Measuring indicators on the availability and geographical accessibility of maternal health services at district level

Case Study: Ghana

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(Date of last revision: 11/10/2022)

Background

Targeted monitoring is crucial for reducing inequalities in the provision of maternal health care services. However, monitoring largely occurs at the national level, despite guidelines for assessing the sub-national coverage of services. This is likely due to historical limitations in the availability and accessibility of spatial data at these sub-national scales. This tutorial demonstrates how to estimate indicators for measuring the availability and geographical accessibility of maternal health services at the district level, using open data and tools.

To estimate the availability of services, we use the World Health Organisation (WHO) guidelines for monitoring emergency obstetric care - defined as the number of CEmONC health facilities per 500,000 population (WHO et al. 2009).

To estimate the geographical accessibility of services, we use proposed indicators by Ebner et al. (2019) for measuring physical access to emergency obstetric and newborn care - defined as the proportion of pregnant women able to access CEmONC health facilities within a given travel time (%) (ACC2). We implement this method in QGIS, using outputs from AccessMod 5, a WHO tool for measuring physical accessibility to health care (https://www.accessmod.org/).

Note: It is important to note that in this tutorial we assume that hospitals provide the comprehensive care as set out in the guidelines for classification of a CEmONC facility.

Software

The following software is required to complete this tutorial:

- QGIS version 3.10 - https://www.qgis.org/en/site
- AccessMod5 - https://www.accessmod.org/ (if not using the example travel-time dataset)

Note: This tutorial assumes a basic knowledge of GIS, for example, familiarity with raster and vector data, and calculating zonal statistics, as well as a background knowledge in the use of maternal health indicators. Please also note that different versions of QGIS may have slightly different menu layout options to those described.

Data

The sample data for this tutorial can be downloaded from https://data.worldpop.org/repo/docs/wigley2022countdown_t1/. Download this data and save in a new project folder. All data are in the WGS-84 geographic coordinate system. The data includes:

Hospital locations:

Hospital locations for Ghana, clipped to the extent of the country, using the GADM level-0 dataset. The original dataset is available to download from the Sub-Saharan Public Hospitals Geo-coded database **(gha_hospitals.shp).**

Ouma, P., Okiro, E. A., & Snow, R. W. (2017). Sub-Saharan Public Hospitals Geo-coded database - Population Health Dataverse.
https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/JTL9VY

Note: We use the hospital locations provided by the Sub-Saharan Public Hospitals Geo-coded database, as it is a free and open data source. Though you could substitute this data for a more comprehensive one, including a facilities CEmONC status, if available for your application.

Administrative boundaries:

National and sub-national administrative boundaries for Ghana (adm0/adm2), available to download from the database of Global Administrative areas (GADM) **(gadm36_GHA_2.shp).**

GADM. (2022). GADM data. https://gadm.org/data.html

Note: We use GADM administrative boundaries because they are provided as open data, though you could substitute these to another boundary data set that you would like to aggregate the estimates for.

Travel-time:

Travel-time to hospital locations, clipped to the extent for Ghana, again using the GADM level-0 dataset. The original dataset is available to download from the figshare repository. Travel-time is measured in minutes, based on combined motorised transport and walking (Alegana et al. 2018) **(TT_GHA_Extract.tif).**

Alegana, V. A. (2018). National and subnational variation in pattern of febrile case management in sub-Saharan Africa.
https://figshare.com/articles/dataset/National_and_subnational_variation_in_pattern_of_febrile_case_management_in_sub-Saharan_Africa/7160363

Note: We use this dataset for the example, which relates specifically to the hospital dataset for sub-Saharan Africa. However, you could re-create this using AccessMod5, to be able to customise the input travel-time to your specific needs (you would need to do this if using an alternative health facility dataset).

Population estimates:

Estimates of population per (1km x 1km) grid square for Ghana for 2015, available to download from the WorldPop website **(gha_ppp_2015_1km_Aggregated.tiff).**

WorldPop. (2022). WorldPop :: Population Counts.
https://hub.worldpop.org/geodata/summary?id=31430

Note: We use this dataset as an example, but you can use other raster population data. We use the 2015 population estimates to match the pregnancy estimates (see next).

Pregnancies estimates:

Estimates of the number of pregnancies per (1km x 1km) grid square for Ghana for 2015, available to download from the WorldPop website **(GHA_pregs_2015_Resample.tiff).**

WorldPop. (2022). WorldPop :: Pregnancies. https://hub.worldpop.org/geodata/summary?id=991

Note: The pregnancy estimates are only available for 2015, so we also use the population estimates for 2015 also, despite more recent estimates available. This data set has been resampled to align the pixels to the population dataset.

Setting up the project

With the data downloaded and saved in project folder we can now set-up the project in QGIS.

1. Open QGIS and double click on **New Empty Project** *(see below),* to load up a new map document *(note: that the project coordinate system is set to EPSG:4326 - WGS 84).* This will open a new QGIS project. We can now save this document by selecting **Project → Save As** and saving the project in the project file. You will need to select the location and name of the project file.
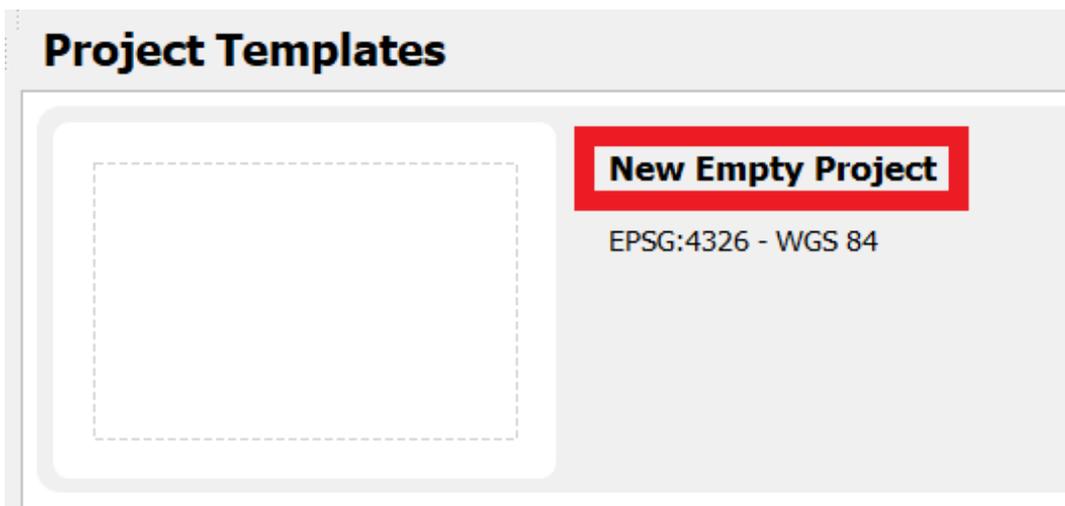

2. Now, we can add the sample data to the project from the project file. First, we will add the population data. From the **Layer** drop down menu select **Add Layer → Add Raster Layer…** This will open the **Data Source Manager|Raster** dialogue box. Navigate to the project folder and select the population raster *(gha_ppp_2015_1km_Aggregated.tiff) (note: you will need to make sure you select the .tiff file extension to load the data correctly).*
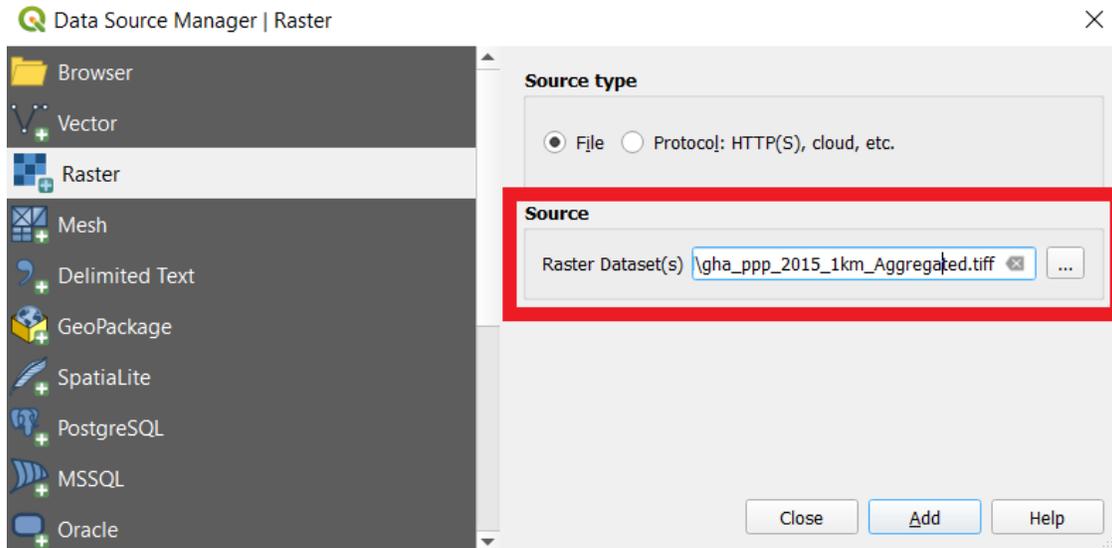
Add the pregnancies raster and the travel-time raster using the same steps.

3. We will now visually explore the data and check the data aligns. Right click on the population raster in the **Layers** panel and select **Properties...** to open up the **Layer Properties** dialogue box *(make sure that only the population raster is selected),* the **Symbology tab** should be selected *(see below).* From the **Min/Max Value Settings** , set the **Cumulative count cut** and check/select +2.0 and -98.0 % and select **OK**.

The symbology now highlights the minimum and maximum value areas in the raster more clearly, and we can see a minimum value of 4.26511 and maximum value of 511.806 in the Layers panel.
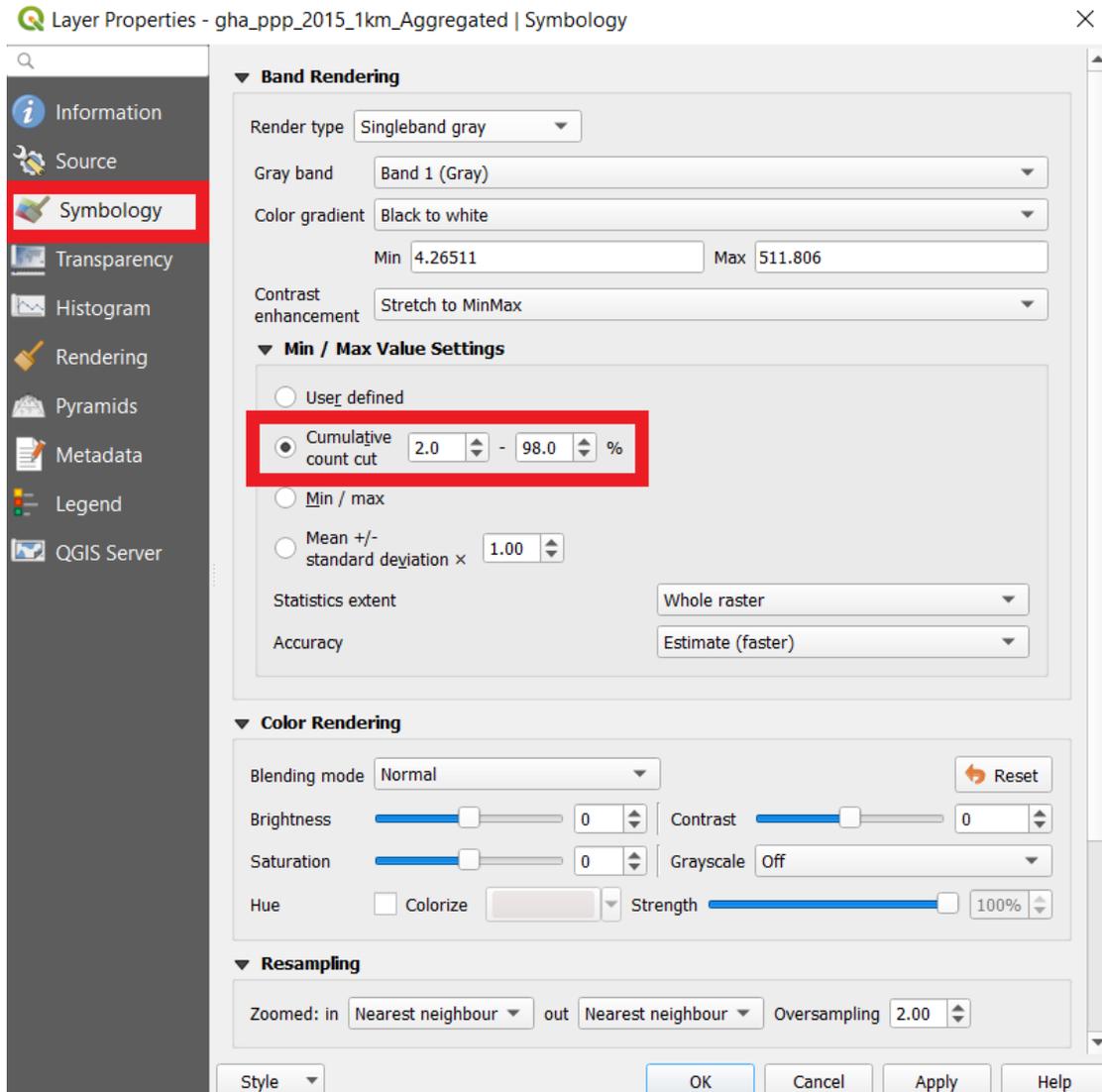
4. We will do the same for the pregnancies and travel-time raster and experiment with the **Render type** to show these in a different colour. For this we need to select **Singleband Pseudocolor**, choose a **color ramp** from the drop-down menu, and **Apply** to preview the adjusted layer symbology

5. Now we need to add the hospital locations and administrative boundary data. From the **Layer** drop down menu select **Add Layer → Add Vector Layer…** From the **Data Source Manager|Vector** dialogue box, navigate to the project folder and select the hospital locations *(gha_hospitals.shp),* and administrative boundaries *(gadm36_GHA_2.shp).* Again, we can adjust the symbology by right-clicking on the layer in the **Layers** pane and selecting properties.

   Now all the data has been added we can begin the analysis.

Availability analysis

First, we will look at the availability of services according to the WHO guidelines for monitoring emergency obstetric care, *defined as the number of hospitals per 500,000 population.*

This indicator is calculated by multiplying the number of hospitals within a defined administrative unit, by 500,000 *(see below calculation, from pg 107 (Form 4) of the guidelines - Calculation of indicators for geographic area),* and states a minimum acceptable level of **≥ 1 per 500,000 population.**

**(Total no. of comprehensive EmOC facilities in area/Population of area) x 500,000**

= No. of comprehensive EmOC facilities per 500,000 population (Indicator 1b)

1. To calculate this we need to know a) the total no. of hospitals/CEmONC facilities per geographic unit, and b) the total population per geographic unit.

    a) To find the total no. of hospitals/CEmONC facilities per geographical areas *(or district),* we can use the **Count Points in Polygon** tool:

        Click on **Vector → Analysis Tools → Count Points in Polygon…** and select the administrative boundary layer in the **Polygons** drop down menu, and the hospital location layer in the **Points** drop down menu. Set the output location and file name *(gha_hospitals_count.shp, for example)* in the **Count** box and set the file type to **.shp** to save the output file as a new shapefile. Select **Run.**

        Right click the layer in the **Layers** panel and select **Open Attribute Table.** The **NUMPOINTS** column will show the total number of hospitals/CEmONC facilities per administrative unit *(see below).*

ENGTYPE_2	CC_2	HASC_2	NUMPOINTS
District	NULL	NULL	1
District	NULL	NULL	1
District	NULL	NULL	1
District	NULL	GH.WP.SW	3
Metropolitan Di...	NULL	GH.WP.SA	3
District	NULL	NULL	1
District	NULL	GH.TV.ST	1
District	NULL	GH.TV.NK	2
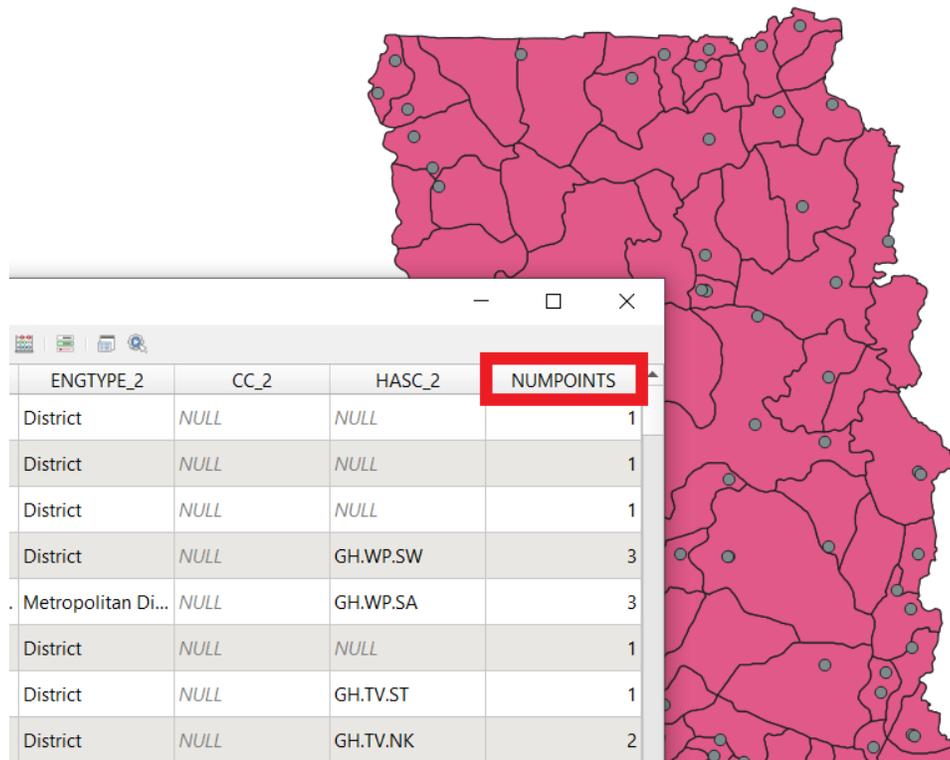
    b) To find the population per geographical area *(or district),* we can use the **Zonal statistics** tool.

From the **Processing** drop down menu, select **Toolbox**, and search for **Zonal statistics** *(see below).* Double click to open the dialogue box.
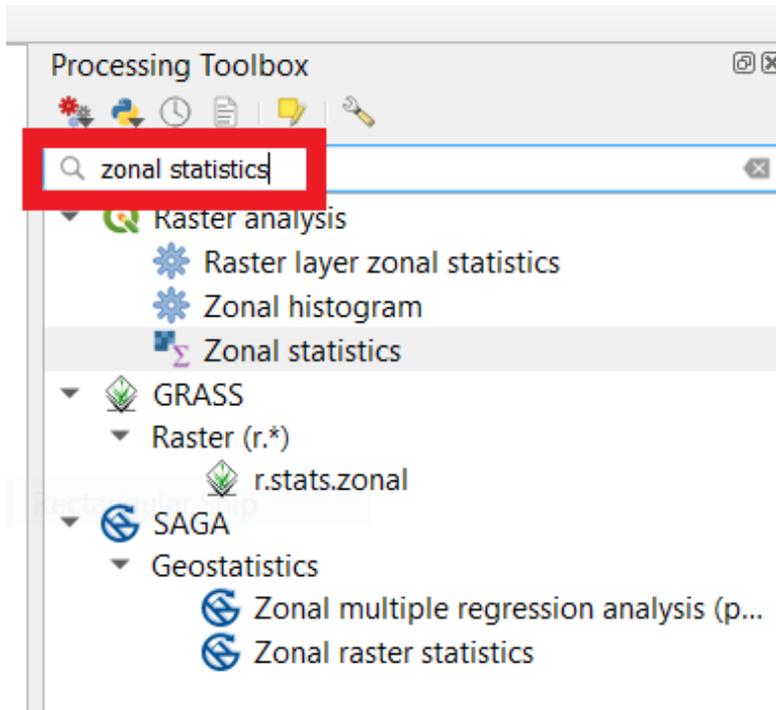
Select the population raster in the **Raster layer** drop down menu, and select the layer that was created using the **Count Points in Polygon** tool *(i.e. gha_hospitals_count.shp)* in the **Vector layer containing zones** drop down menu. In the **Statistics to calculate** option select **Sum** *(see below),* then **Run**.

Close the dialogue box and open the attribute table for the *input vector layer*, where there will be a new column **sum**, displaying the total population per administrative unit in addition to the already calculated **NUMPOINTS** *(see below)*.

HASC_2	NUMPOINTS	_sum
NULL	1	147032.856701...
NULL	1	97874.5289258...
NULL	1	156918.372995...
GH.WP.SW	3	258428.094933...
GH.WP.SA	3	766697.274881...
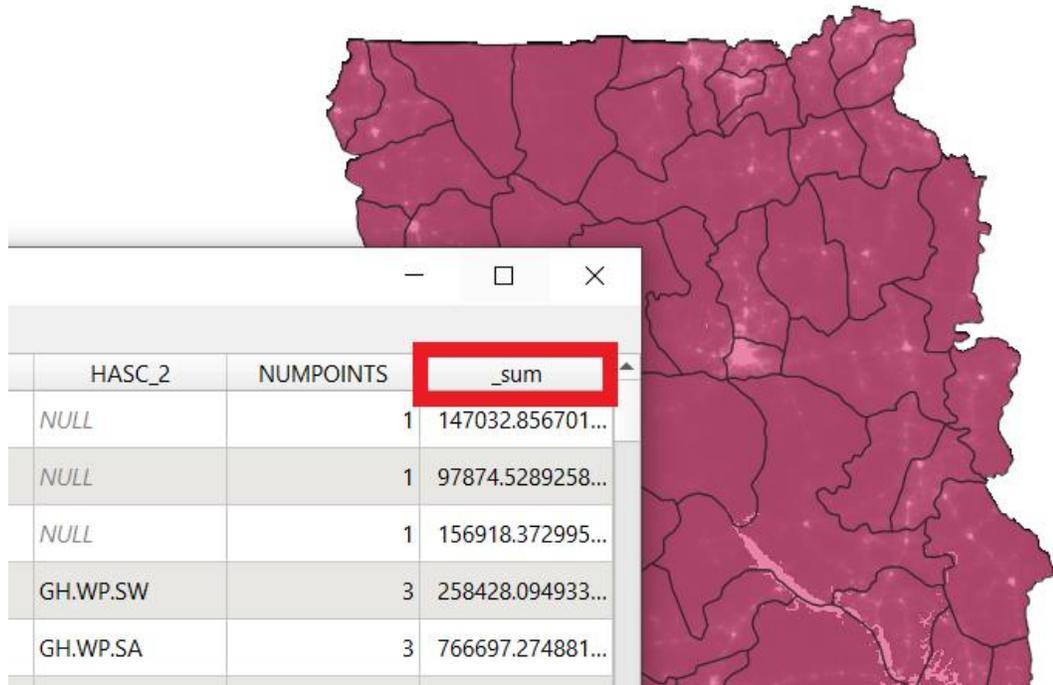
2. We can now calculate the availability of hospitals per district/adm2 unit using the **Field Calculator.** Using the above calculation *((Total no. of comprehensive EmOC facilities in area/Population of area) x 500,000).*

   In the **Processing toolbox**, search for **Field calculator**. In the open dialogue box, select the updated administrative boundary data set *(i.e. gha_hospitals_count.shp),* **Create a new field** *(name: calc),* and set the **Output field Type** to Float. Then under the **Fields and Values** drop down menu, type in the calculation using the **"NUMPOINTS"** and **"_sum"** fields *(see below).* Click **OK** to run the tool.
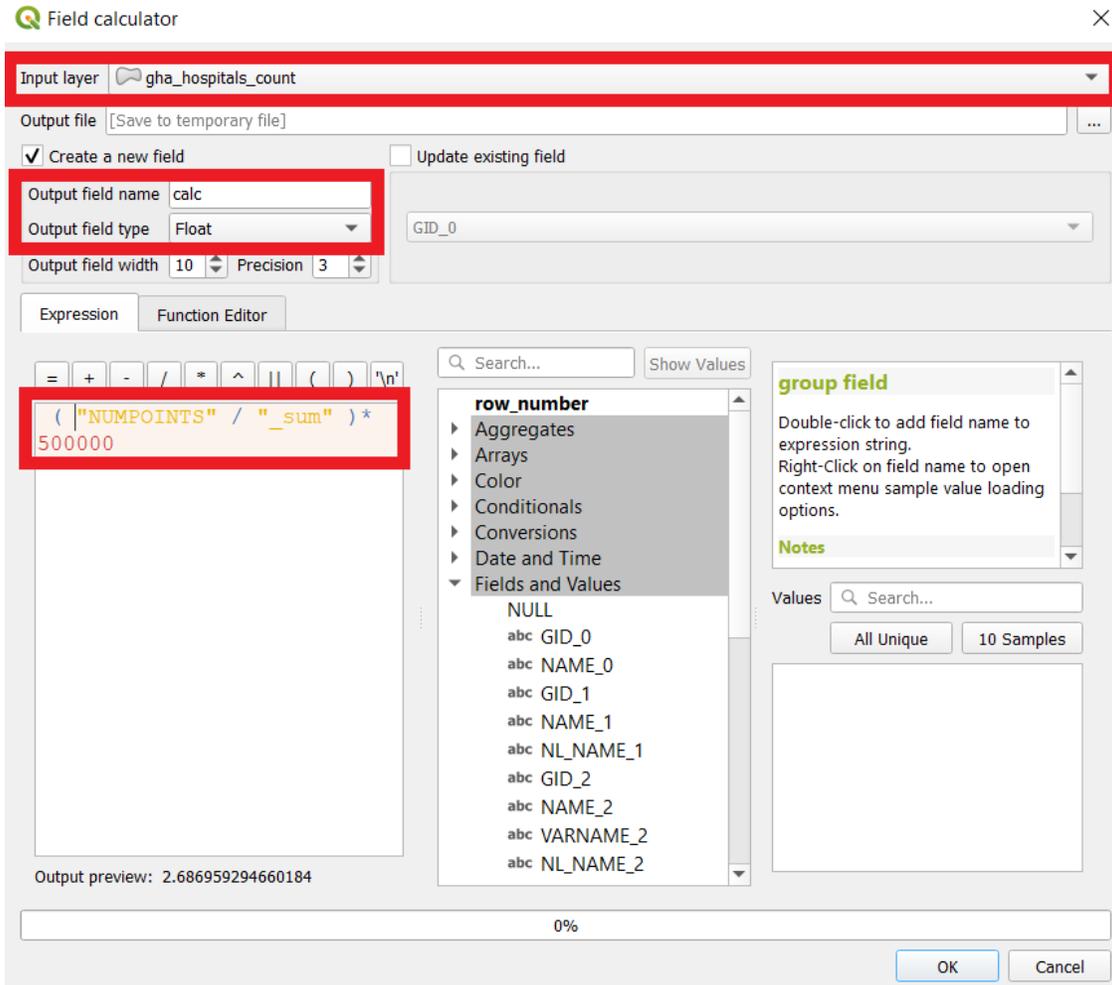
A temporary layer called will have been created, inspect this layer, and then **Export → Save Features As…** to save to a permanent file *(e.g. gha_EmOC_availability.shp).* Open the attribute table to view the results of the calculation *(see below).* The **calc** field shows the number of hospitals/CEmONC facilities per 500,000 population, and states a minimum acceptable level of **≥ 1 per 500,000 population.**

NUMPOINTS	_sum	calc
1	147032.856701...	3.401
1	97874.5289258...	5.109
1	156918.372995...	3.186
3	258428.094933...	5.804
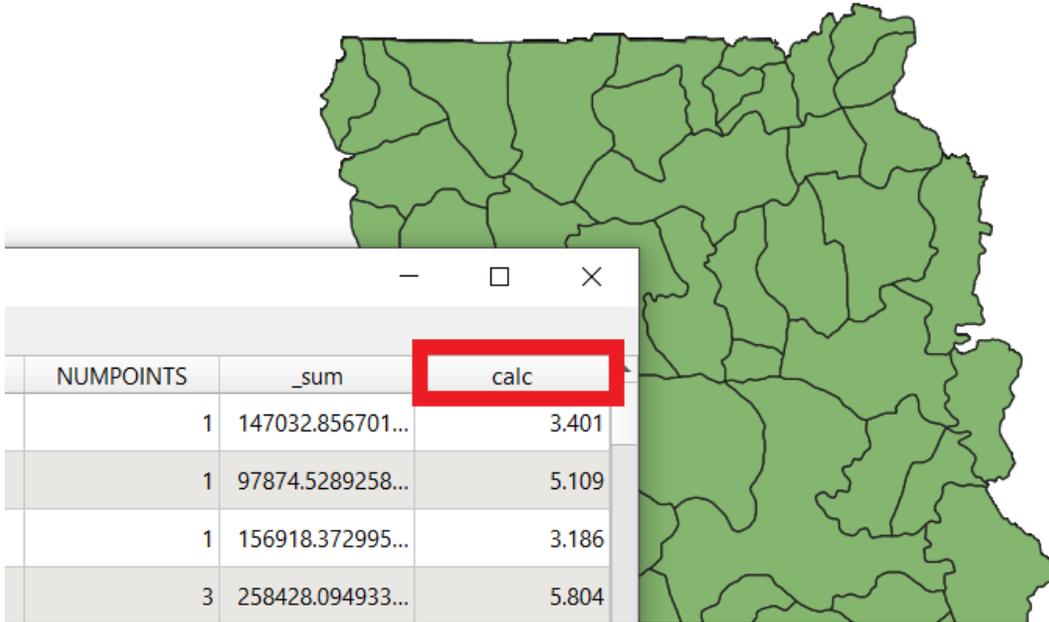
3. Adjust the symbology to see the districts where the number of hospitals/CEmONC facilities is less than 1. Select the symbol type to **Graduated** , choose a **Color ramp** , and **Classify** into 2 **Classes** of 0 to 1, and < 1 *(see below).* Use the **Identify Features** tool to see the calculated value.
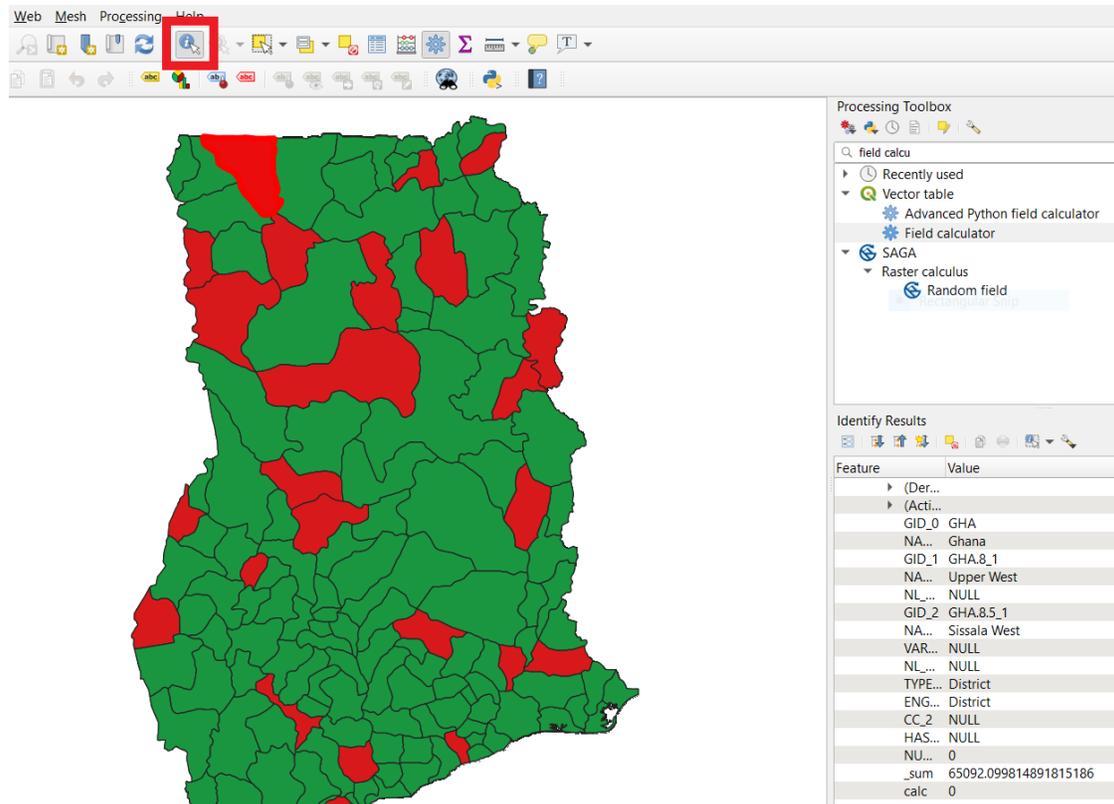
Accessibility analysis

Now we will look at the accessibility of services using indicators proposed by *Ebner et al. 2019* for measuring physical access to emergency obstetric and newborn care *(defined as the proportion of pregnant women able to access CEmONC health facilities within a given travel time (%) (ACC2)) (Ebner et al. 2018).*

We will consider an **80% minimum coverage,** as suggested by the Lancet commission on Global Surgery (Meara et al. 2015), to determine *access* to timely essential surgery.

This indicator is calculated by dividing the number of pregnant women residing in a specific geographical area *(who are able to access a CEmONC health facility within a given travel time (numerator))* by the total number of pregnant women residing in the same geographical area *(denominator),* with a **maximum suggested travel-time of 2-h:**

number of pregnant women living within 0 – 120 mins of the nearest hospital / total number of pregnant women (per district)

Note: Again, we assume hospitals provide CEmONC functions as outlined in the guidelines.

1. For this, we need to know a) the number of pregnant women residing in a specific geographical area who are able to access a hospital within 2-h travel time, and b) the total number of pregnant women residing in the same geographical area.

a) To find the number of pregnant women residing in a specific geographical area we need to first reclassify the travel-time raster into travel-time classes of '0 to 120' minutes, and '120 minutes or more'.

In the Processing toolbox search for **Reclassify by Table**, select the travel-time raster in the **Raster layer** drop down menu, and open the **Reclassification table** dialogue box. In this, by clicking on **Add row** twice, enter the ranges 0 - 120, with a value of 1, and 120 - 140, with a value of 0. Click **OK**, then **Run** the tool.

Note: In the output raster we can see very few areas that have a travel-time of more than 120 minutes to the nearest hospital, suggesting good accessibility for most areas. Now **Export** and **Save Features As…** to save the layer to permanent file *(tt_0_180.tiff)*
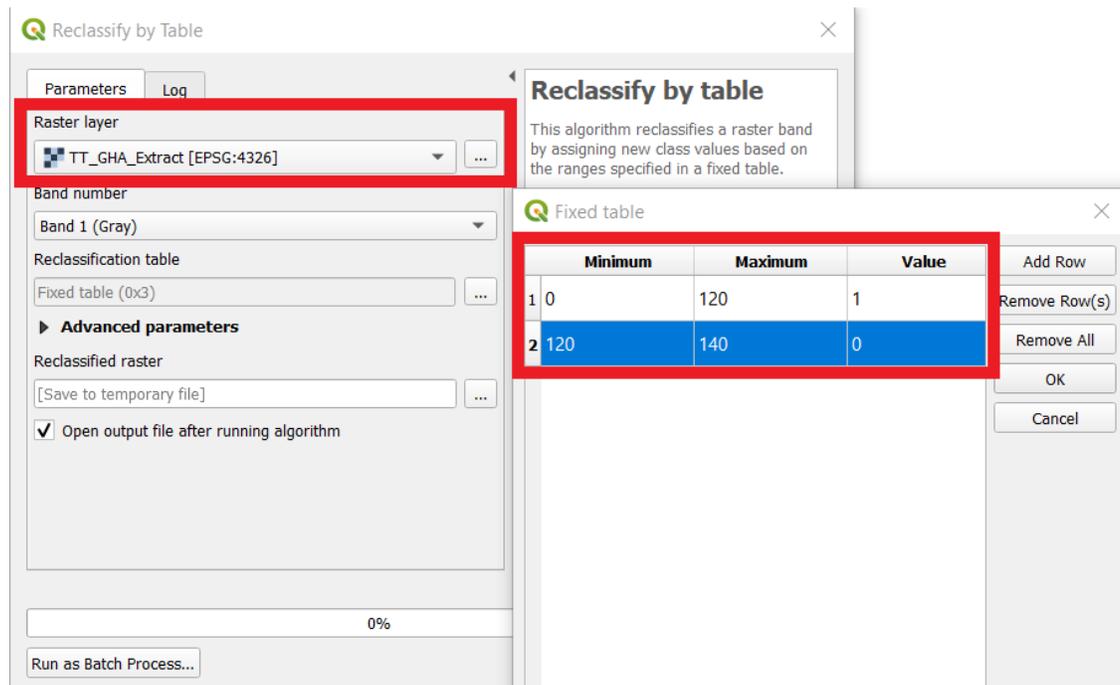
Now multiply the reclassified travel raster with the pregnancies raster to find the numbers of pregnant women living within 0 to 120 minutes of the nearest hospital.

In the processing toolbox search for **Raster Calculator** and multiply the reclassified travel-time raster with the pregnancies raster. Additionally, set the **Reference layer** to the pregnancies raster, to automatically define the extent, cell size and CRS of the output raster. Set the **Output** file location and name *(i.e. GHA_pregs_2015_tt_0_120.tif)* to save the output as a permanent layer.
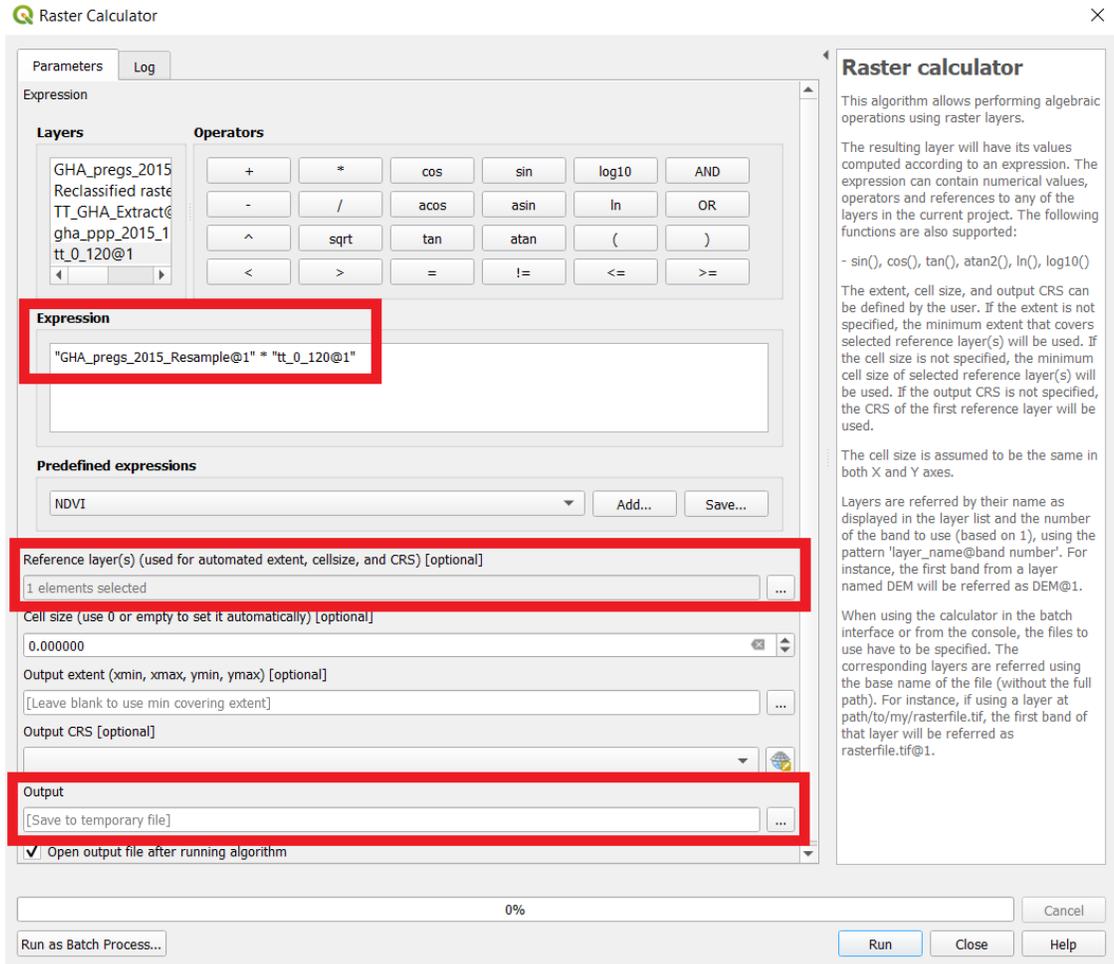
Then run the **Zonal statistics** tool to find the number of pregnant women residing in each district who are able to access a hospital within a 2-h travel time.

From the Processing drop down menu search for **Zonal statistics** and double click to open the dialogue box. Select the *'pregnancies within 0 to 120 minutes'* raster *(GHA_pregs_2015_tt_0_120.tiff)* in the **Raster layer** drop down menu and select the administrative boundary data set in the **Vector layer containing zones** drop down menu. In the **Statistics to calculate** option select **Sum**, and set the **Output column prefix** to **'0_120_preg_'** then **Run**.

b)   Run the tool again to find the total number of pregnancies per district, selecting the pregnancies raster *(GHA_pregs_2015_Resample.tiff)* in the **Raster layer** drop down menu, and setting the **Output column prefix** to **'total_preg_'**. Now we have both number of pregnant women within 0 to 120 mins of the nearest hospital, and the total number of pregnant women calculated for each district. Now **Export** and **Save Features As...** to save the layer to permanent file *(gadm_pregs.shp).*

	VARNAME_2	NL_NAME_2	TYPE_2	ENGTYPE_2	CC_2	HASC_2	0_120_preg	total_preg
1	NULL	NULL	District	District	NULL	GH.CP.AB	7093.04547327...	7278.26999109...
2	Agona-Swedru	NULL	District	District	NULL	GH.CP.AG	14223.7826820...	14246.3062835...
3	Ajumako Enyan|...	NULL	District	District	NULL	GH.CP.AJ	7045.88502231...	7077.02678790...
4	NULL	NULL	District	District	NULL	GH.CP.AO	6624.63328808...	6641.10560482...
5	NULL	NULL	District	District	NULL	NULL	8418.16672512...	8433.09279914...
6	NULL	NULL	District	District	NULL	NULL	5542.10449865...	5542.10449865...
7	Awutu-Afutu-Se...	NULL	District	District	NULL	GH.CP.AE	18358.0096022...	18435.9925200...
8	NULL	NULL	Municipal District	Municipal District	NULL	GH.CP.CC	7759.79711946...	7787.48858770...
9	Gomua	NULL	District	District	NULL	GH.CP.GO	12731.2040550...	12774.5077964...
10	Komenda/Edin...	NULL	District	District	NULL	GH.CP.KE	6265.57993006...	6265.57993006...
11	Twifo-Hemang-...	NULL	District	District	NULL	GH.CP.LD	5593.89601273...	5613.17369408...
12	Mfantseman	NULL	District	District	NULL	GH.CP.MF	9707.47047409...	9729.75087723...
13	Upper Denkhira	NULL	District	District	NULL	GH.CP.UD	5474.23700390	5474.23700390

Show All Features

2. We can now calculate the accessibility of hospitals per district/adm2 unit using the **Field Calculator**, using the above calculation *(number of pregnant women living within 0 – 120 mins of the nearest hospital / total number of pregnant women (per district)).*

In the **Processing toolbox**, search for **Field calculator**. In the open dialogue box and select the administrative boundary data set (gadm36_GHA_2.shp). **Create a new field** *(name: calc)* and set the **Output field Type** to Float. Then under the **Fields and Values** drop down menu, type in the calculation using the **'0_120_preg'** and **'total_preg'** fields *(see below).* Click **OK** to run the tool. Set the **Output file** location and name to save the output as a permanent layer.

If we sort the column with the resulting calculated values we can see all districts have over the 80% threshold of pregnant women living within 0 to 120 minutes of the nearest hospital, and again we can adjust the symbology to visualise these values geographically.

Results

Having completed the analysis we can now ask the following questions:

- How do the availability and accessibility of maternal health services vary geographically across Ghana?
- What do the results indicate to be the biggest barrier to the accessibility of maternal health services in Ghana – availability or accessibility?
- How are these definitions of availability and accessibility limited? How could the analysis be refined to better characterise the availability and accessibility of maternal health care services across Ghana.

Further analysis: Repeat the accessibility analysis using a maximum travel-time of 60 minutes to the nearest hospital, how does this affect the definition of accessibility?

Contributions

This tutorial has been prepared by A. S. Wigley, based on previous work carried out by Wigley at al. 2020.

Funding

License

Disclaimer

Suggested citation:

Wigley A., Nilsen K., Tejedor-Garavito N. 2022. Measuring indicators on the availability and geographical accessibility of maternal health services at district level. WorldPop, University of Southampton. doi: 10.5258/SOTON/WP00741

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https://figshare.com/articles/dataset/National_and_subnational_variation_in_pattern_of_febrile_case_management_in_sub-Saharan_Africa/7160363

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Meara, J. G., Leather, A. J. M., Hagander, L., et al. (2015). Global Surgery 2030: Evidence and solutions for achieving health, welfare, and economic development. *The Lancet*, *386*(9993), 569–624. https://doi.org/10.1016/S0140-6736(15)60160-X/ATTACHMENT/ADEF8156-4288-458F-8882-EC796E44A661/MMC2.MP4

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