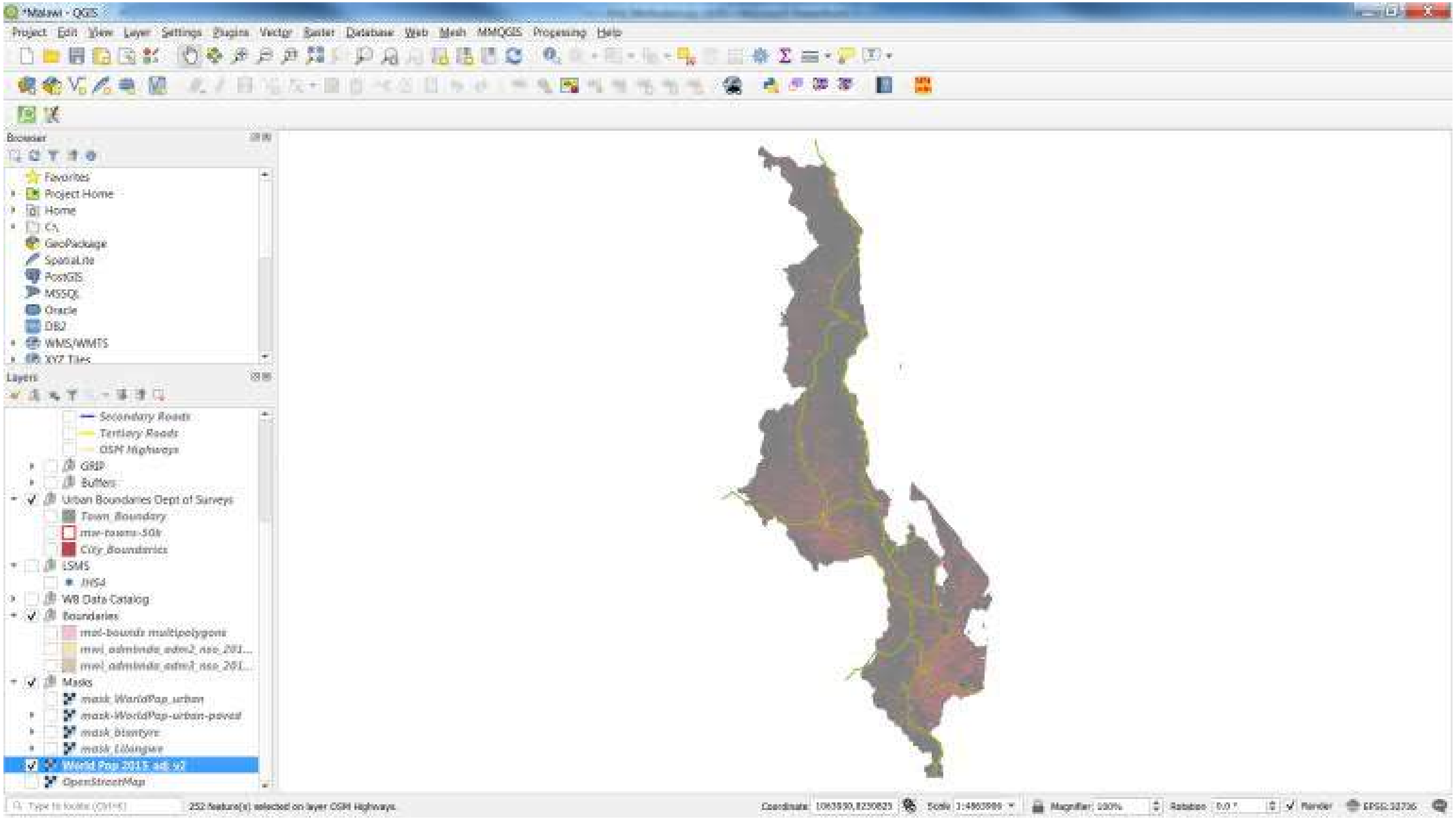
Step 7: Filter OSM data – additional notes

It is not uncommon for an OSM download for a country to contain roads that are outside the national boundary. This can be due to the road overlapping the national boundary by even a few metres. Ideally, the user should truncate the road at the national boundary. However, in practice, if it is not truncated, it will make very little difference to the RAI calculation, and so can be ignored.

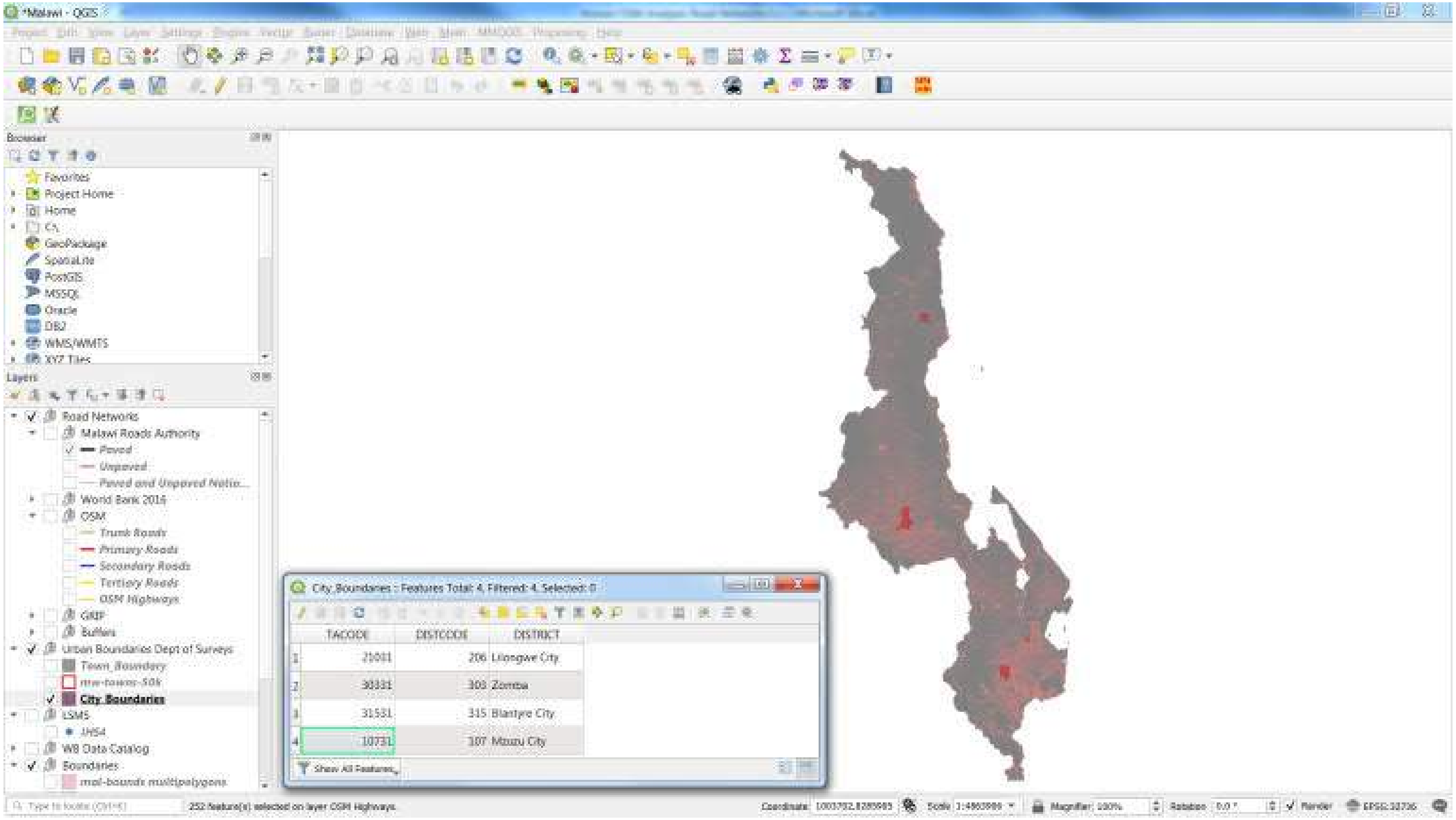
Step 8: Download WorldPop data



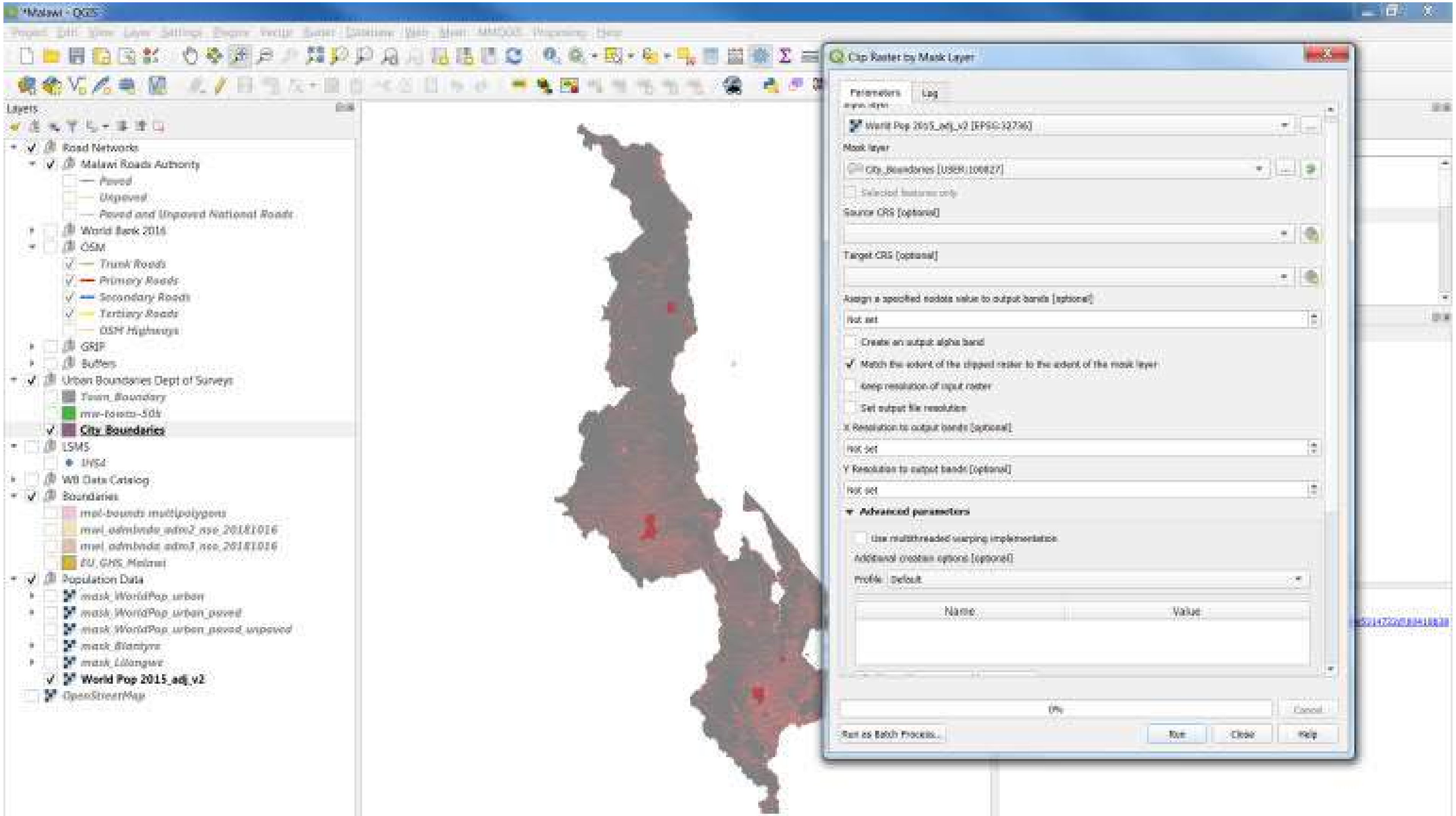
Step 9: Load Population Data into QGIS (overlay road network to verify referencing)



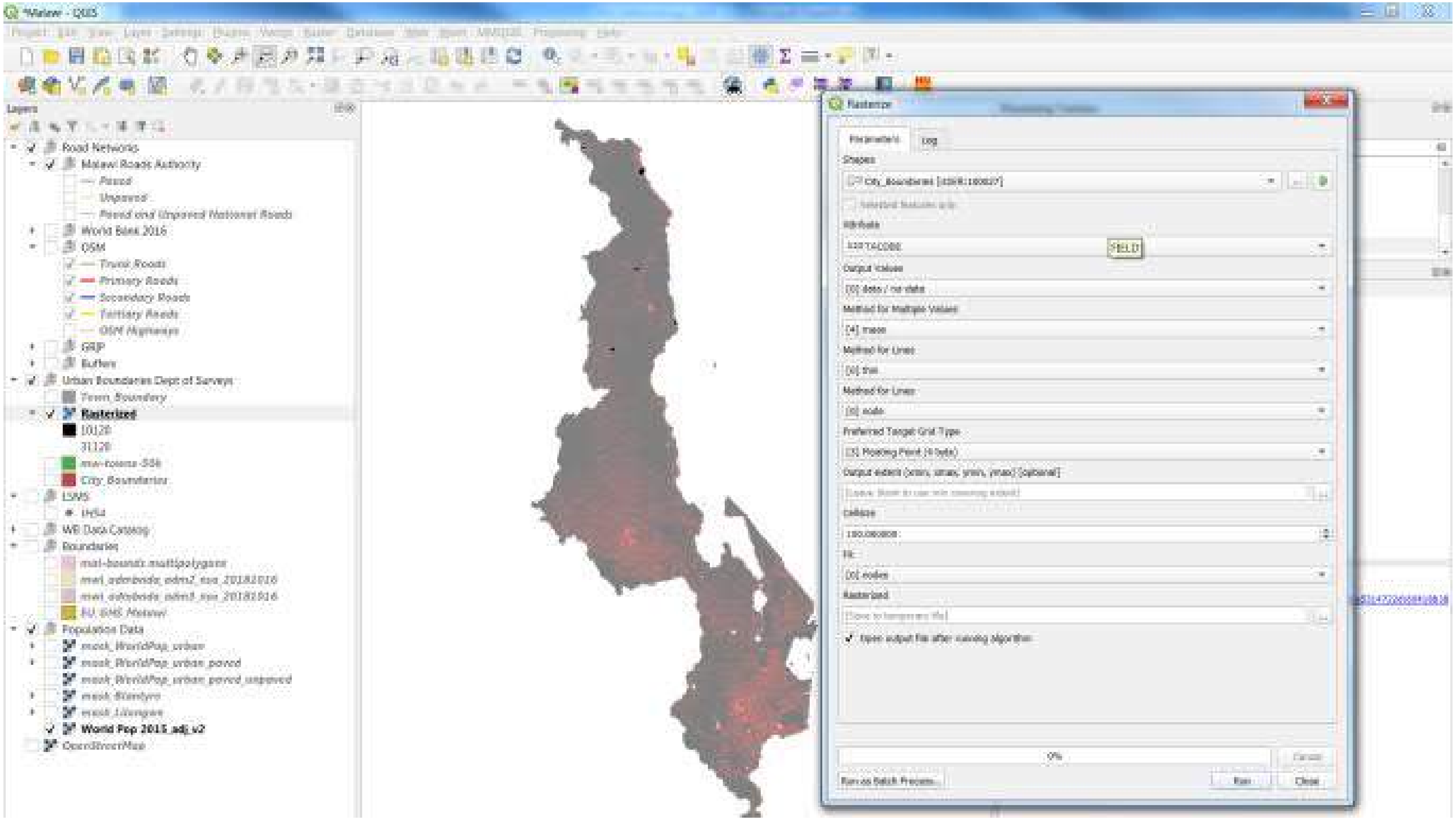
Step 10: Load City Boundaries (as vectors)



Step 11: Clip city vectors out of the raster to create a raster of city population data only

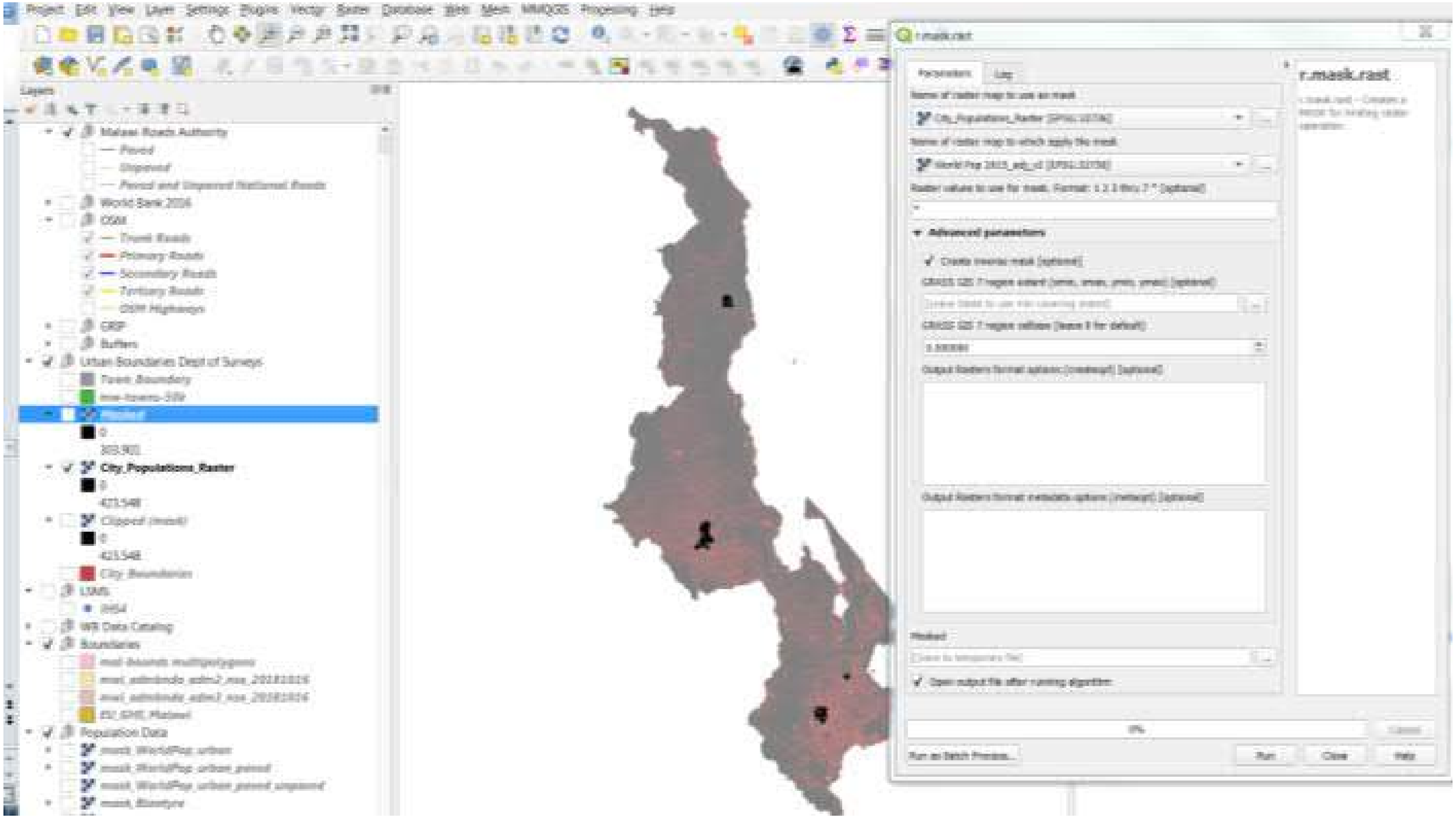


Step 11 A: Alternatively, use the Rasterize Tool to rasterize the City Boundaries

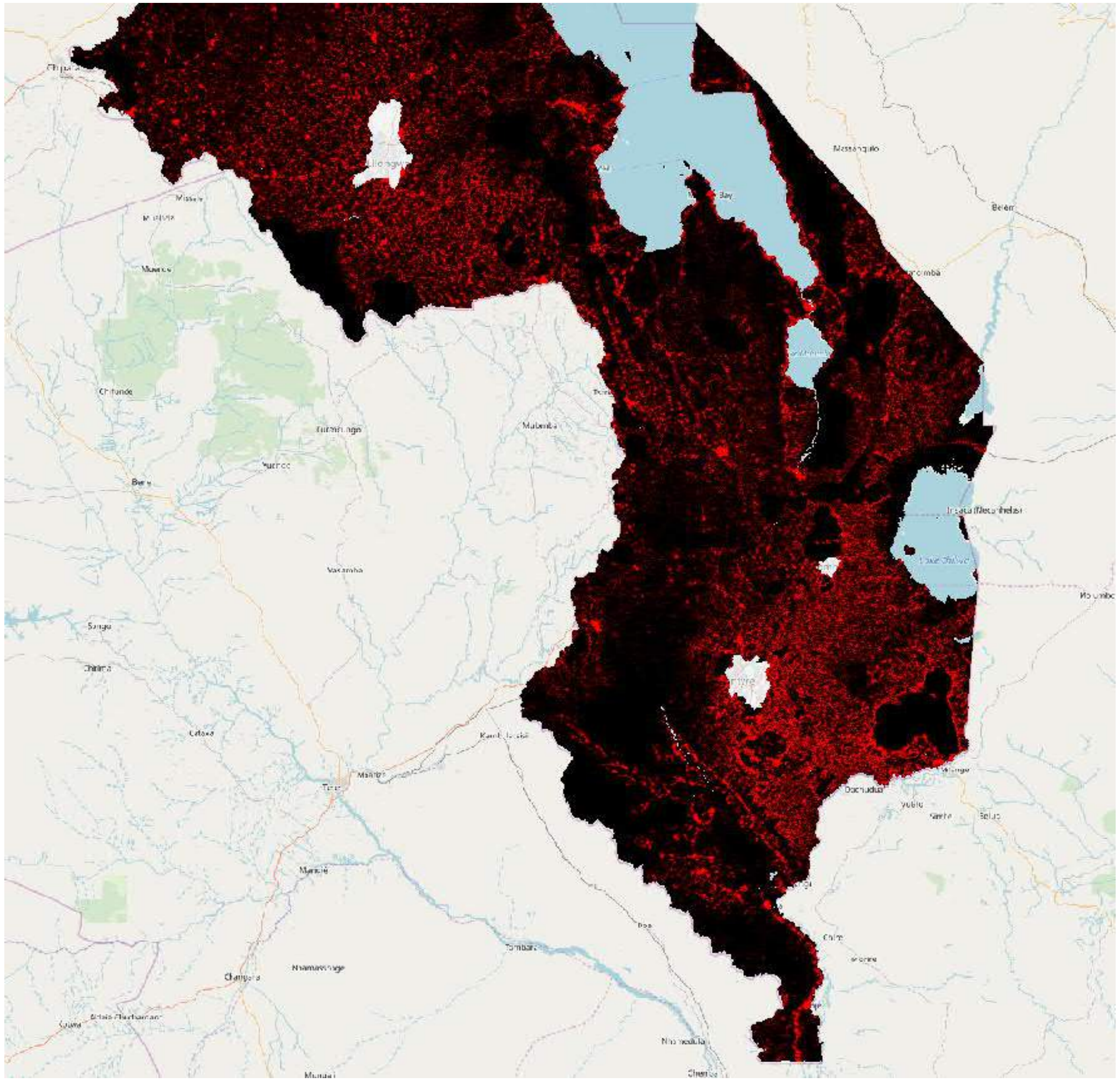


Step 12: Clip city rasters out of the glaobal raster to create a raster of rural population

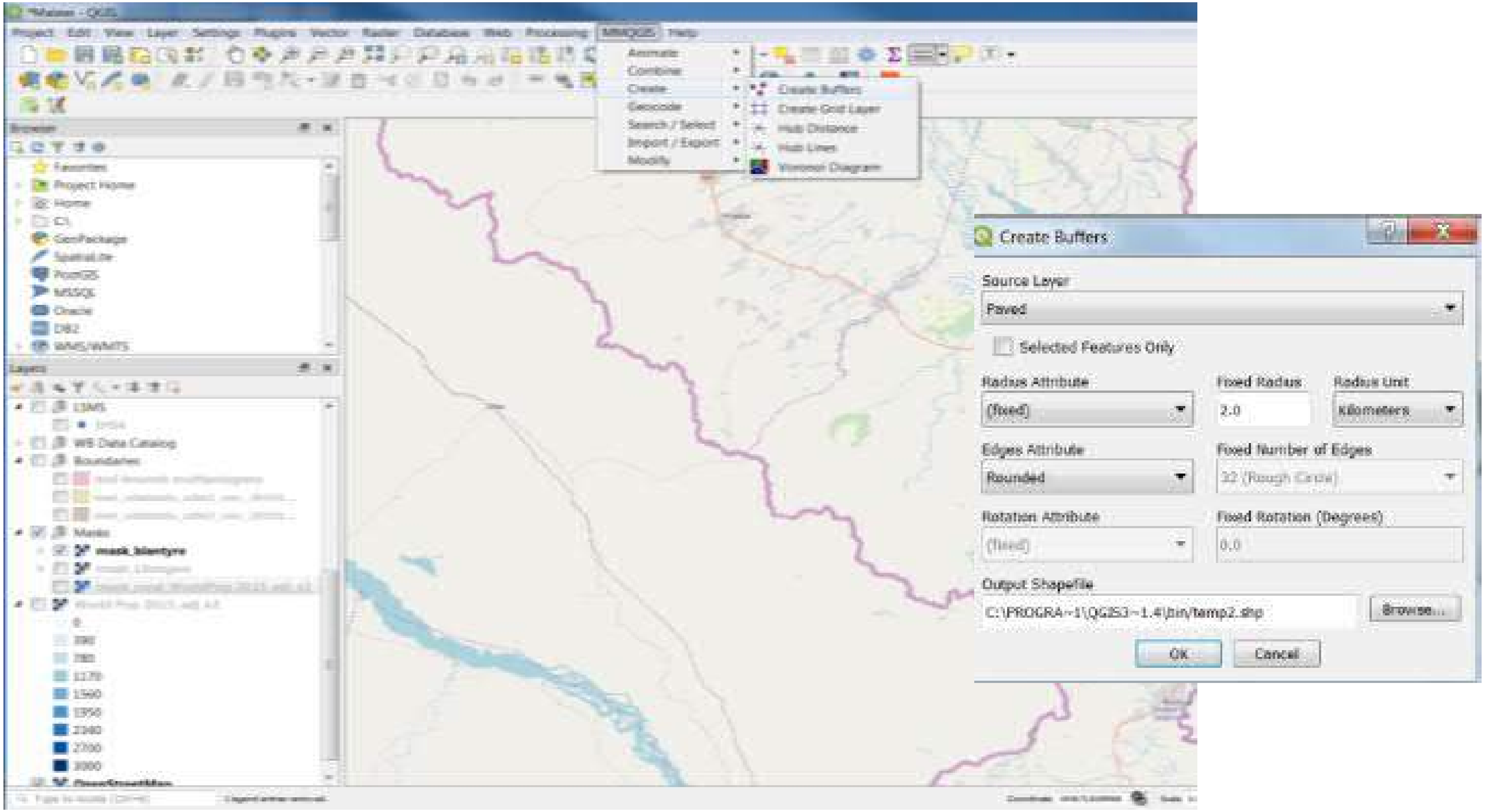
Note: use the GRASS r.mask.rast function with inverse mask



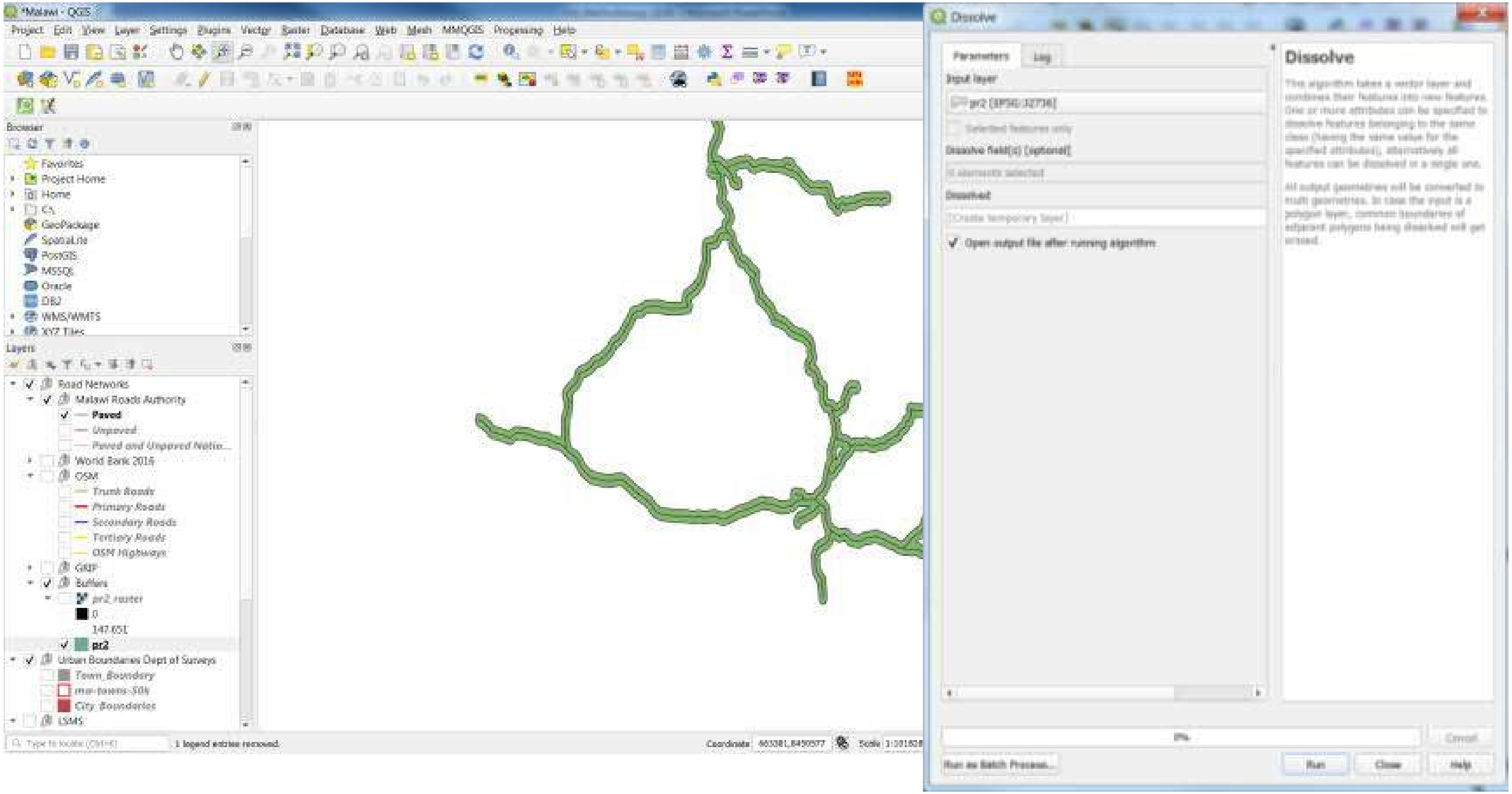
Step 13: View Raster of Rural Population (with holes for cities)



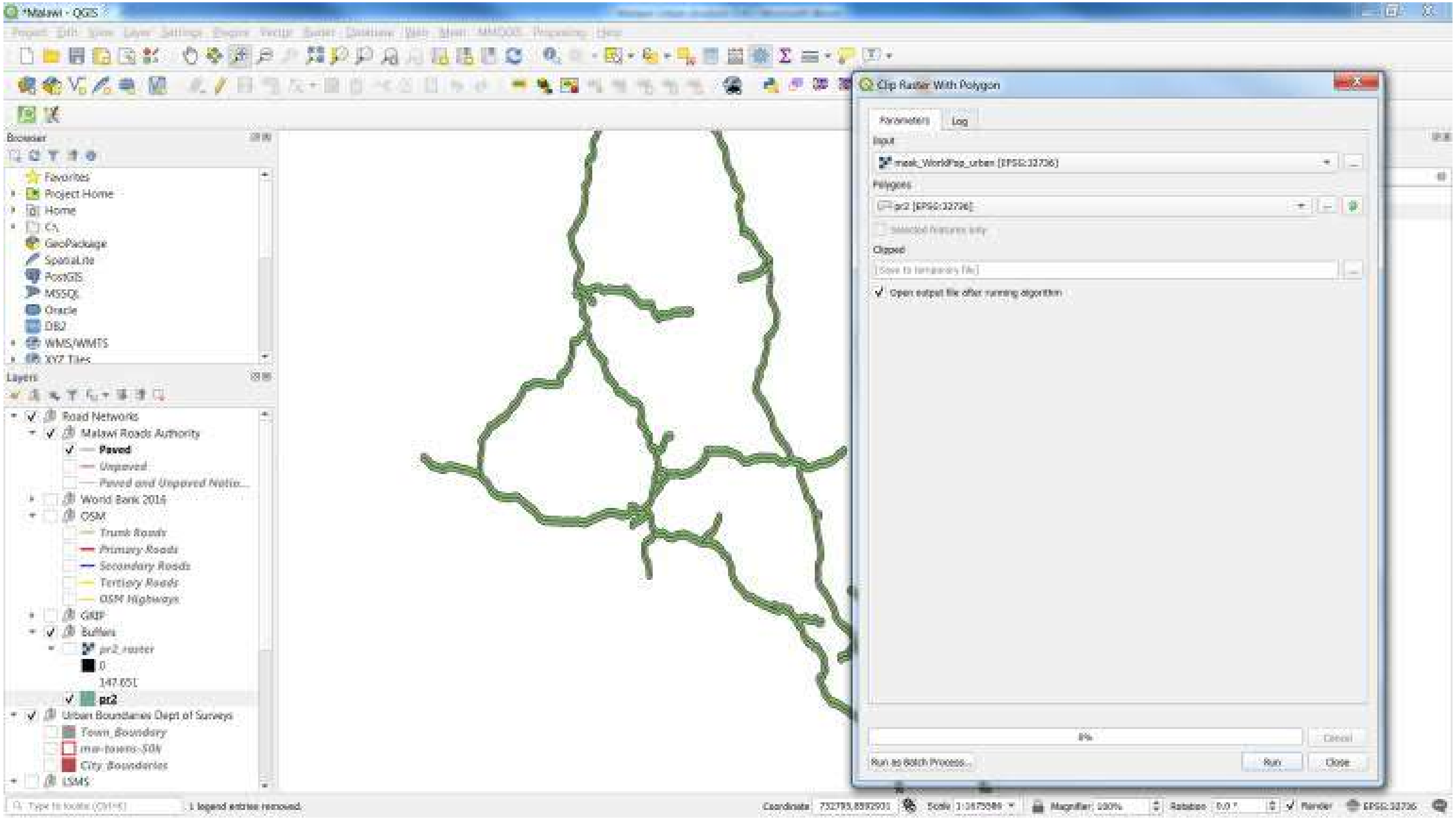
Step 14: Create a 2 km buffer around the paved roads



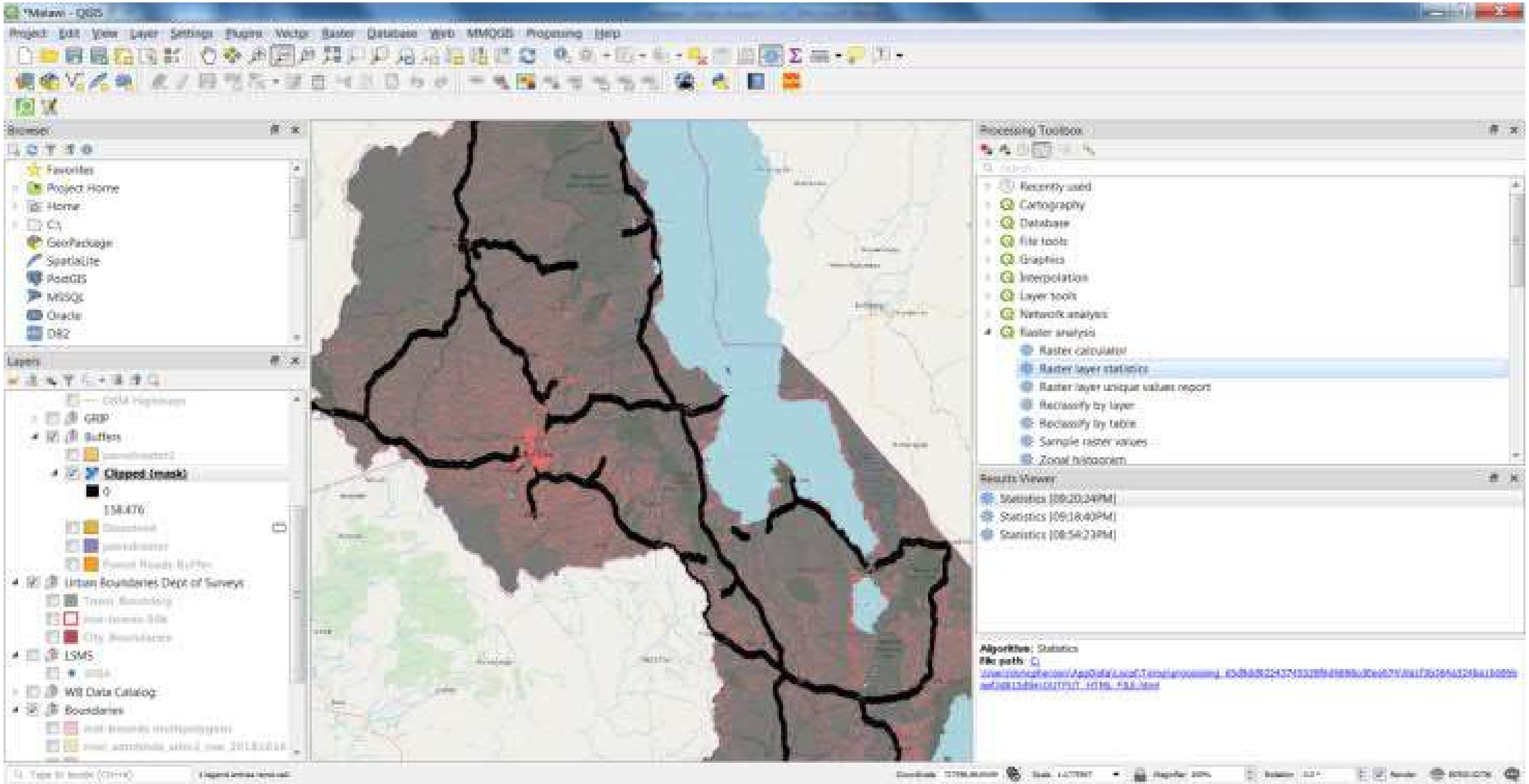
Step 15: Dissolve the buffer into a single feature for ease of processing



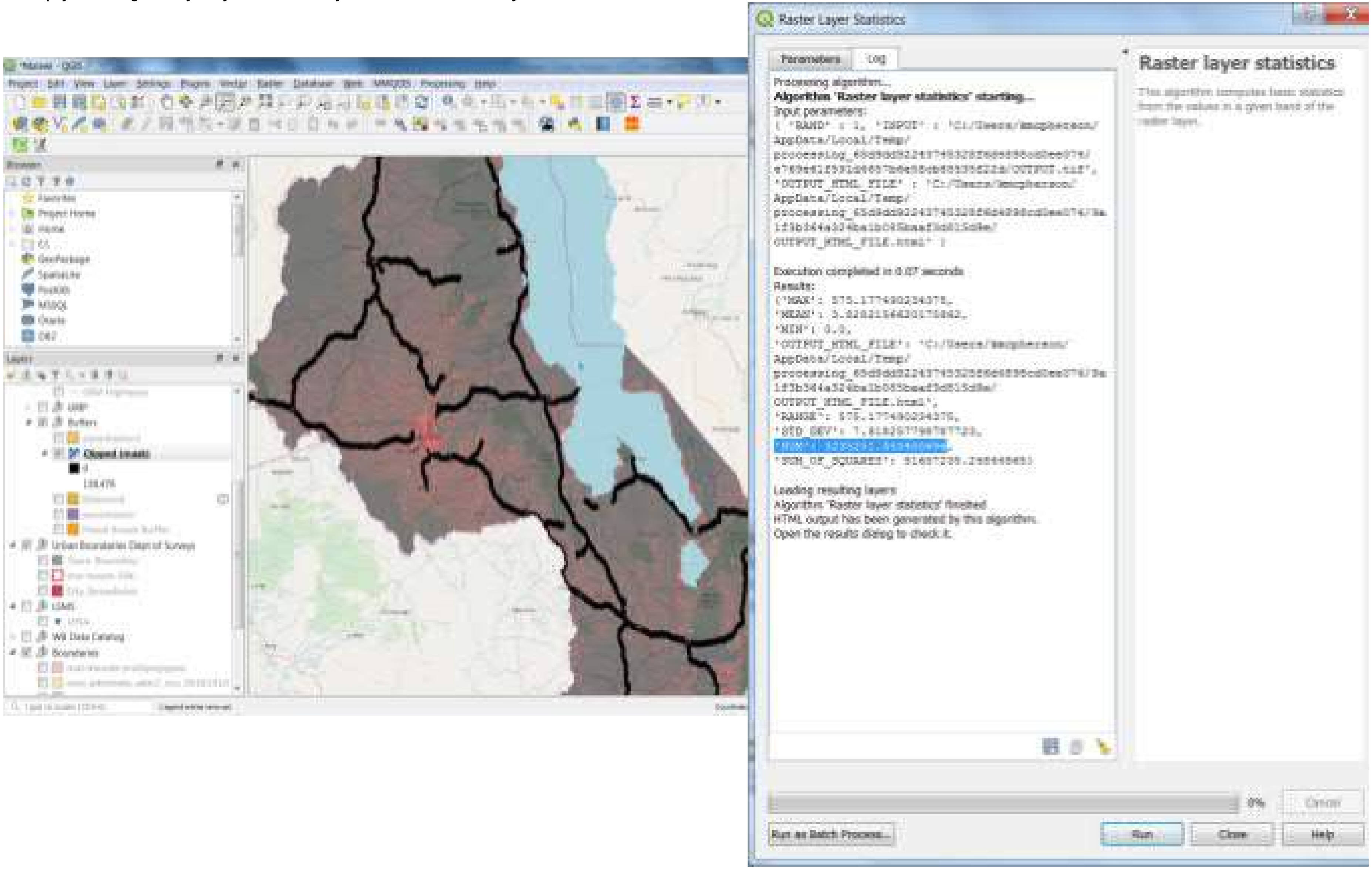
Step 16: Clip the paved 2 km buffer from the WorldPop data (rural only from previous step)



Step 17: …to give raster layer of WorldPop data only for the 2 km paved buffer

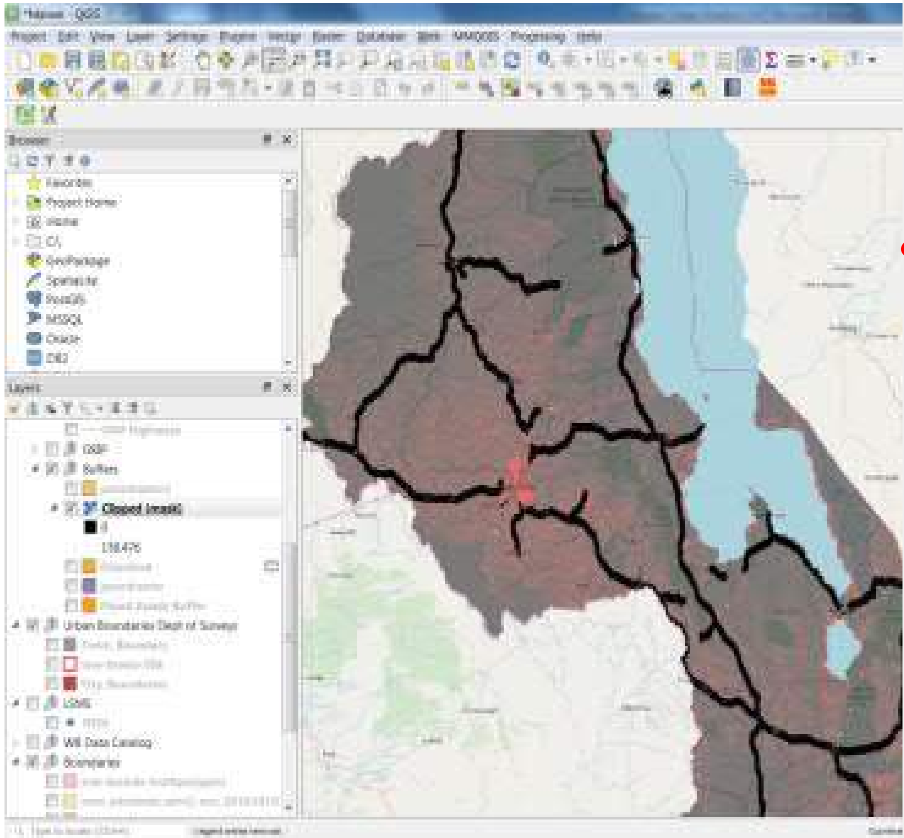


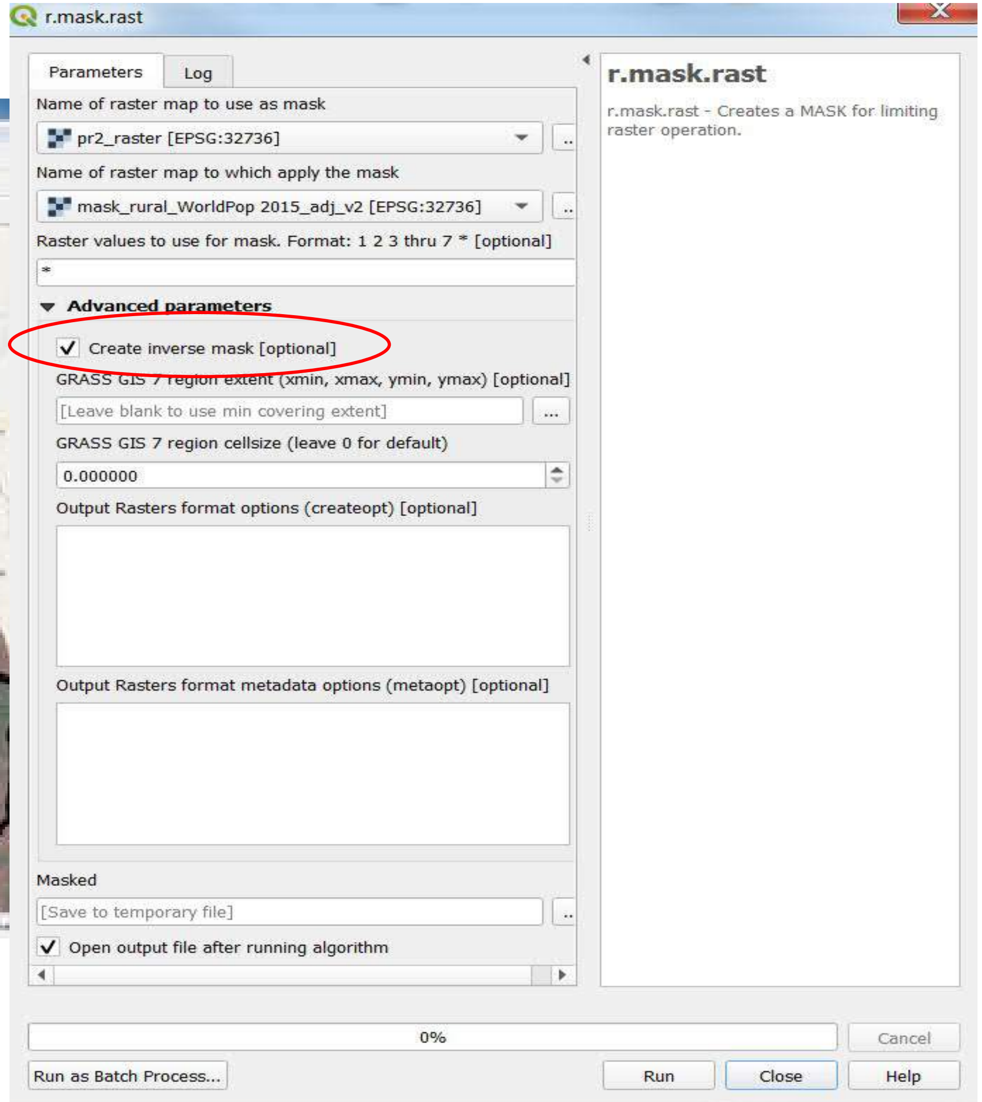
Step 18: Calculate the layer statistics to identify rural population living within 2 km of paved road. Multiply that figure by any Accessibility Factor as necessary, and record it.



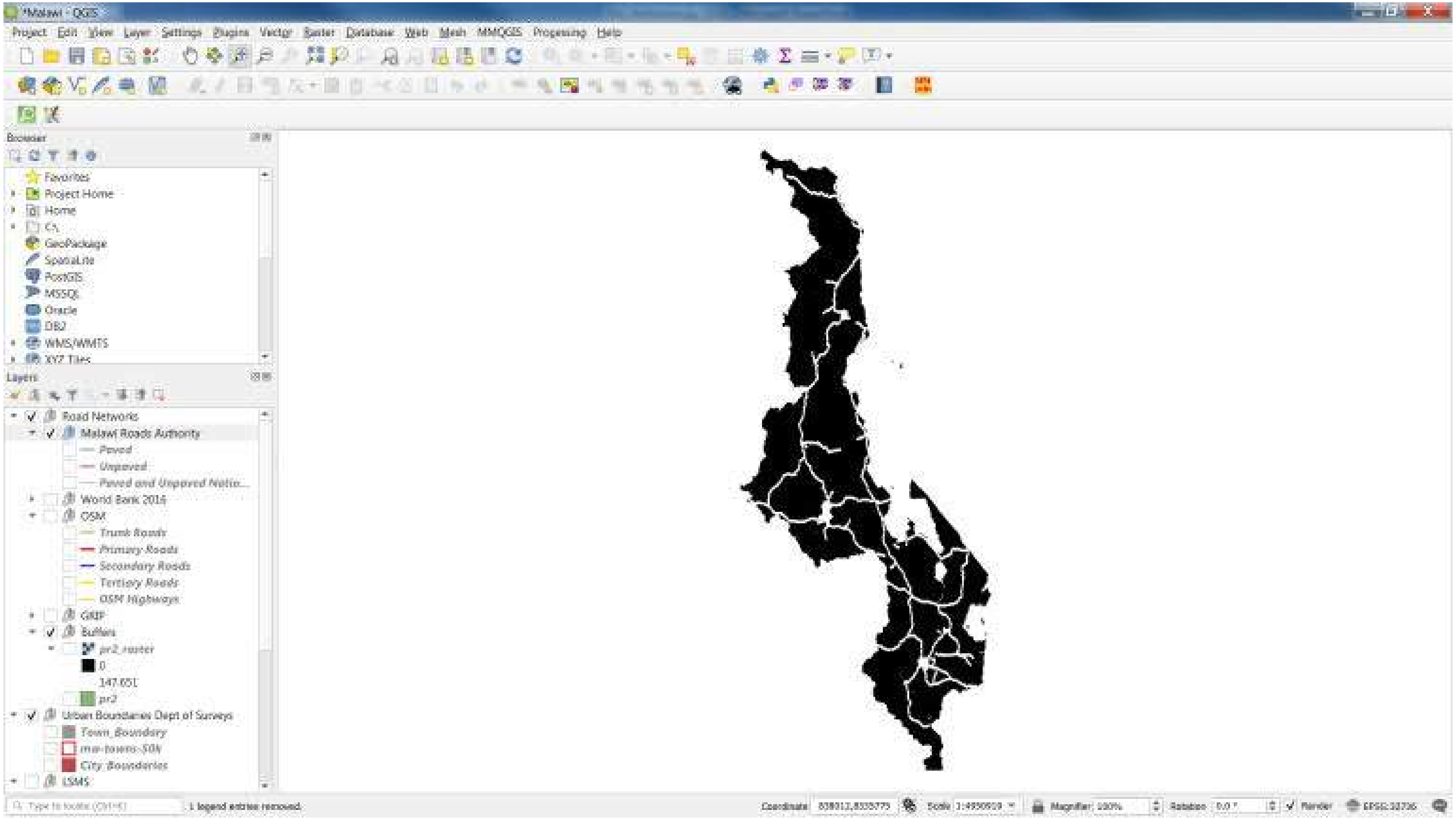
Step 19: Remove the Paved Road Buffer from the WorldPop (clip with invert mask)

Note: use the GRASS r.mask.rast function with inverse mask

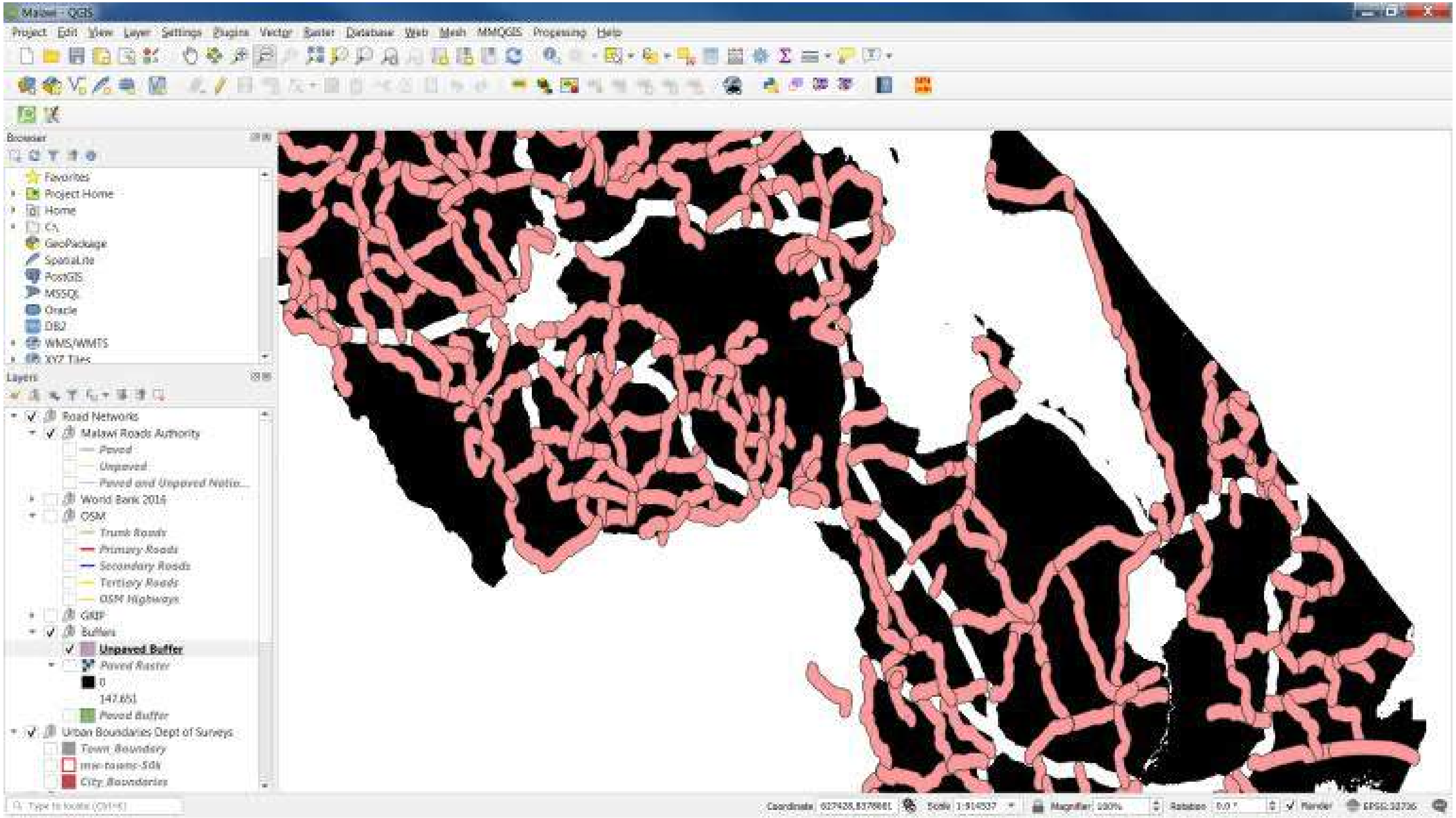




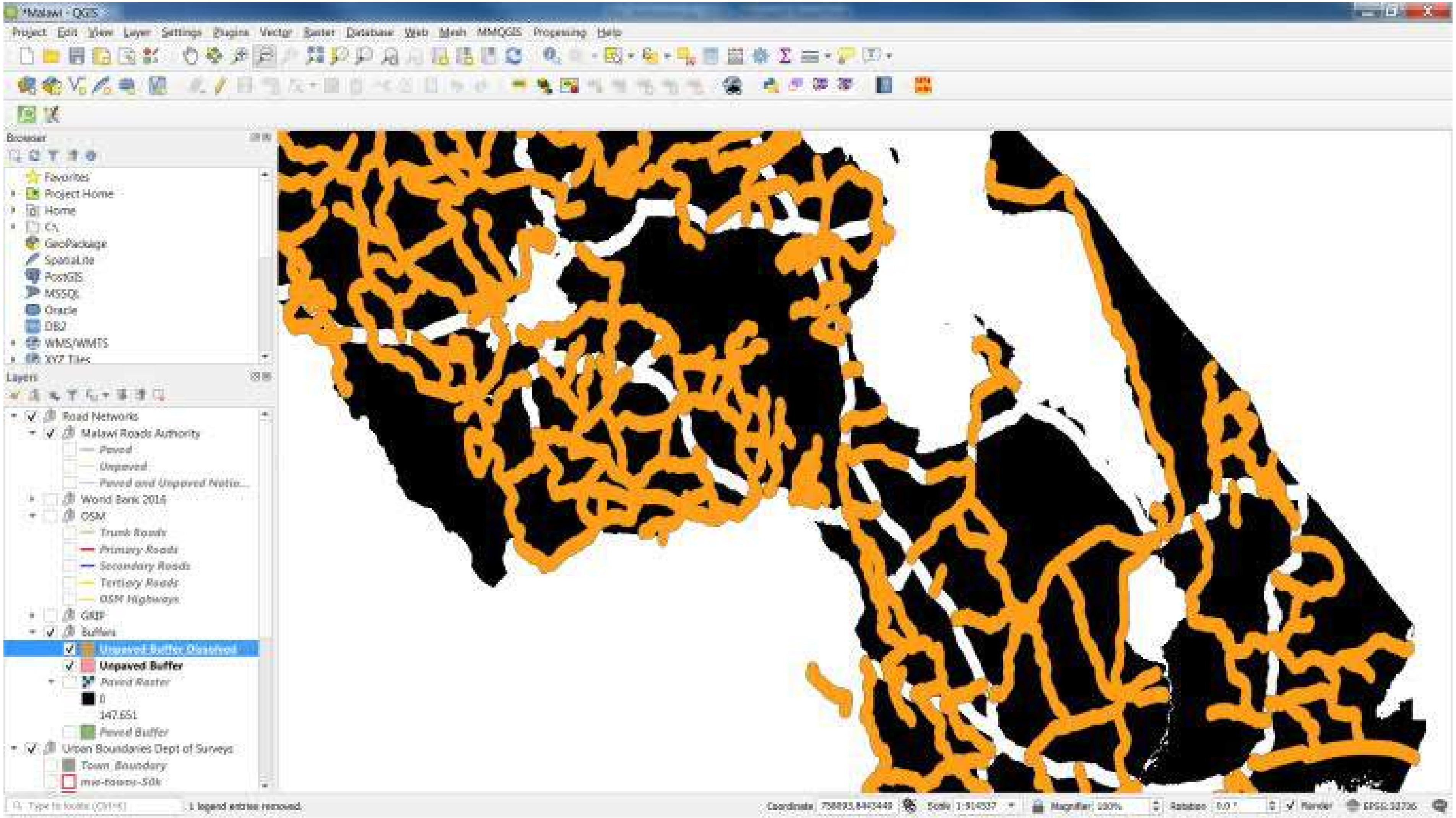
Step 20: This leaves a raster of Rural Pop outside 2 km of paved road



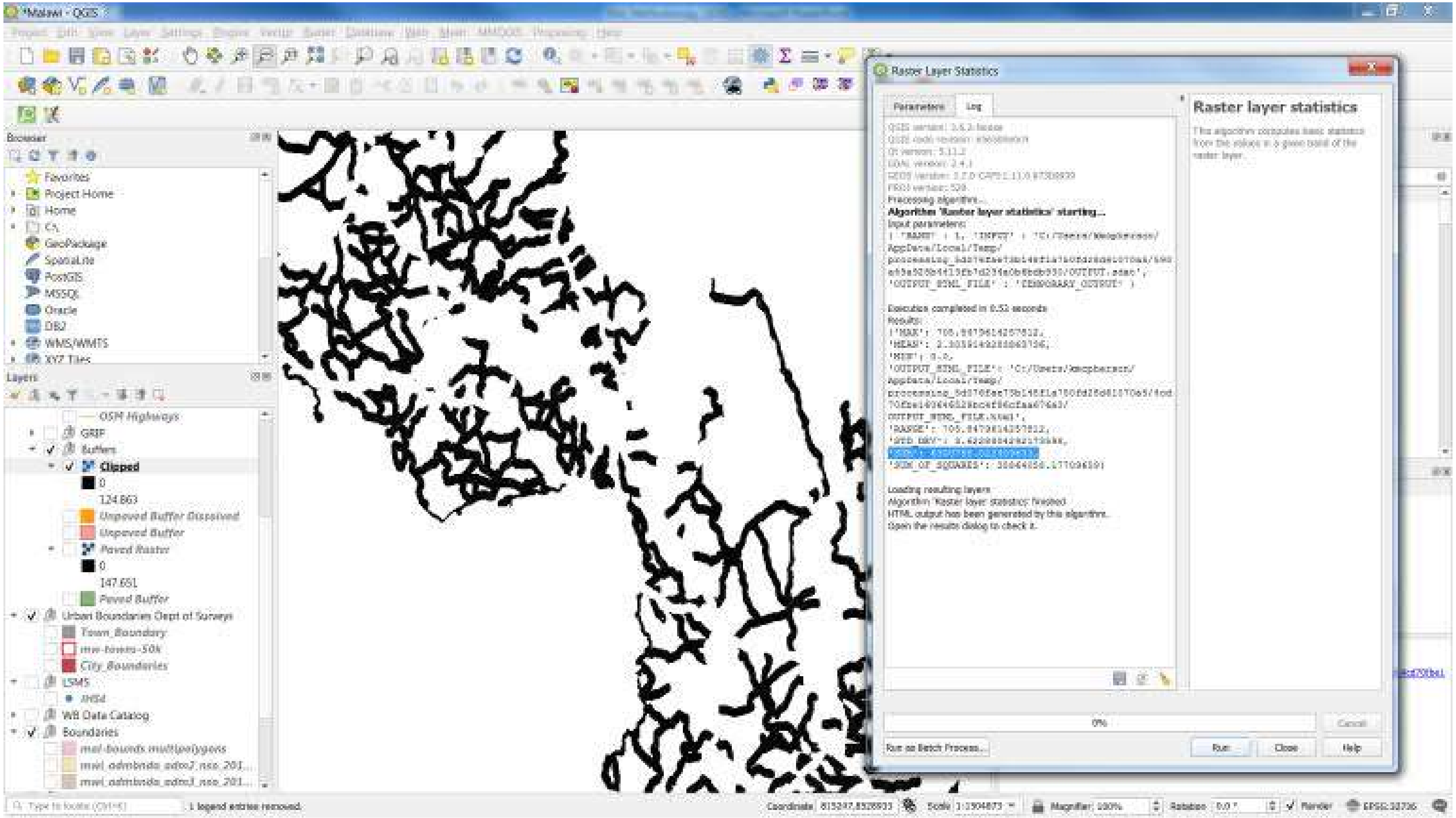
Step 21: Create a 2 km buffer around unpaved roads



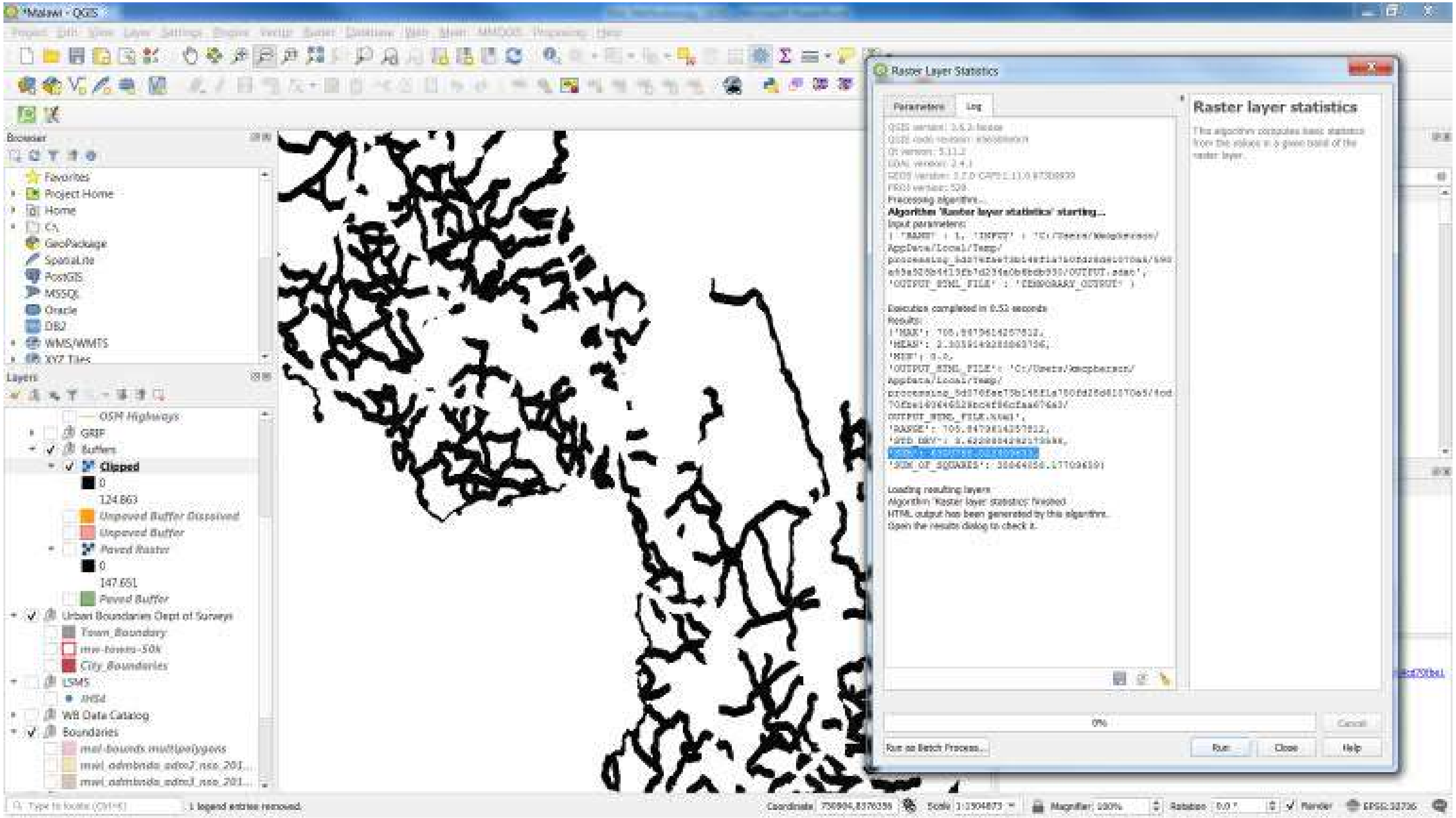
Step 22: ...dissolve the buffer...



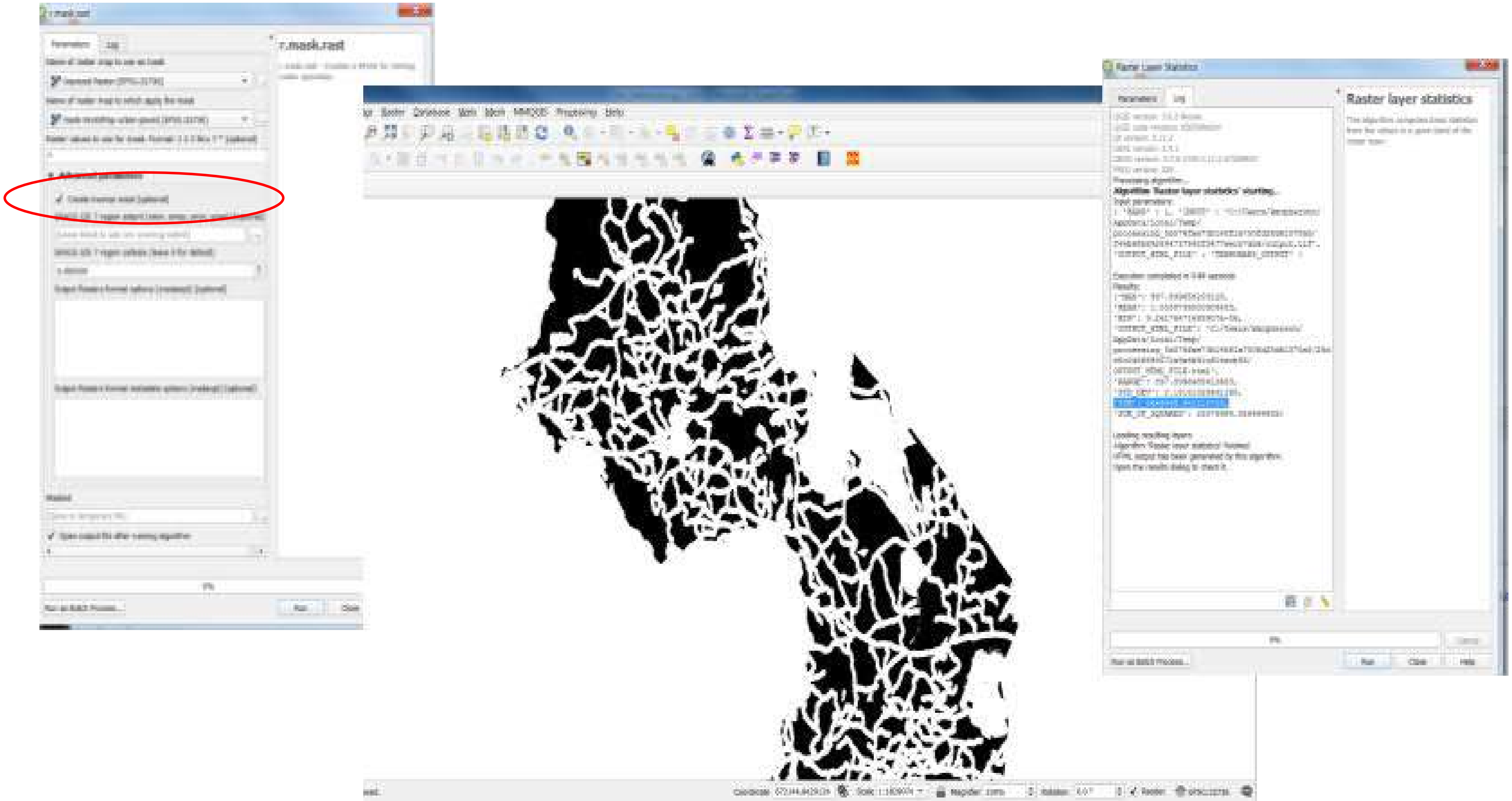
Step 23: ...clip the unpaved roads from the WorldPop (rural, paved only)



Step 24: ...note the rural pop within 2 km of the unpaved roads, and multiply by the accessibility factor if any



Step 25: Apply the raster mask (inverted) to produce final map showing all rural population living more than 2 km from either paved or unpaved road. Note: this final statistic does not take account of Accessibility Factors – they were calculated at intermediate steps, and should be totalled at the end.



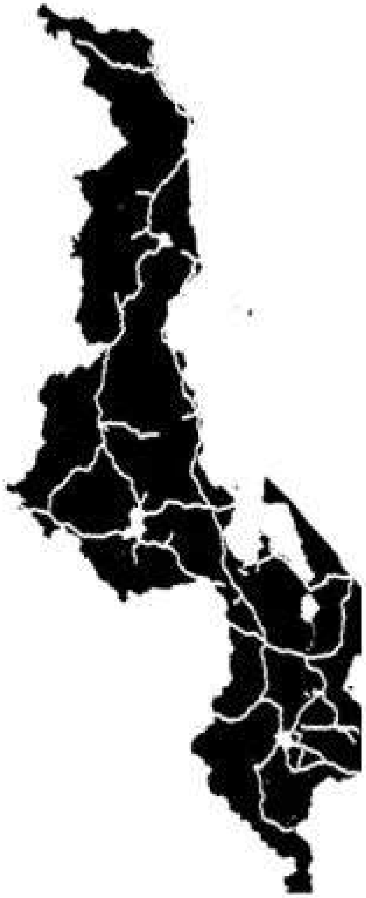
Summary:

17,308,684

Total Population

15,200,988

Rural Population



11,965,736

Rural Population
Living > 2 km from
Paved Road

5,664,948

Rural Population
Living > 2 km from
Paved / Unpaved Road
("raw" RAI = 63%)

Summary Statistics

City	Population	Area (m^2)
Lilongwe City	922,374	401,008,717
Zomba	87,336	40,123,805
Blantyre City	884,817	236,380,439
Mzuzu City	213,169	140,277,253
Total	**2,107,696**	**817,790,214**

Road Network	Length (km)
Paved Network length	2,994
Unpaved Network length	11,023
Total	**14,017**

	Calculations	Accessibility Factors	Accessibility Factors Applied
Total Population	17,308,684		
Rural Population	15,200,988		
Rural Population within 2 km of a Paved Road	3,234,663	1	3,234,663
Additional Rural Population within 2 km of an Unpaved Road	6,300,788	0.9	5,670,709
Total Rural Population within 2 km of Paved or Unpaved Road	9,535,451		8,905,372
RAI	**62.7**		**58.6**

QGIS Tips (for Desktop Processing):

1. Choose the projection at the start, and stick to it throughout the project.
2. Convert any input files to that project projection, and save them as projected files as you go – this saves processing time for "on-the-fly processing", also it has been noted that some QGIS tools don't work if the input files are in a different projection from the project file.
3. Always save any temporary files created (e.g. in the buffering process) as local files to save re-processing afterwards and to prevent possible error during later processing functions.
4. After running the buffer programs, always dissolve the features to create a single polygon from which to clip later – otherwise the clipping functions may not operate properly.
5. QGIS sometimes contains multiple tools from different suppliers (through plug-ins) that purport to do the same thing. Difficulties were experienced with some tools, possibly due to complex polygons. If one doesn't work, try another tool.
6. Accessibility Factors must be applied in order of importance (e.g. Paved first, then Unpaved).
7. Use meaningful names for layers / folders.

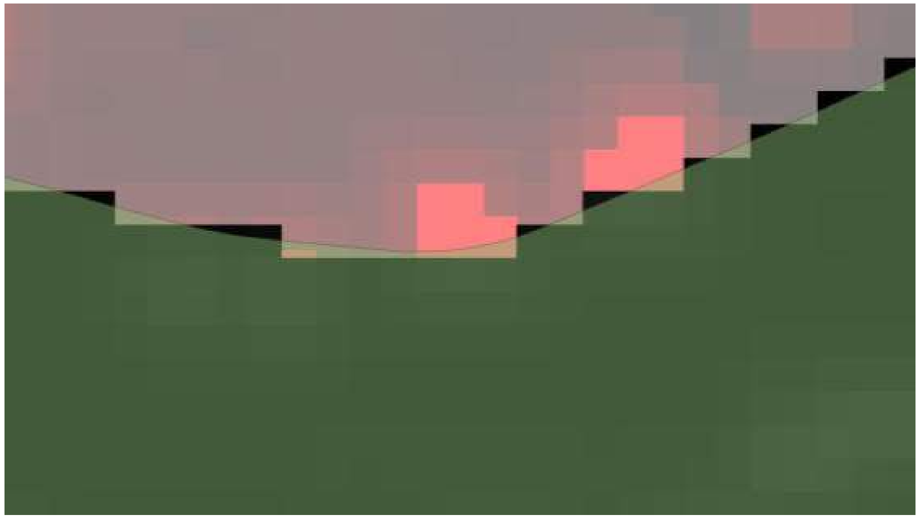
Clipping the raster data

What the QGIS "Clip Raster with Polygon" tool does is:

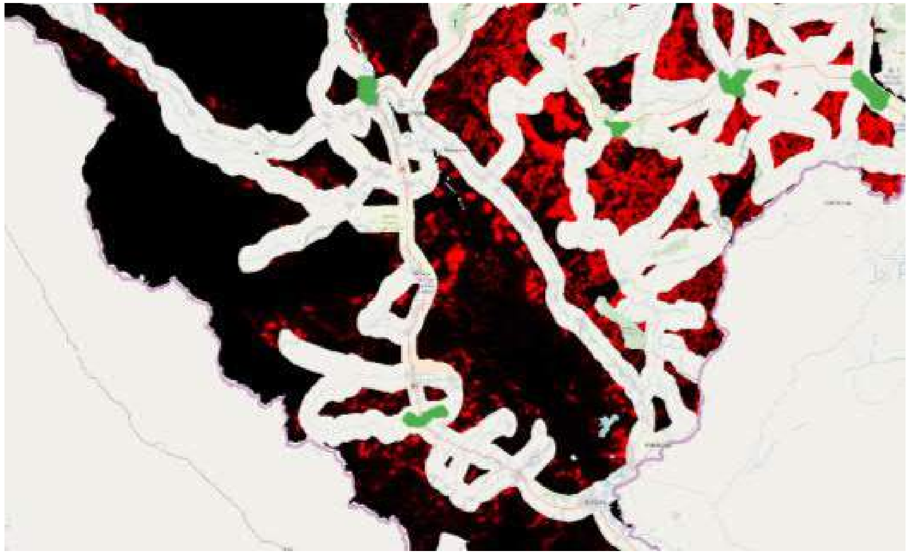
If the polygon intersects the raster at > =50% area, then the cell is included

If it intersects at < 50%, then it is excluded

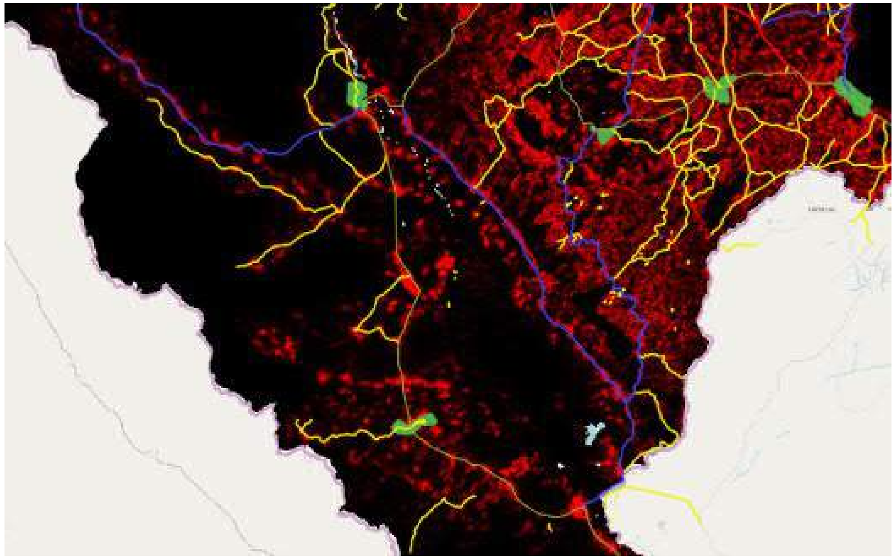
It is assumed that this evens out over the totality of city boundaries and road buffers



By-products



Removing the 2km buffer data identifies clearly those areas that are not serviced by an all-season road, and identifies the areas of highest population density.



Shows the extent of ribbon development against the existing network, and highlights areas where ribbon development is not so prevalent.

Annex C: Secondary RAI Measurement Options and Methodology

C1. Introduction

In his review of the RAI, Vincent (2018) recommended that a secondary, supplementary indicator be developed to allow countries to take into account local infrastructure that might not be included in the standard RAI measurement. One example would be motorcycle trails, and another could be navigable waterways. This has been further discussed in subsequent RAI research reports (Workman et al, 2018; Workman and McPherson, 2019a and 2019b).

Such an indicator would be voluntary (depending on the country's interests) and in addition to the standard RAI measurement required for SDG indicator 9.1.1. Like the RAI, it should be a measure related to infrastructure provision and its all-season availability.

This methodology in this annex is therefore not part of the standard RAI methodology, but should be considered as a methodology for a future separate indicator in addition to RAI.

C2. Alternative rural access and mobility indicator

This annex relates to that optional secondary RAI measurement, and not to a new rural access indicator that relates more to rural mobility, which was another suggestion in the Vincent Scoping Report (2018). For example, an alternative indicator could be related to the time required to access medical facilities, markets or other services. For land-based transport, such an indicator would, in part, depend on road provision and condition (as the current RAI) but would also depend on the availability of transport services and/or means of transport. Such a new rural mobility indicator has merit, for 'roads are not enough': people need to access means of transport to allow them, and their goods, to reach service centres. As Vincent (2018) reported, countries are increasingly collecting data relating to mobility, and there is interest in measuring people and freight movements in rural areas among multi-lateral development banks.

The SuM4All Global Tracking Framework (GTF) for Universal Access has the RAI (SDG 9.1.1) as its principal indicator for rural access (GTF, 2019). For urban access it has SDG 11.2.1: the proportion of [the urban] population that has convenient access to public transport, by age, sex and persons with disabilities. The SuM4All Global Tracking Framework has six general, national-level supporting indicators relating to the quality of roads, rail infrastructure, air transport infrastructure, port infrastructure and passenger volumes by mode of transport, notably air and rail. All these indicators are currently being tracked, based mainly on information compiled by the World Economic Forum, the International Civil Aviation Organization and the World Bank. The GTF also has eight supporting rural indicators and thirteen supporting urban indicators, although these are not yet being tracked on the SuM4All website (GTF, 2019). The GTF supporting rural indicators are:

- Proportion of rural roads in "good and fair condition" (as developed by new RAI)
- Percentage of markets accessible by all-season road
- Percentage of national government budget spent on low volume rural transport infrastructure
- Percentage of the rural population with access to affordable and reliable passenger transport services
- Ratio of national to local passenger transport fares (collection of data on rural passenger transport US$ per km for short distance and long-distance trips which would be disaggregated by most common modes e.g. bus, motorbike, other IMT)
- Percentage of household monthly expenditure spent on transport
- Percentage of rural population with at least daily transport service – from Living Standards Surveys (LSS)
- Percentage of households that make one motorized trip per month.

These are available on the SuM4All website at http://www.sum4all.org/global-tracking-framework . The main urban access indicator relates to public transport and is disaggregated by age, gender and disability. In addition, eleven of the thirteen urban-access supporting indicators relate to transport services. In contrast, the main rural access indicator (the RAI) relates to infrastructure, and only three of the eight supporting, rural-access indicators relate to transport services. There is currently no disaggregation by gender, age or disability within the rural transport indicators, and only one indicator, the number of motorised trips made per month, that could be easily disaggregated (subject to appropriate survey questions).

Many of the current, supporting global tracking framework indicators appear to be work-in-progress ideas, rather than clearly-defined and measured indicators. Agreeing on the key parameters to measure a rural-access-and-mobility indicator, and developing a suitable methodology would be a major undertaking. It might also detract from the current importance of this RAI initiative. This current research is mandated to concentrate on the RAI. Another separate research project is being commissioned to look at SDG 9.1.2: passenger and freight volumes by mode of transport. For these reasons, this research is concentrating on the RAI itself and its supplementary, optional secondary RAI measurement that takes into account alternative transport infrastructure that is used for rural mobility. This secondary RAI indicator will be a fully-compatible derivative of the infrastructure-based RAI, using the same methodological principles, but differing in the definition of the infrastructure being measured.

C3. Secondary, optional RAI indicator

While the standard RAI will measure the percentage of the rural population within 2 km of an all-season road, the supplementary RAI will measure the percentage of the rural population within 2 km of an all-season transport route or waterway jetty. This will include motorcycle trails and navigable waterways, which will be discussed in more detail in the following sections.
If the entire rural transport network were considered, the provision of railways and airstrips could be included, but this is not likely to be relevant to many situations. While railways and airstrips can be very important for rural access in certain countries, their provision is unlikely to greatly affect the overall RAI value. This is because in most circumstances, railways and aeroplanes only provide access at particular places (stations, halts and airstrips), around which there would probably be some all-season road access.

There are some countries, including Cambodia, Liberia and Madagascar, where local entrepreneurs have developed artisanally-made intermediate means of transport that can operate on little-used rail tracks (generally without authorisation). Such examples are rare and small scale, and are not likely to be considered worthy of inclusion in national access statistics. Similarly, there would be very few air-strips that are not connected to any all-season roads and yet have significant populations living within 2 km of them to affect the overall national RAI percentage. Some countries, such as Papua New Guinea, have vital rural airstrips that are not accessible from the road network.

However, they have small populations living within 2 km of them, and due to the local weather conditions, few could be considered all-season infrastructure (being unusable due to poor weather for more than seven days of the year). For these reasons, the suggested secondary RAI indicator will only consider motorcycle trails and navigable waterways with jetties.

C.3.1 Motorcycle trails, tracks and seasonal roads

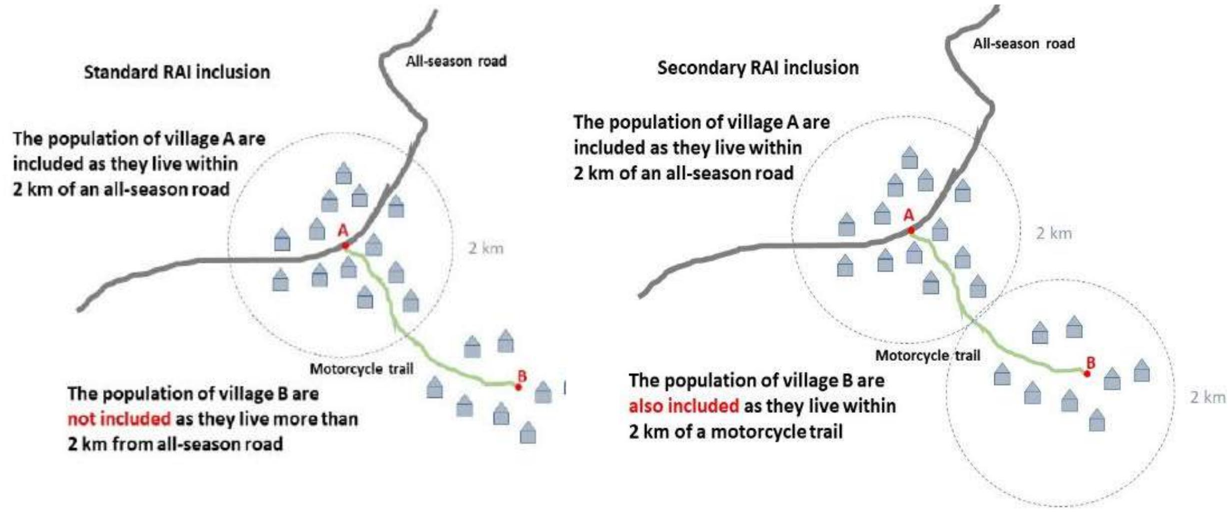
SuM4All (2019) has recognised motorcycle trails as a low-cost infrastructure option for connecting off-road villages with the road network and mainstream services. They allow personal motorcycles (and in some countries motorcycle taxis) to provide small-scale motorised transport for people and goods. Some are sufficiently wide and smooth to allow three-wheelers and/or two-wheel tractors and trailers, which can also provide small-scale passenger and freight transport (with different advantages and disadvantages). Some motorcycle trails are earth trails, but in swampy areas trails may be constructed using concrete or bricks (see Figure C.1). In many countries there are unclassified roads and tracks that are passable by motorcycles and robust vehicles. These may not be part of the official road network, but if they are passable in all seasons by motor vehicles, they provide important rural access for the local populations.

Figure C.1 Examples of brick (Bangladesh) and concrete (Myanmar) motorcycle trails

If a village is 2 km from a road, but connected by a simple track or motorcycle trail, its inhabitants have much better rural access than those villages only connected by footpaths. For villagers travelling to markets, shops, clinics and schools, if there are affordable means of transport, the potential mobility offered by simple tracks and trails can be transformational. Trails and tracks can overcome the slow and labour-intensive 'walking and carrying' required when the 'first mile' is only a footpath.

For this reason, the secondary RAI value will acknowledge this. It may be that in a country with an RAI of 60% (60% of the rural population within 2 km of an all-season road), a further 20% of people live within 2 km of an all-season motorcycle trail or track. This would give a secondary RAI value of 80%. The inclusion of villages connected by motorcycle trails is illustrated in Figure C.2.

Figure C.2 Motorcycle trail population inclusion in the standard RAI (left) and secondary RAI (right)



There may be some classified or unclassified roads that do not meet the criteria for the main RAI, but are passable throughout the year by motorcycles and robust 4-wheel drive vehicles. Indeed, in the 'ground-truthing' for the accessibility factors, it may be concluded that while 20% of roads 'fail to qualify' for inclusion in the RAI, most (or all) of these remain open all year round for motorcycles and/or 4x4s. Examples, could include roads subject to landslides that are blocked to 'conventional' traffic until heavy earth-moving equipment becomes available. Frequently, in such circumstances, motorcycles quickly find a path over the fallen debris, and keep the road open for motorcycle use. In another example, some roads develop large mud holes, causing larger-vehicles to get stuck, and such vehicles may block and further damage the roads. The larger vehicles cannot travel until conditions improve. Again, motorcycles can often negotiate routes around these problem areas, allowing the road to remain open for motorcycle traffic. Such roads, which are excluded for the main RAI, can be included in the secondary RAI.

Most countries do not record details or condition of motorcycle trails, and the burden of data collection should not be increased due to the RAI. In terms of location and length, is very likely that a good estimation of the motorcycle trail network can be identified through satellite imagery and machine learning technologies that already exist. In terms of condition, one way of including such roads can be through the accessibility factor. For example, 'ground-truthing' may suggest that 20% of roads in mountainous regions are not-all season, the accessibility factor for such roads would be 0.8 for the standard RAI. If three-quarters of these were accessible all year for motorcycles, the accessibility factor for calculating the secondary RAI would be 0.95.

OpenStreetMap (OSM) includes several subcategories ('tags') for highways, including 'Minor/ Unclassified roads', 'Service roads', 'Unmaintained track roads', and 'Paths' (OSM, 2019). All these may be passable by motorcycles, although paths in steep terrain may not be appropriate for motorcycles. Where possible OSM should be reconciled to official country records. The process for calculating the secondary RAI will be the same as for the standard RAI, but the categories of 'highways' to be included can be increased, and the accessibility factor can be adjusted.
This will allow countries that wish to include this optional secondary indicator to calculate and additional value, that will be higher than the standard RAI by taking into account the access provided by motorcycles.

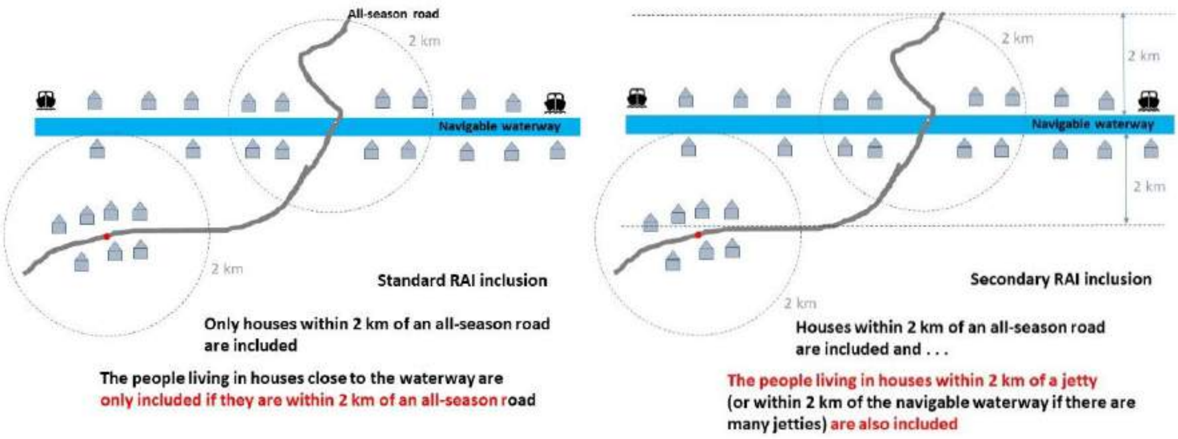
C.3.2 Navigable waterways

In some countries, water transport is very important for rural access (see Figure C.3). Communities living by navigable rivers, may have access to personal craft or transport services that allow them to reach markets, clinics, schools and the road network. Similarly, communities on islands (marine or on lakes) can be linked to mainland services and the road network by small craft or larger ferries. These riverine and island communities can be included among those with access in the secondary RAI measurement, using similar criteria to those developed for the main RAI. Navigable waterways on rivers, lakes and canals are included in Open Street Map (OSM, 2019b).

Figure C.3 Lake, canal and river-based rural transport in Cambodia, Madagascar and Myanmar

The main RAI and the secondary RAI are both measures of infrastructure provision (as opposed to the availability of transport services). Infrastructure related to water transport includes the waterway itself and the provision of jetties or docks to facilitate loading and unloading. Therefore, people can be considered as having secondary RAI access if they live within 2 km of a dock or jetty. The definition of a jetty will depend on the country using the secondary RAI, but simple wooden jetties along waterways can be included, if they are used for the embarkation and disembarkation of people and goods travelling along the river. For busy rivers and canals, there may be jetties every 2 km, so that the whole navigable waterway can be included, using OSM. However, some rivers are not widely used for passenger and freight transport, and on these only known jetties should be included. Small jetties are not yet included on OSM, and so information may need to be collected from the relevant water-transport authorities. Jetties nearby all-season roads would be automatically included in the standard RAI measurement, and so this secondary RAI calculation will only be applicable to navigable rivers away from the road network, and to islands (or parts of islands) without road networks. If water transport is of minor importance, and if most waterway jetties are connected to the road network, a secondary RAI value for waterways would not be very different from the standard RAI measurement. Figure C.4 shows how a secondary RAI value for waterways would include a larger population than the standard RAI.

Figure C.4 Waterway population inclusion in the standard RAI (left) and secondary RAI (right)



C4. References

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