METEOR

Modelling Exposure Through Earth Observation Routines

Nepal Level-3 Exposure Development

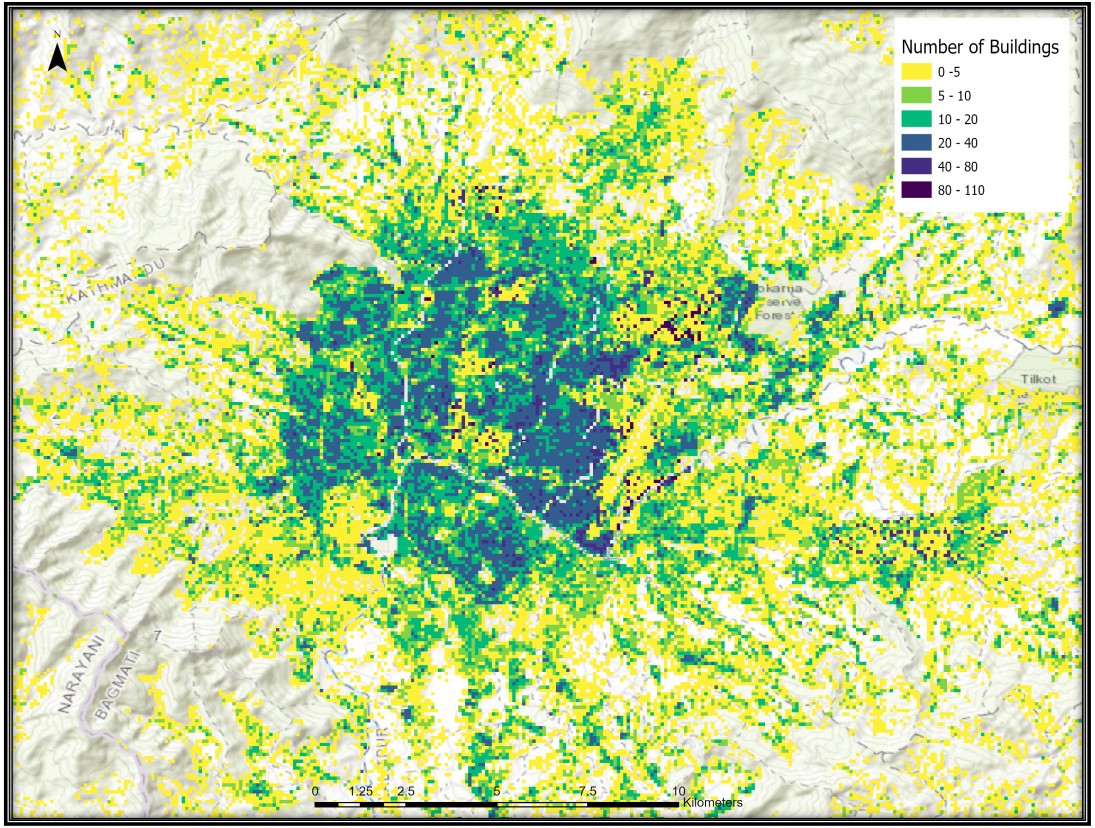
This section will go step-by-step through the Level-3 flowcharts used for gathering data to develop the Level-3 building exposure for Nepal.

Level 3- Data improvement at the sub-national scale

Examples:

1. Subdividing the country by climate or cultural regions to reflect construction patterns

2. Identifying major urban areas and enhancing building counts or structural mapping schemes in these areas



Datasets used to develop the Nepal Building Exposure

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4. Center for International Earth Science Information Network - CIESIN - Columbia University, International Food Policy Research Institute - IFPRI, The World Bank, and Centro Internacional de Agricultura Tropical – CIAT. (2011). Global Rural-Urban Mapping Project, Version 1 (GRUMPv1): Urban Extents Grid [raster, map, map service]. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). Retrieved from https://sedac.ciesin.columbia.edu/data/set/grump-v1-urban-extents
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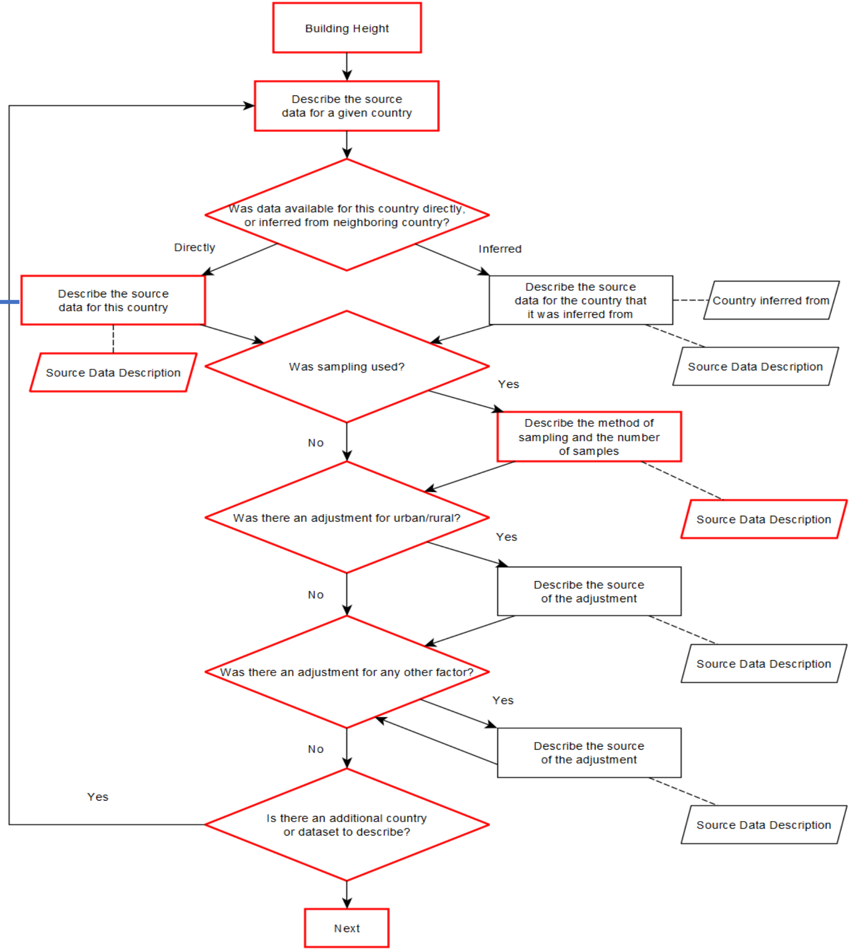
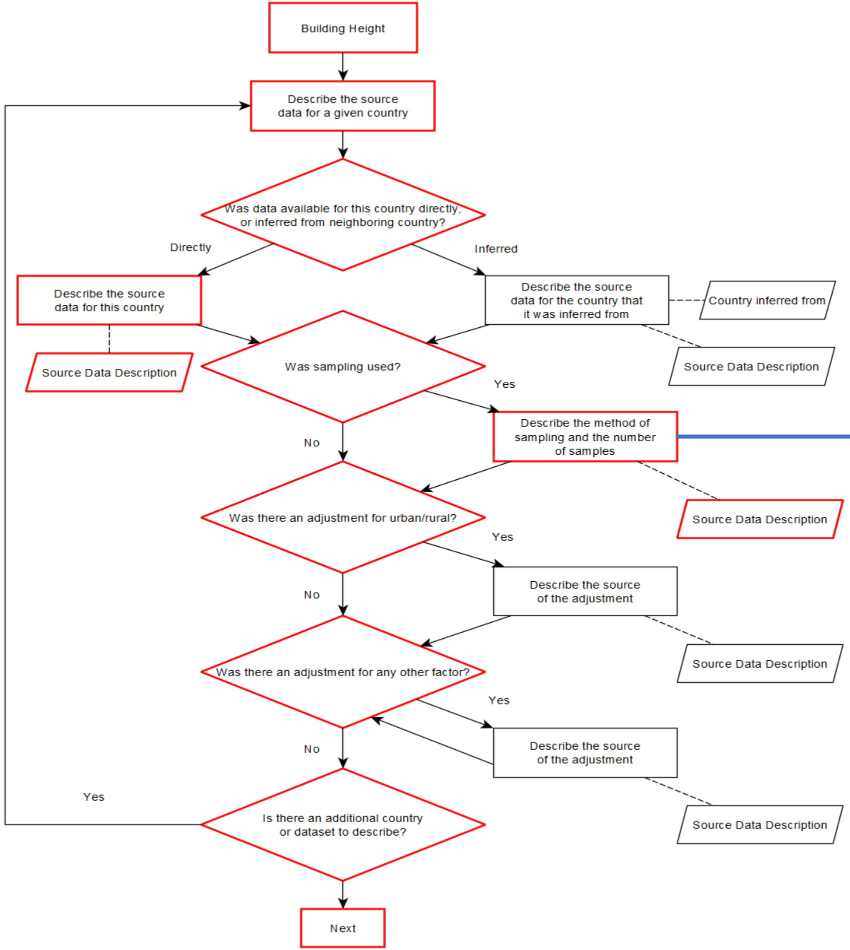
Level-3 Flowcharts

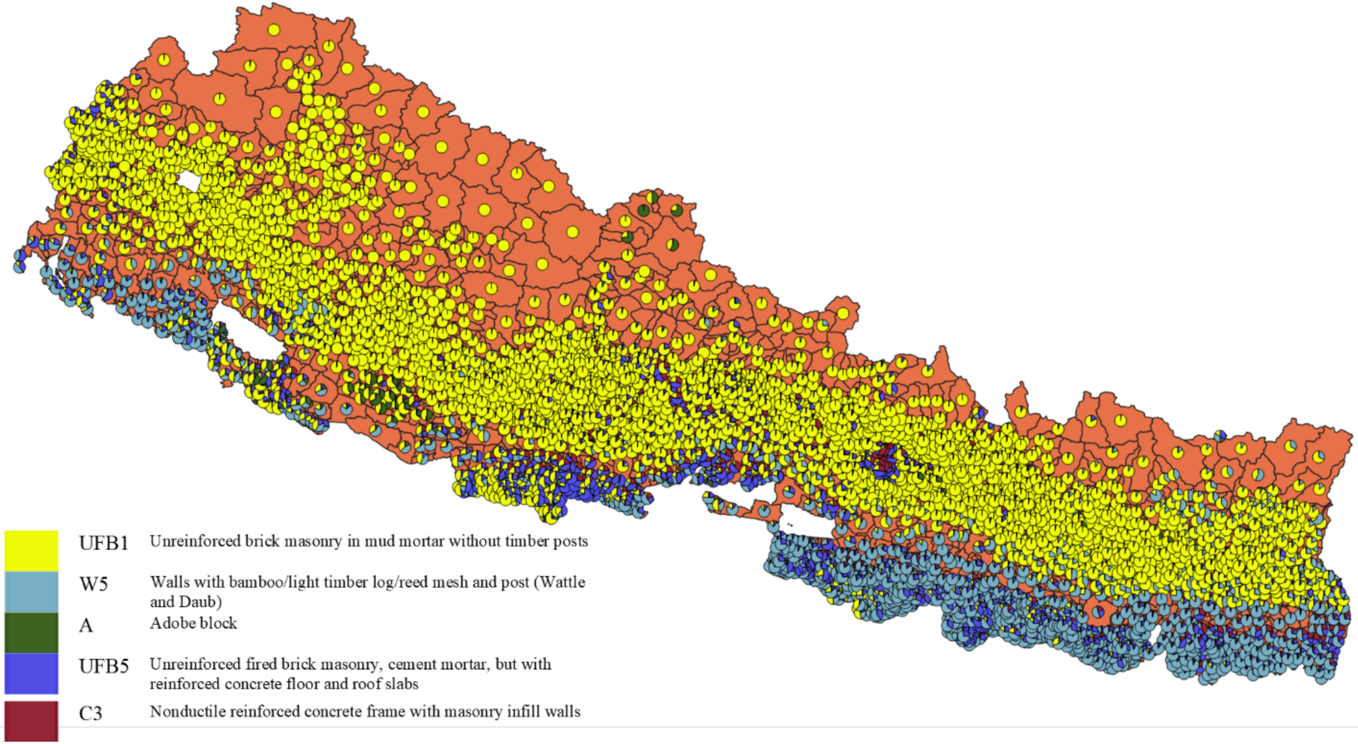
- Building Height
- Structural Distribution
- Number of Buildings
- Dasymetric Mapping
- Replacement Cost
- Building Area

There are two sources for the building height values IPUMS and the field survey data collected by HOTOSM (Humanitarian OpenStreetMap Team, 2019).

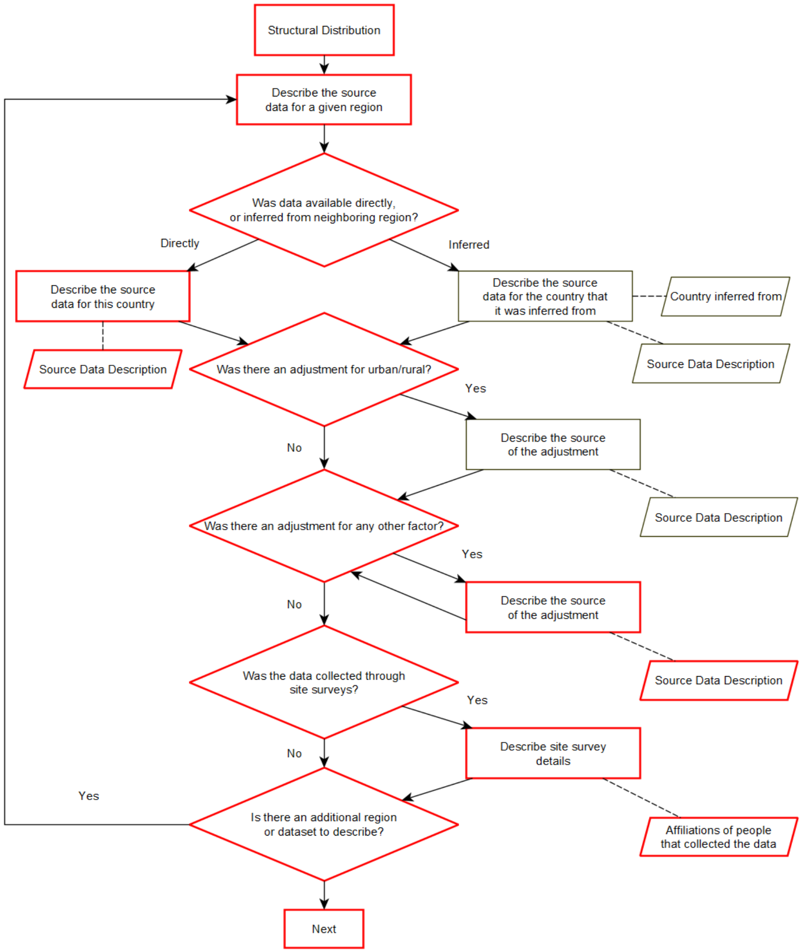




Data collected by the HOT field team is used to characterize the height distribution in urban areas. In rural areas, the distribution of buildings by administrative level-2 was used to characterize the building stock, as gleaned from IPUMS data. Building height varies throughout the country depending on terrain, but the buildings are primarily low rise.

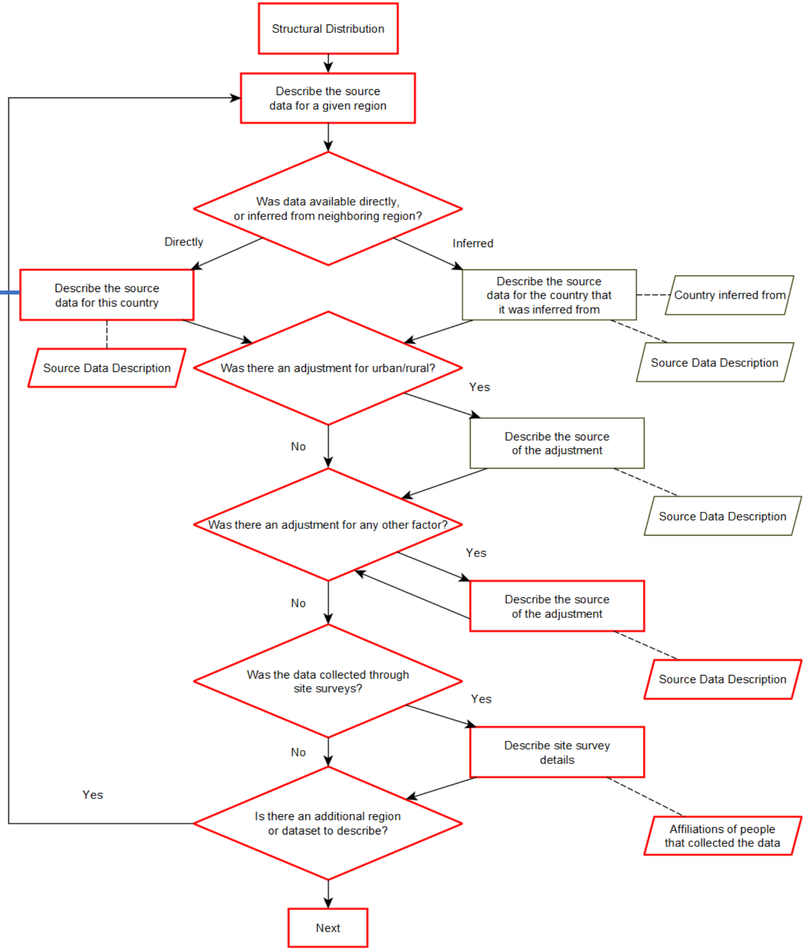


Nepal mapping scheme per Village Development Committee


Structural Distribution
Describe the source data for a given region
Was data available directly, or inferred from neighboring region?
Directly
Inferred
Describe the source data for this country
Source Data Description
Describe the source data for the country that it was inferred from
Country inferred from
Source Data Description
Was there an adjustment for urban/rural?
Yes
Describe the source of the adjustment
Source Data Description
No
Was there an adjustment for any other factor?
Yes
Describe the source of the adjustment
Source Data Description
No
Was the data collected through site surveys?
Yes
Describe site survey details
Affiliations of people that collected the data
No
Yes
Is there an additional region or dataset to describe?
Next

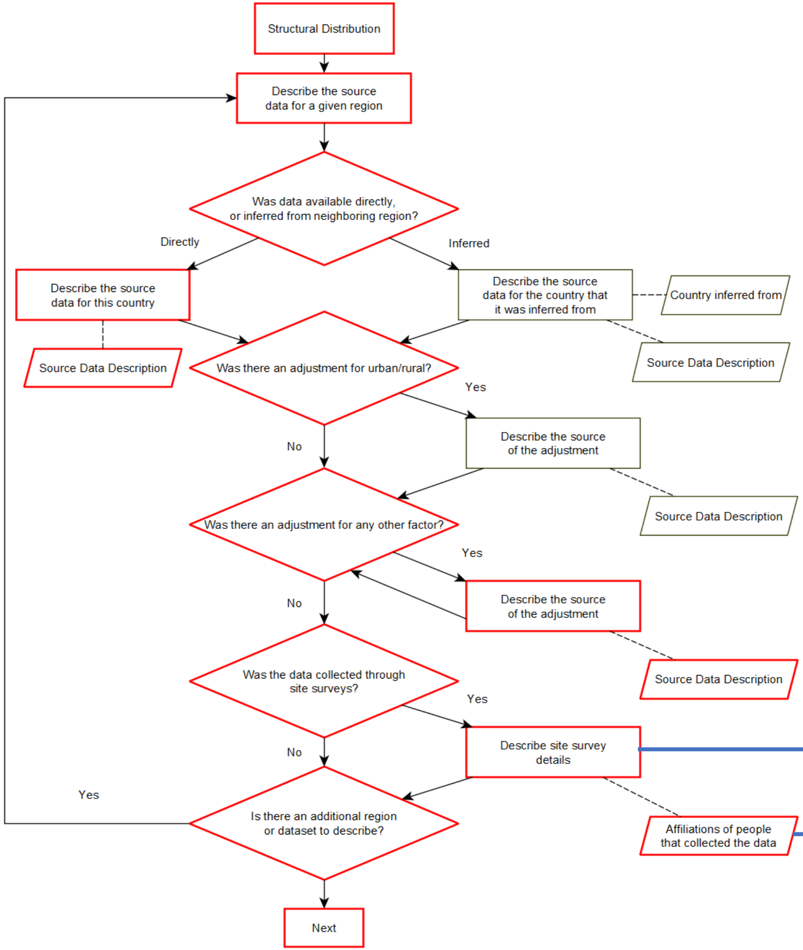
Estimates of structural distributions, or mapping schemes, was two-fold. First, a structural engineer conducts a web reconnaissance of any available data regarding both typical construction materials and methodologies within the region, as well as any data inferring structural distribution within the country. Sources such as the World Housing Encyclopedia [WHE], Prompt Assessment of Global Earthquakes for Response [PAGER] (Wald, et al. 2008), and Global Earthquake Model [GEM] (Brzev et al., 2013) were reviewed to identify all known structural types within the country. These preliminary types were validated through the Nepal National Building Code and Google StreetView survey.

After the web reconnaissance the structural engineer begins to formulate the mapping scheme by development pattern. Using the 2011 Nepal VDC-level census data the rural development pattern was assigned a mapping scheme using the building wall material type and number of household value. The building height values for UFB-1 and UFB-5 within the rural development pattern zones were obtained from Integrated Public Use Microdata Series (or IPUMS) data set. Based on discussion with Sharad Wagle, a Nepali Structural Engineer, cement mortar was assumed for those unreinforced masonry structures 5 stories or greater. The increased durability and bonding strength (in comparison to mud mortar) required for multi-story buildings was the logic behind such decisions. For low-rise, rural regions, mud mortar assumed as the bonding agent. For the remaining non-rural development patterns, the field survey data collected by HOTOSM was used to establish the mapping scheme for each of those development pattern types.



There was no urban-rural adjustment factor however Kathmandu Living Labs conducted a building survey for HOTOSM. The field team implemented a stratified sampling strategy and used a Bayesian updating approach. (Porter, et al. 2014). The survey data provided the structural mapping scheme for each development pattern.

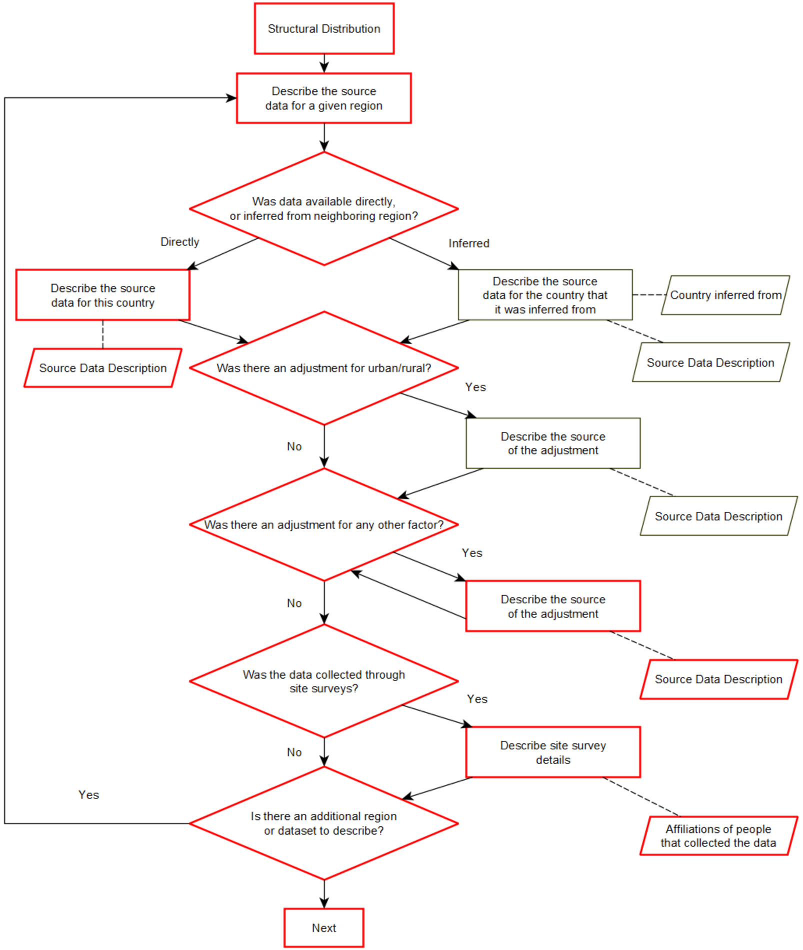
Kathmandu Living Labs (KLL). (2019). In-situ structural building type, height, and footprint area sampling polygons of Nepal [dataset]. Provided by Humanitarian OpenStreetMap Team.



GEM Class	DP1	DP2	DP3	DP4	DP5	DP6	DP7
MUR+ADO/HBET:1,3	1%	-	-	-	-	-	-
MUR+ADO/HBET:4,7	-	-	-	-	-	-	-
CR/LFINF+DNO/HBET:1,3	49%	37%	14%	28%	8%	17%	19%
CR/LFINF+DNO/HBET:4,7	22%	35%	56%	23%	4%	45%	22%
CR/LFINF+DNO/HBET:8,20	-	1%	3%	-	-	8%	1%
MATO/LN	-	-	-	2%	23%	-	-
S/LFM	-	-	-	-	-	-	-
S/LFBR	-	-	-	-	-	-	-
S/LO	2%	1%	-	9%	-	-	1%
S/LFINF	2%	-	-	3%	-	3%	1%
MUR+CL99/HBET:1,2	16%	13%	5%	30%	54%	14%	32%
MUR+CL99/HBET:3,5	7%	13%	21%	5%	-	13%	22%
W	-	-	-	-	6%	-	1%
W+WWD	1%	-	-	-	6%	-	-

The HOTOSM building survey data was verified by a local in-country engineer (Sharad Wagle) and in-house engineer (Michael Eguchi). All of the mapping schemes are then mapped to the PAGER standard structural types. These structure types are overlaid with the manually delineated development pattern sample polygons to create a refined mapping scheme. A final round of sanity checking is conducted by ImageCat engineers.

Sharad Wagle (NSET) and Michael Eguchi (ImageCat)



Development patterns are patterns of construction in a given country that typify the building structure development and density as much as possible. They sometimes correspond with land use, but not always. The development patterns are determined by a structural engineer working with GIS analysts to conduct a web reconnaissance exercise using Google Earth, and structural distribution web searches to characterize the urbanity density and development patterns for each country. For Nepal, the ImageCat engineer characterized 8 development pattern types:

Development Pattern 1: Rural development found outside of city boundaries and is typically associated with agricultural development. The regions typically consist of small, remote villages with single roads in and out. Buildings are typically spaced far apart and are almost exclusively 1 to 2 stories. Local materials and construction practices are generally used and performed in these areas.

Development Pattern 2: This development pattern reflects areas typically dominated by single family residential structures. Commercial properties, such as local markets, are present, however residential structures are the primary occupancy. The built-up area is denser than rural class 1, however open land (yards, vacant lots, etc.) are present and can be observed via satellite imagery. All structures are low-rise, with most in the 1 to 2 story range.

Development Pattern 3: This development pattern is representative of regions with dense residential and commercial development. Apartments are typically located above first floor commercial properties. Structures are predominantly low to mid-rise, with an occasional high-rise structure located within the development pattern. Buildings are tightly spaced.

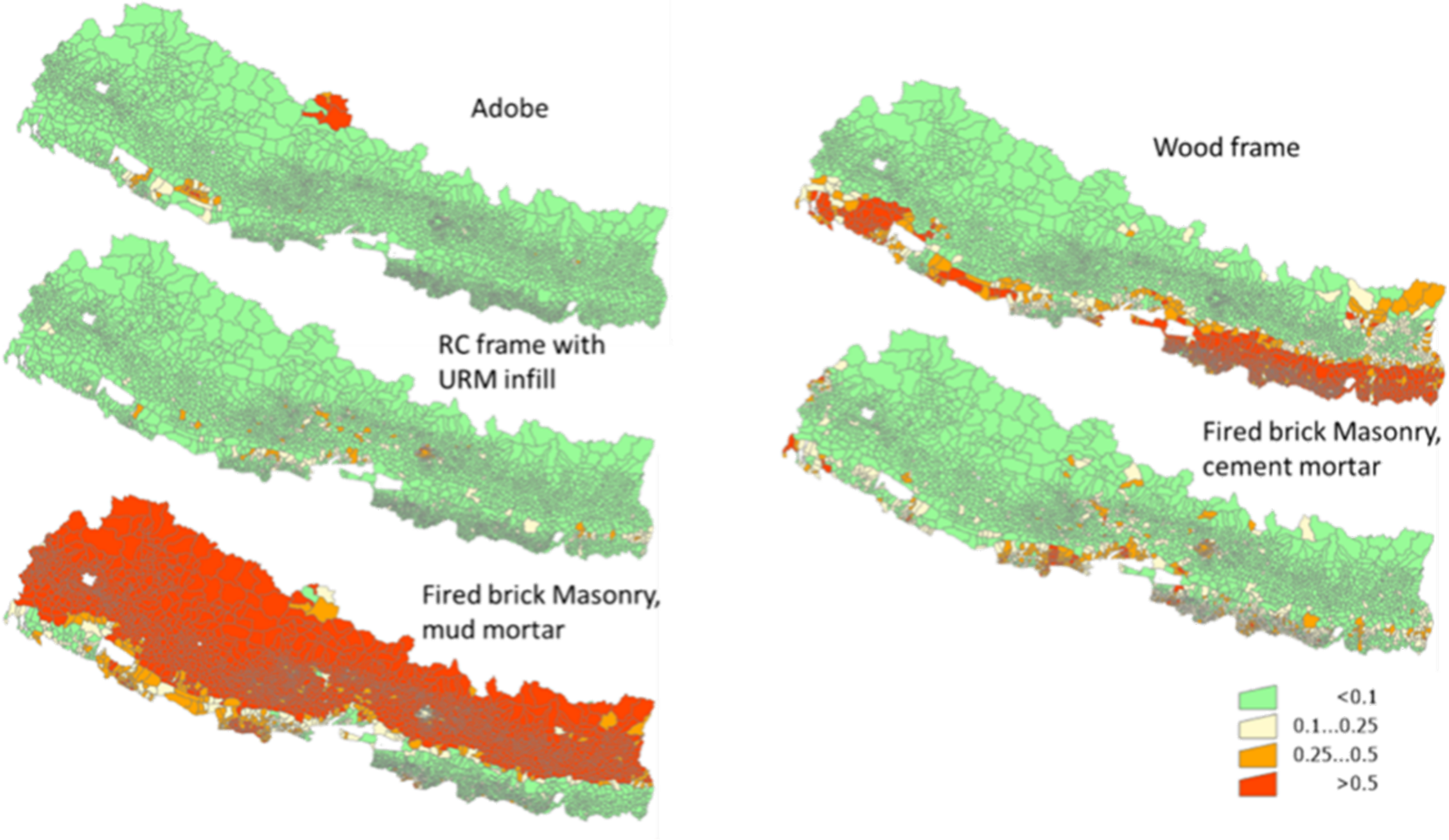
Development Pattern 4: This development pattern is typically associated with extremely dense, informal settlements. They are usually found within boundaries of large cities and are typically comprised of very small (<100 m^2) standalone structures with little to no space between adjacent buildings. The settlement is unplanned, therefore there is no organization to the configuration of building layouts. Almost all structures are 1-story and are typically erected using cheap and accessible local materials.

Development Pattern 5: Development pattern 5 is characterized by urban areas predominantly occupied by low to mid-rise residential and commercial structures. An occasional high-rise apartment or office building may be present. These developments are typically found near or around major city centers. Buildings are tightly spaced and are fairly regular in shape.

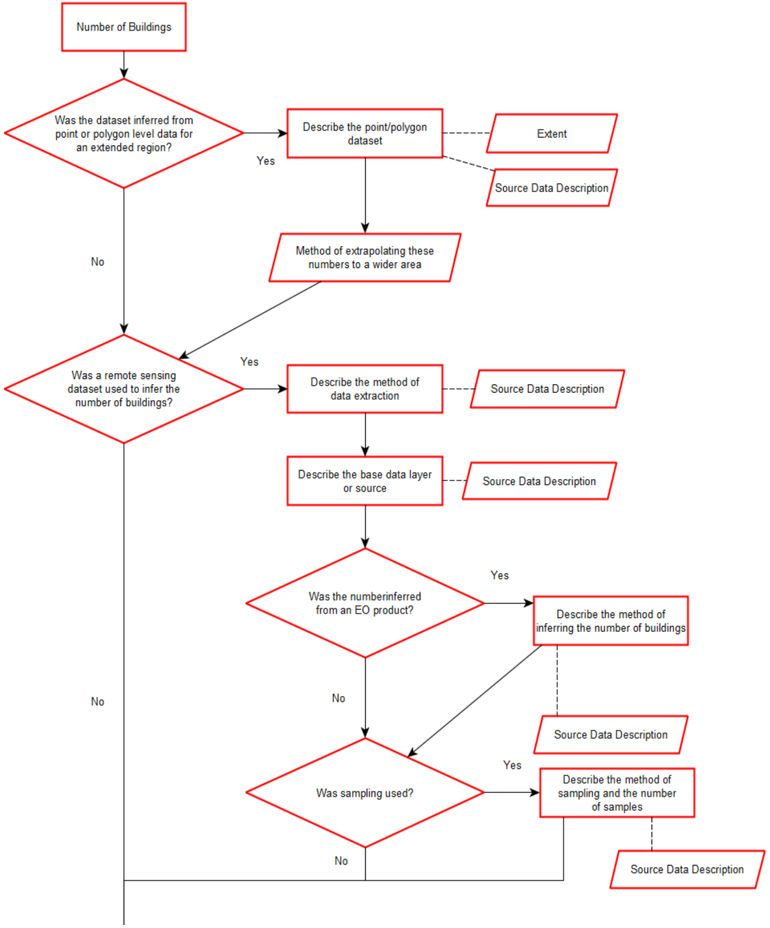
Development Pattern 6: This development pattern is the central business district of urban areas within the major cities. The region is occupied by low to high-rise apartments and commercial offices. Most structures are under 7-stories, however high-rise (8+ stories) can be found within the region. Building footprints are larger than most non-industrial development patterns. This development pattern will be found only in major cities and along the major, paved roads.

Development Pattern 7: This development pattern is characterized by areas dominated by ports, mining or industrial activities. Structures are typically closely spaced and regular in shape. A majority of buildings within these regions are warehouses, rectangular shape and single story. Smaller low-rise, office and commercial structures can also be found on site.

Development Pattern 8: This development pattern is typically located within the urban region and is comprised of large developments, such as universities. The built-up environment is typically comprised of low to mid-rise structures with large building footprints.



Nepal percentage of households by structural class



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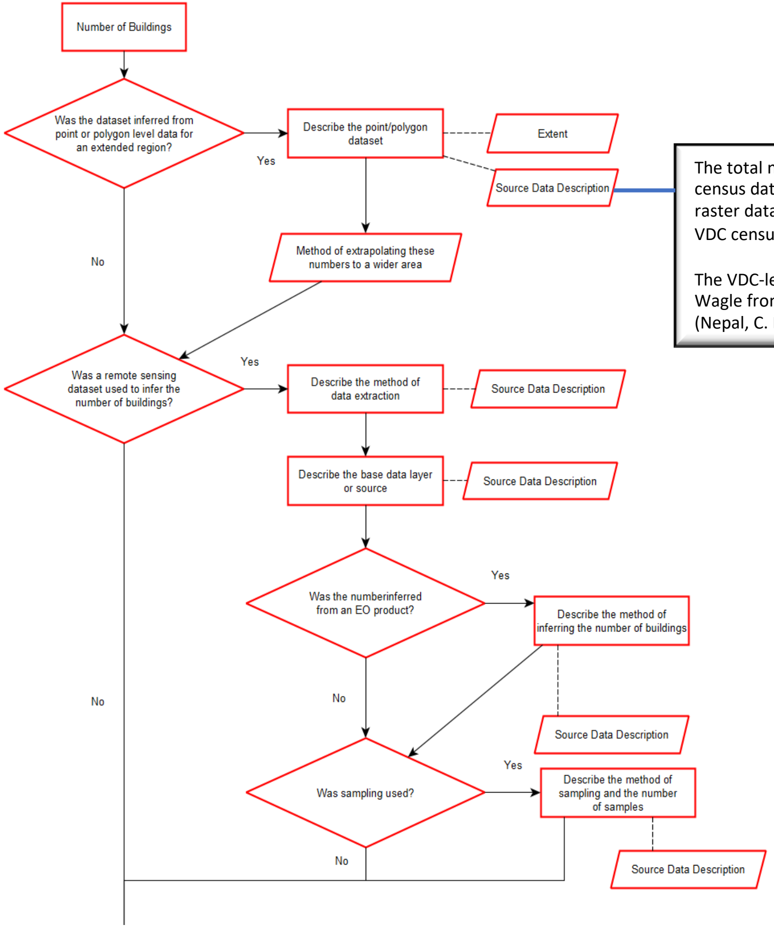
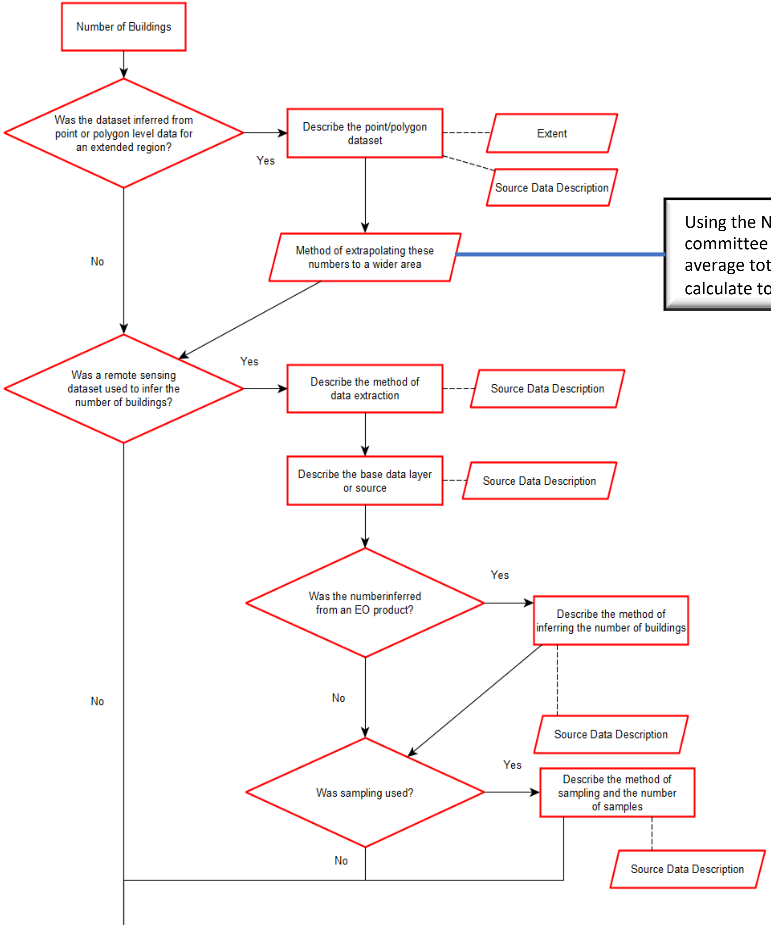
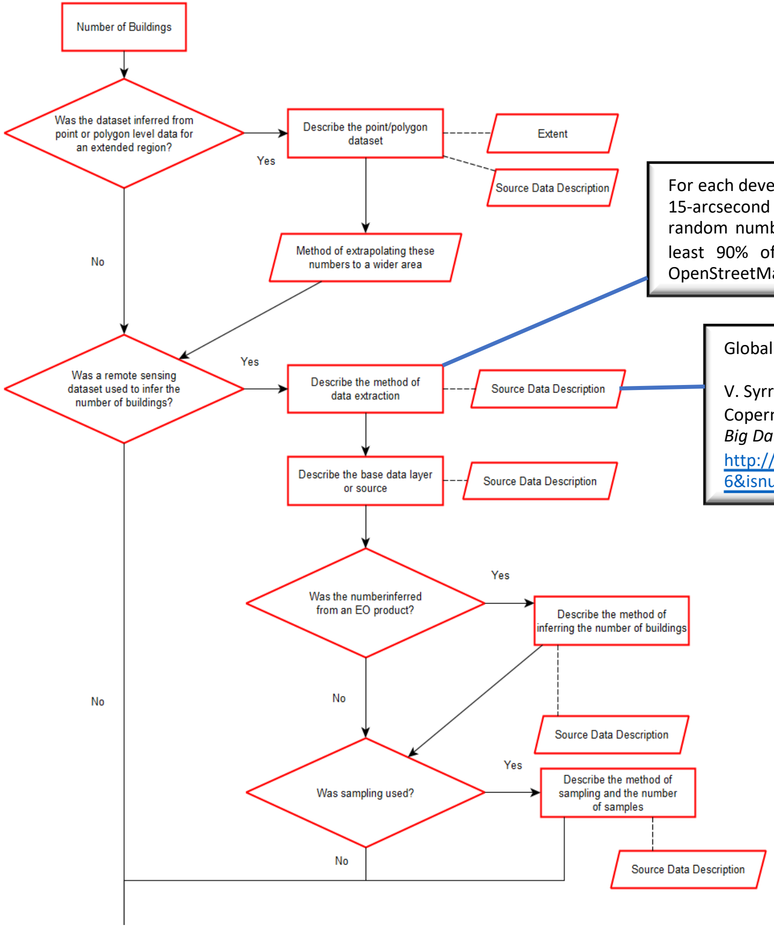


The total number of building was inferred using a combination of IPUMS, VDC census data, OpenStreetMap survey data, and aggregated OSM building raster data sets to estimate average household per each building type per VDC census unit.

The VDC-level census spreadsheets and GIS data were provided by Sharad Wagle from the National Society for Earthquake Technology (NSET) in Nepal (Nepal, C. B. S.(2)).



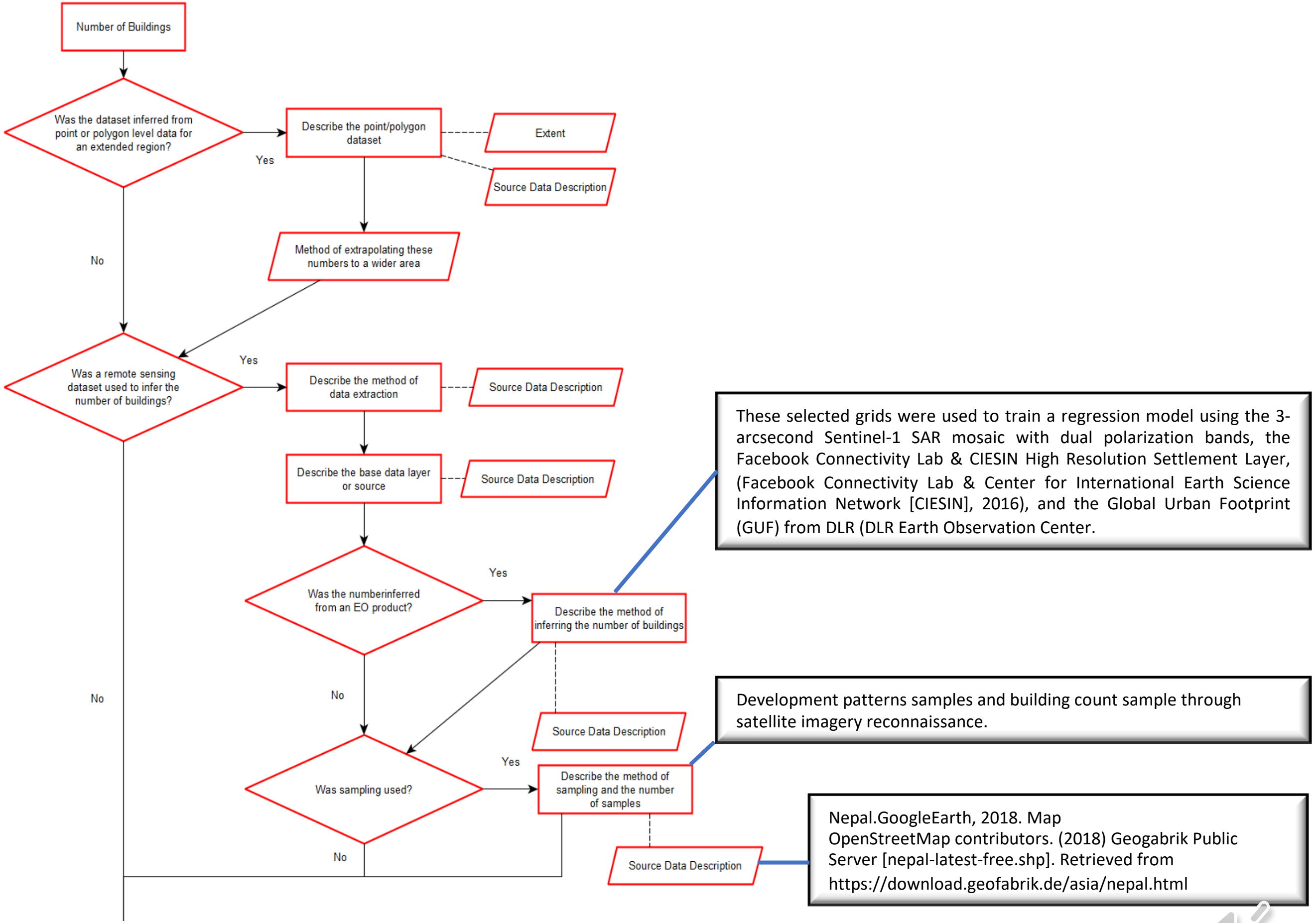
Using the Nepal census count of household per village development committee (VDC) by wall material type a relationship between the average total building area using structural type was created to calculate total number of buildings for the rural zones.



For each development pattern, a project analyst reviewed 15-arcsecond (approximately 500m) grids selected using a random number generator and identified cells where at least 90% of the buildings were represented in the OpenStreetMap building footprint data.

Global Urban Footprint (GUF); DLR 2016.

V. Syrris, C. Corbane, M. Pesaresi and P. Soille, "Mosaicking Copernicus Sentinel-1 Data at Global Scale," in *IEEE Transactions on Big Data*. doi: 10.1109/TBDATA.2018.2846265 URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8428406&isnumber=7153538



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In addition, the model was constrained using OpenStreetMap building footprints with an area between 10 - 5,000 meters square to create an aggregated 3-arcsecond grid OSM building count raster (Humanitarian OpenStreetMap Team, 2019; ImageCat, 2019) as a minimum value.

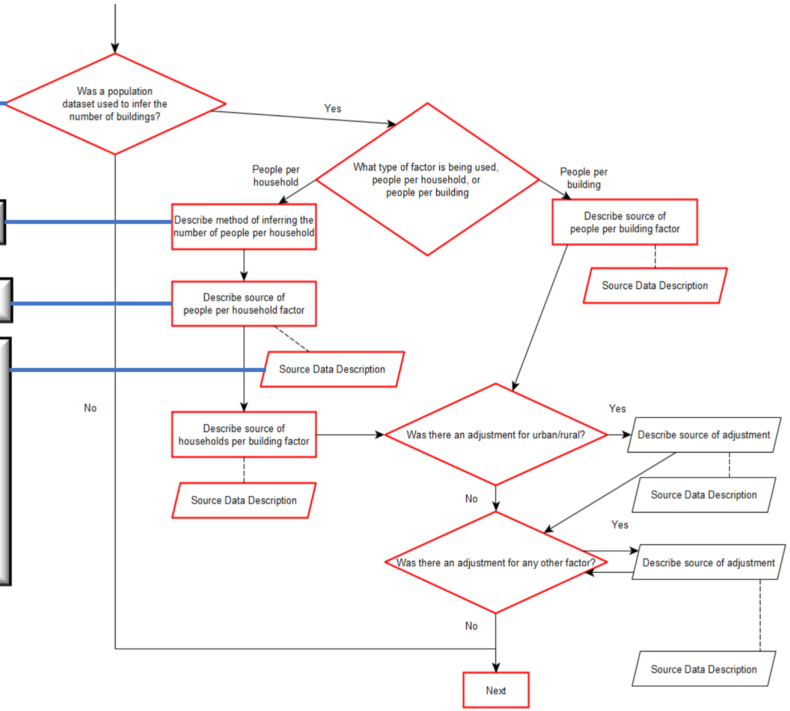
Provided directly in census data at the VDC level

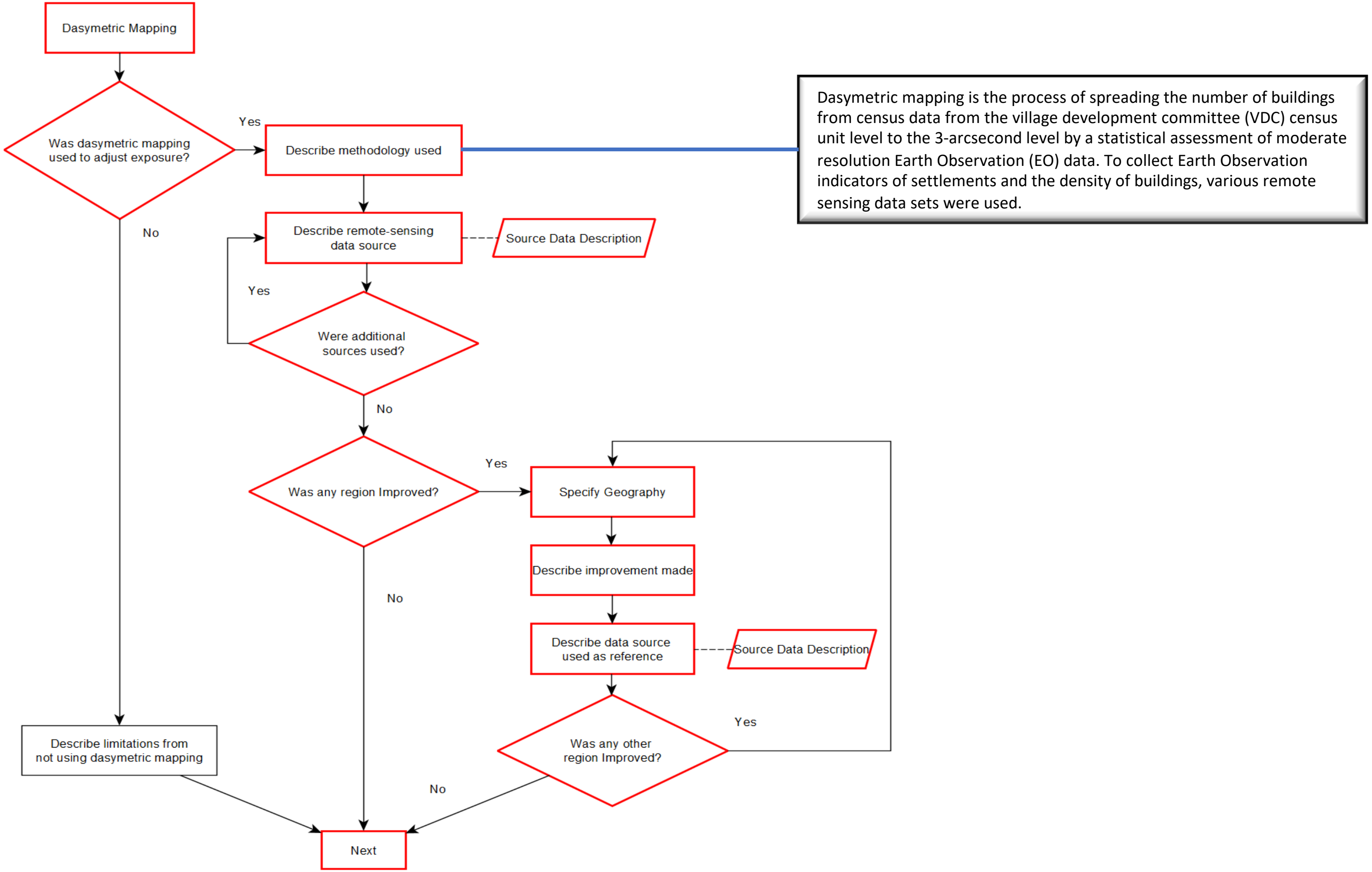
The VDC GIS data was provided by Sharad Wagle from NSET.

Nepal, C. B. S. (2011). National Population Census 2011-Nepal [dataset]. Provided by IPUMS International.

Nepal, C. B. S. (2012)-1. National population and housing census 2011 [National Report]. Gov't of Nepal, Natl Plan Comm Secr Cent Bureau Stat, 1, 1-278

Nepal, C. B. S. (2012)-2. Village Development Committee GIS data [dataset]. Provided by the National Society for Earthquake Technology – Nepal (NSET).





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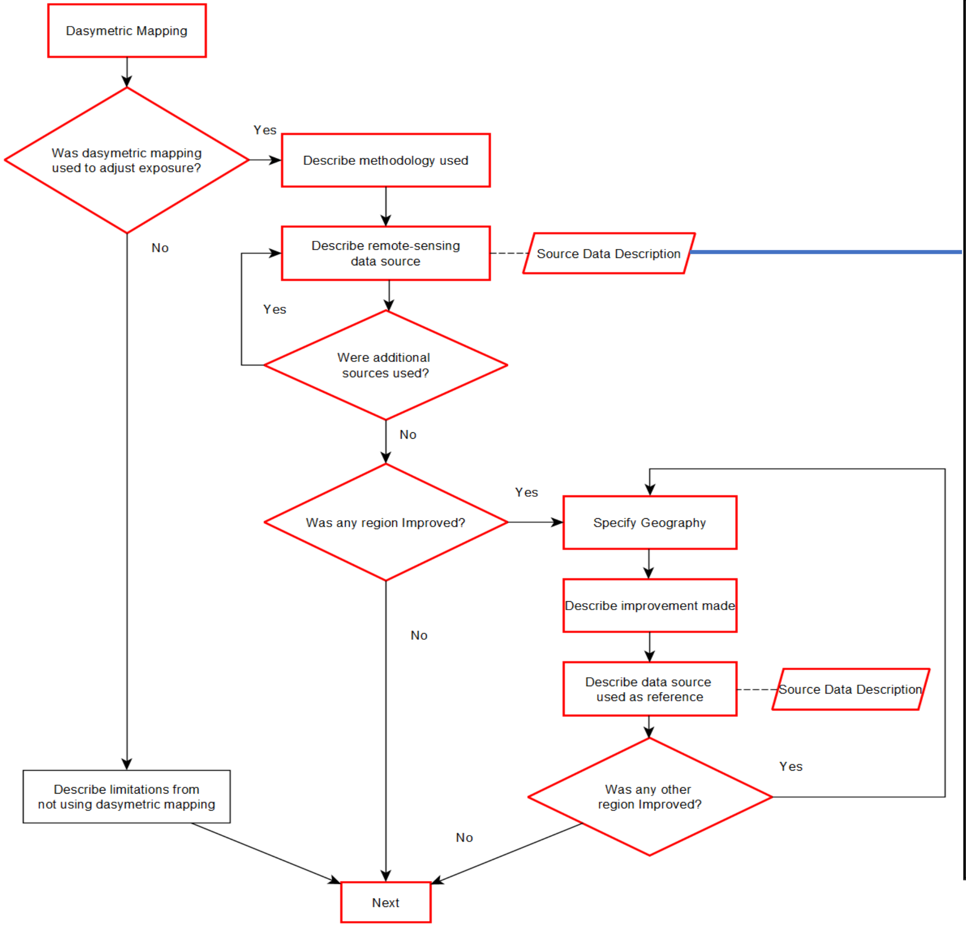


1) NOAA night-time light annual composite (VIIRS) resampled from the 15-arcsecond grid cell to 3-arcsecond (Earth Observation Group NOAA-NCEI (2015))

2) Oak Ridge National Laboratory Landscan ambient population (LSCAN) resampled from the 15-arcsecond grid cell to 3-arcsecond (Oak Ridge National Laboratory. (2012))

3) JRC Global Human Settlement Layer (GHSL-Landsat) derived from Landsat imagery resampled from the 15-arcsecond grid cell to 3-arcsecond (Corbane et al.,(1) 2018)

4) DLR Global Urban Footprint (GUF) resampled from 12-meter grid cells to a 3-arcsecond percentage of human presence raster grid (DLR Earth Observation Center. (2016))

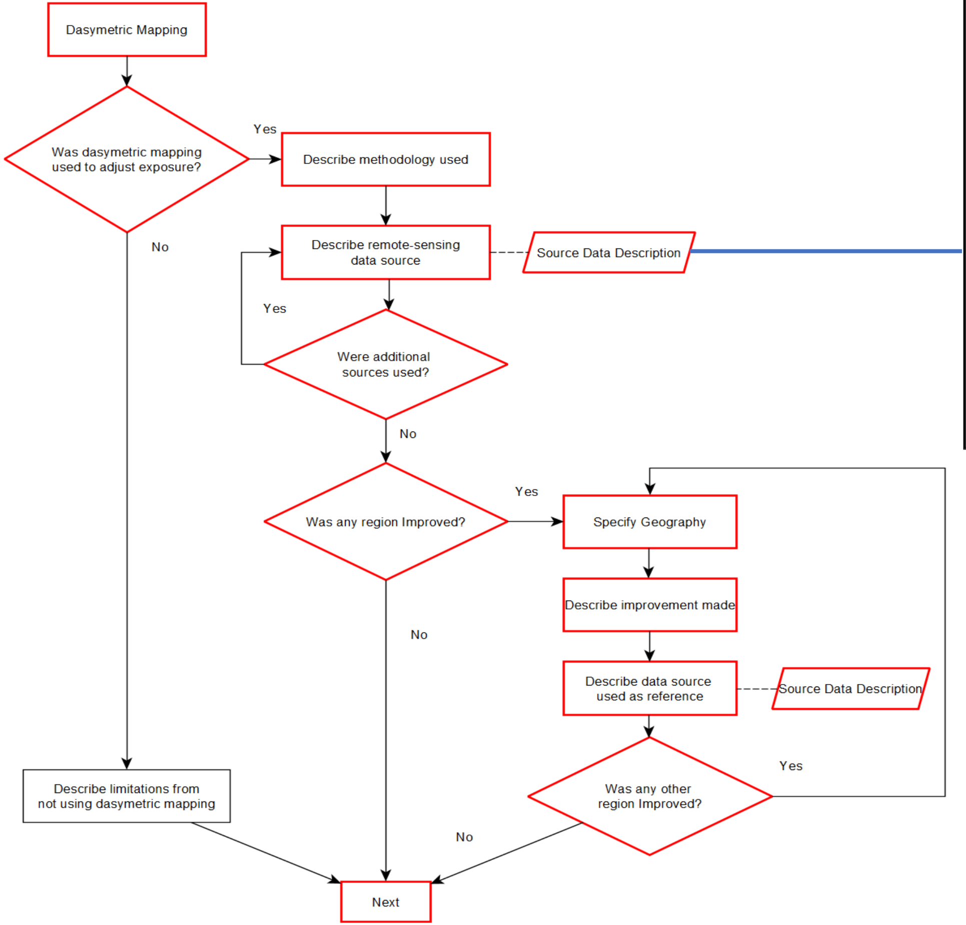
5) JRC GHSL derived from Sentinel-1 SAR (GHSL-SAR) resampled from 20-meter grid cells to a 3-arcsecond percentage of human presence raster grid (Corbane et al.,(2) 2018)

6) CIESIN-Facebook High Resolution Settlement Layer (HRSL) resampled from 1-arcsecond grid cells to a 3-arcsecond percentage of human presence raster grid (Facebook Connectivity Lab and Center for International Earth Science Information Network - CIESIN - Columbia University. (2016))

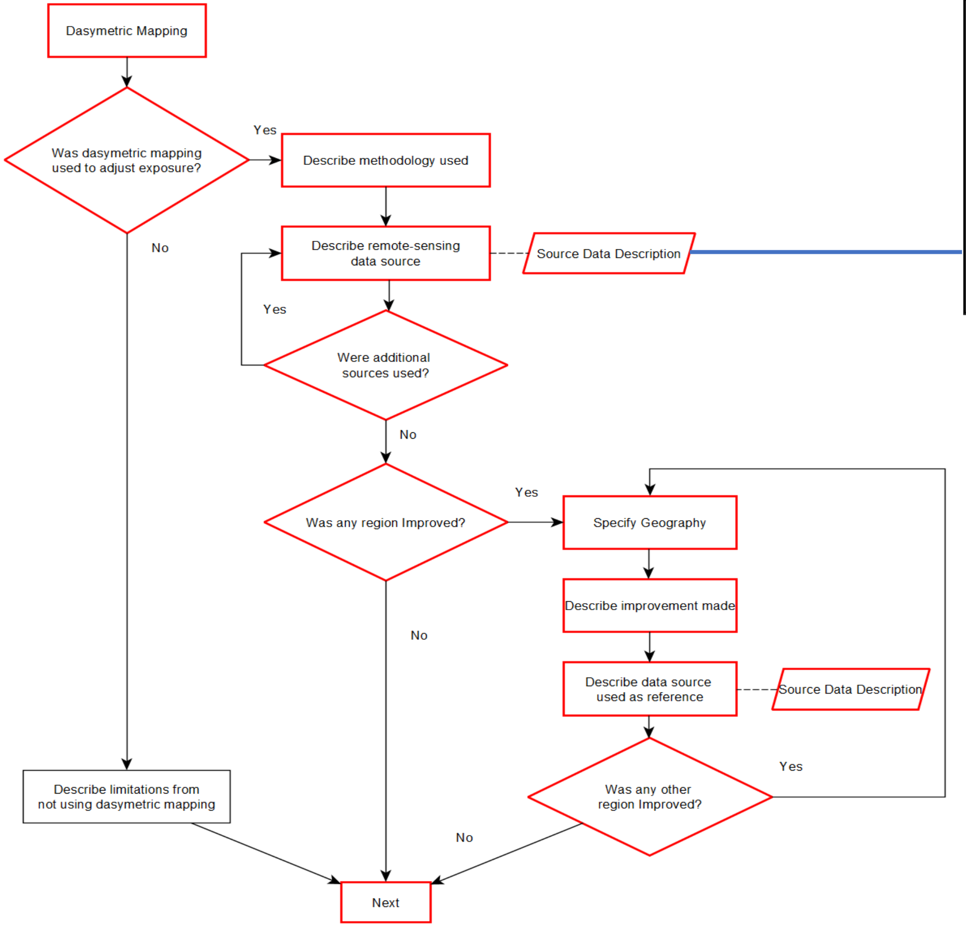
7) JRC mosaiced Sentinel-1 dual polarization bands (SAR B1, B2, B3) resampled from 20-meter resolution to a 3-arcsecond mean raster grid per band and a maximum mean value of the 3 bands (SAR-MaxMean). (Syrris, V., et. al (2018)

8) Nepal gridded population from WorldPop 2020 at 3-arcsecond grid cells (WorldPop(1))

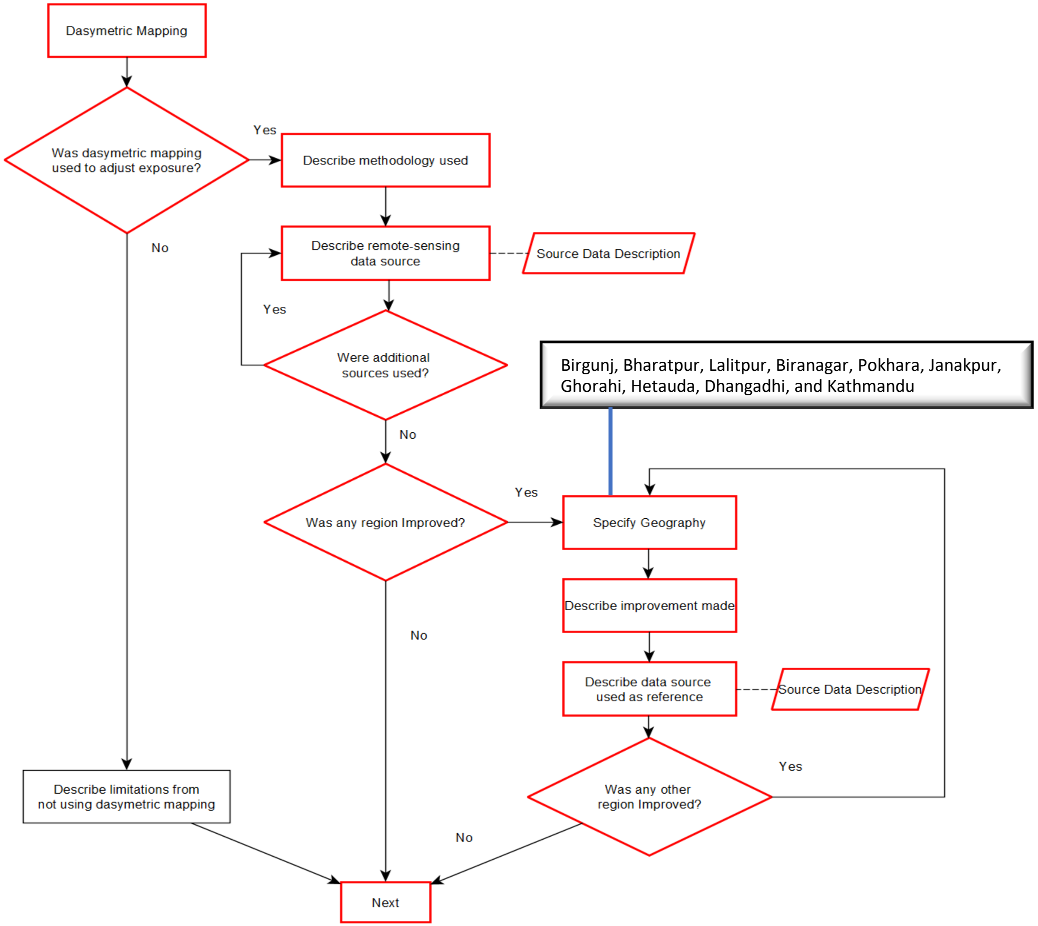
9) An indicator of OSM data throughout the country- building count, area, and maximum building height were calculated from building footprint polygons and aggregated up to create 3-arcsecond grids. (ImageCat, Inc. (2019))

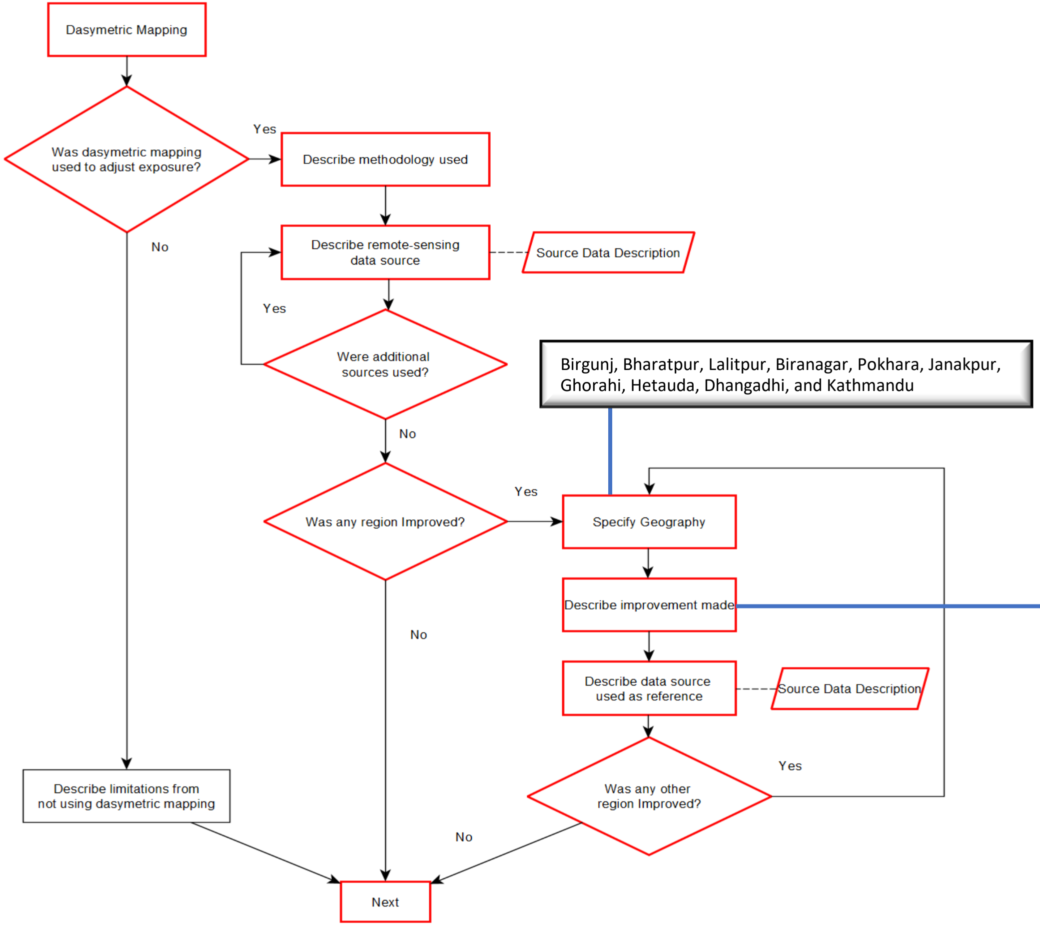


These remotely sensed earth observation products and building footprint aggregates establish the distribution statistics for dispersing buildings by urban density and determining the development pattern type throughout the country. Each of the EO products individually, and in a combination, act as weights to disperse the known number of households per VDC by structural type and development pattern to 3-arcsecond grid cells. For example, with development patterns 1 or 2 (resembling rural or single-family residential communities) the even building distribution of the VDC is reallocated only to grid cells within the VDC associated to human settlement. For determining the weights for distribution within a given VDC tract, several machine learning algorithms were run using the EO to develop a prediction model. In the case of Nepal with complex terrain, GUF was highly weighted, and support vector was determined to be the most effective AI tool, as determined by visual inspection. For developments with higher populations or building density, the reallocation of buildings becomes more complex and requires a more detailed examination of the structural types and mapping schemes.

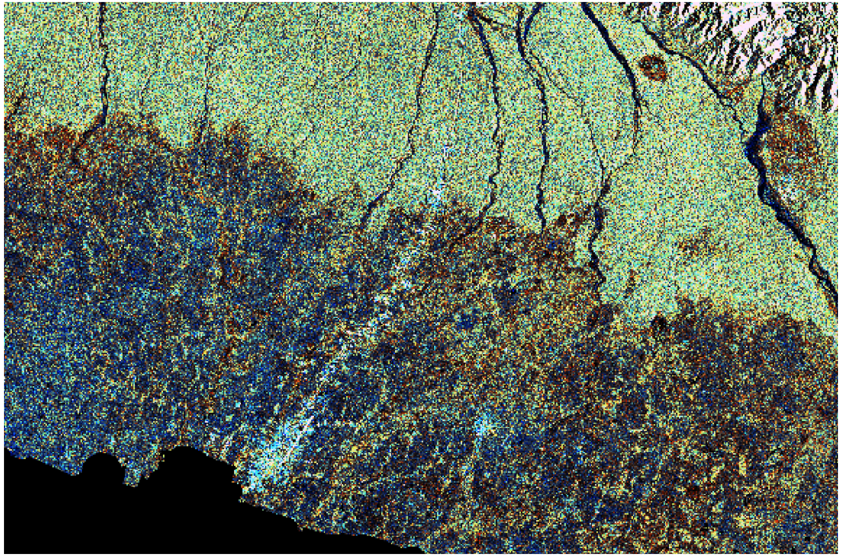


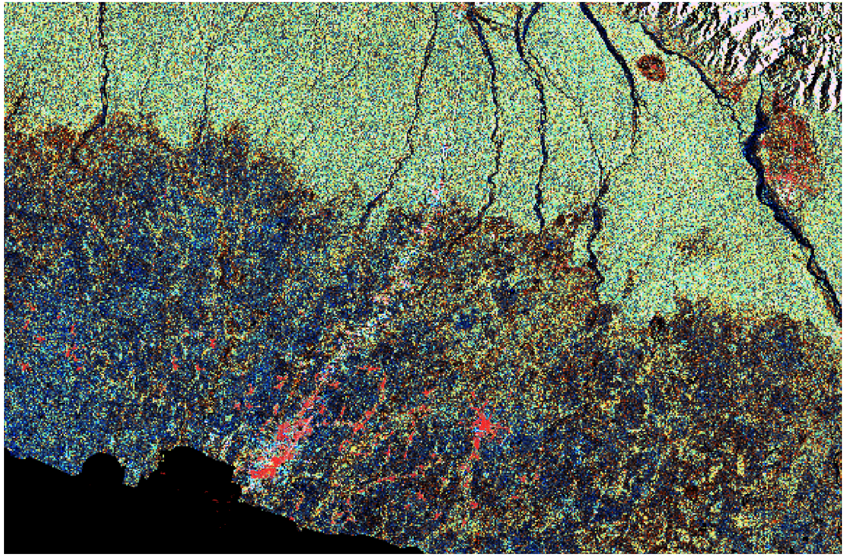
To prevent unpopulated areas from being considered as settlements, especially in the highly mountainous terrain, a mask was created by combining the extents of night-time light (VIIRS), ambient population (LSCAN), and GHSL-Landsat that have been reclassified to inhabited vs. uninhabited using a minimum threshold value determined by visual inspection. These minimum values correspond to even the sparsest human presence. This mask was used to subset the high-resolution Global Urban Footprint (GUF), Sentinel-1 SAR based GHSL product, Sentinel-1 mosaic with dual polarization (Band1 = VH, Band2= linear comparison of VH/VV, Band3 = VV), and CIESIN-Facebook High Resolution Settlement Layer (HRSL) that go into the machine learning process to come up with the development patterns; subsetting the data sets decreases the processing time.

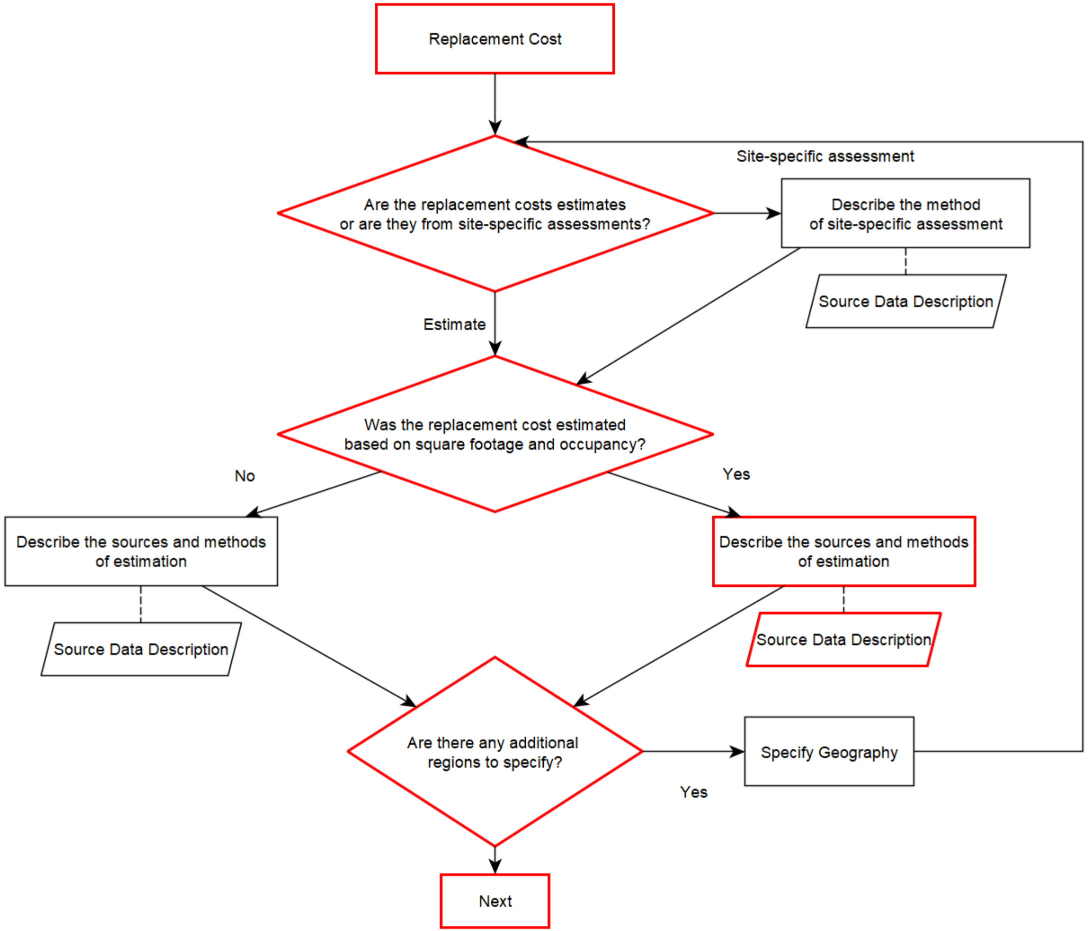

Dasymetric Mapping
Was dasymetric mapping used to adjust exposure?
Yes
No
Describe methodology used
Describe remote-sensing data source
Source Data Description
Yes
Were additional sources used?
No
Birgunj, Bharatpur, Lalitpur, Biranagar, Pokhara, Janakpur, Ghorahi, Hetauda, Dhangadhi, and Kathmandu
Yes
Was any region Improved?
Specify Geography
Describe improvement made
No
Describe data source used as reference
Source Data Description
Yes
Was any other region Improved?
Describe limitations from not using dasymetric mapping
No
Next

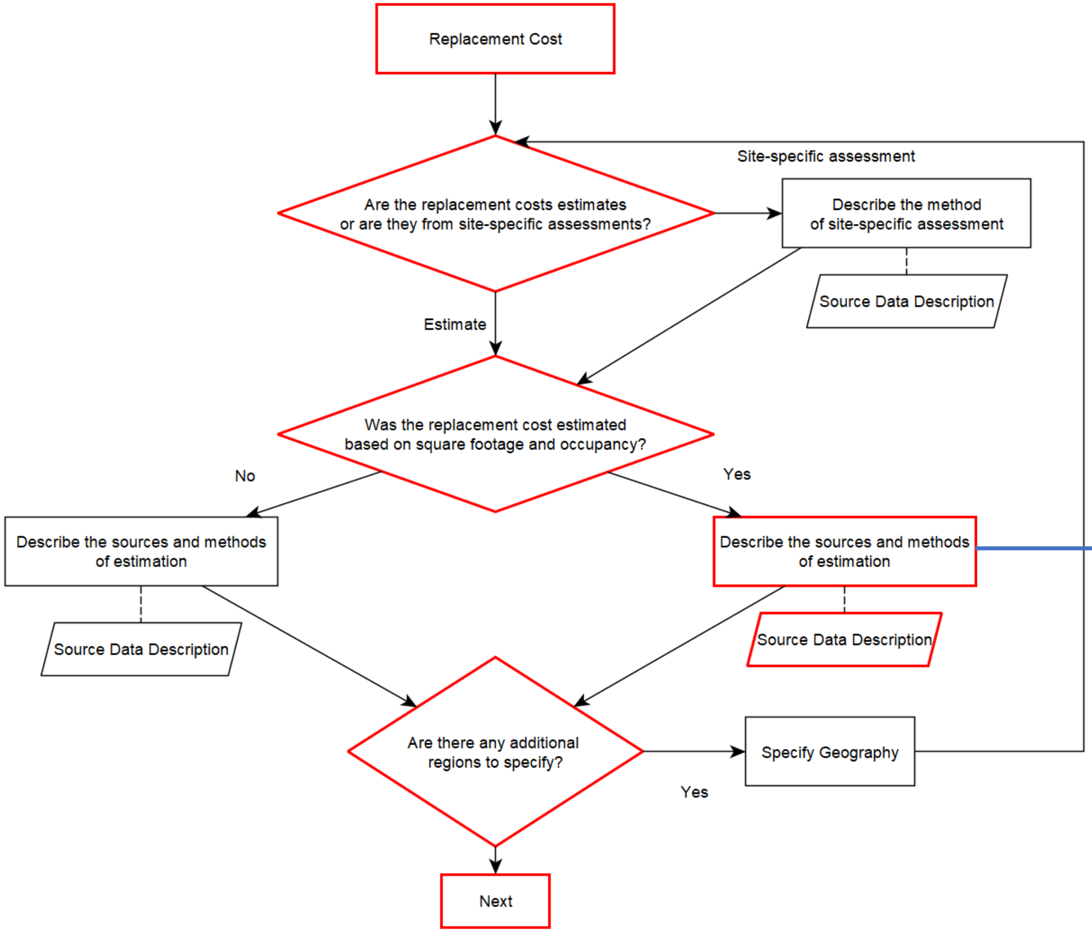


To characterize building density in more populated areas, analysts digitized sample training development patterns polygons in the top 10 most populated cities in the country (World Atlas, 2019; Birgunj, Bharatpur, Lalitpur, Biranagar, Pokhara, Janakpur, Ghorahi, Hetauda, Dhangadhi, and Kathmandu). For these cities, the digitized vector data was used directly, rather than the classified development pattern grid. The delineations are digitized using the Google Earth area tool and saved as KMLs. The basemap vintage and source used during digitization vary by region and zoom level. However, the most current high-resolution satellite images are used. The training polygons and the moderate resolution EO products described above are used in a machine learning process (CART algorithm (Breiman et al., 1984; Khaled et al., 2014), Random forest (Breiman, 2001), and Support Vector Networks (Cortez et al., 1995)) for assigning the development patterns throughout the country, which informs the estimated building density. The intensity of urbanity correlates to both the building density and the structural distribution. For Nepal, the ImageCat engineer characterized 8 development pattern types.

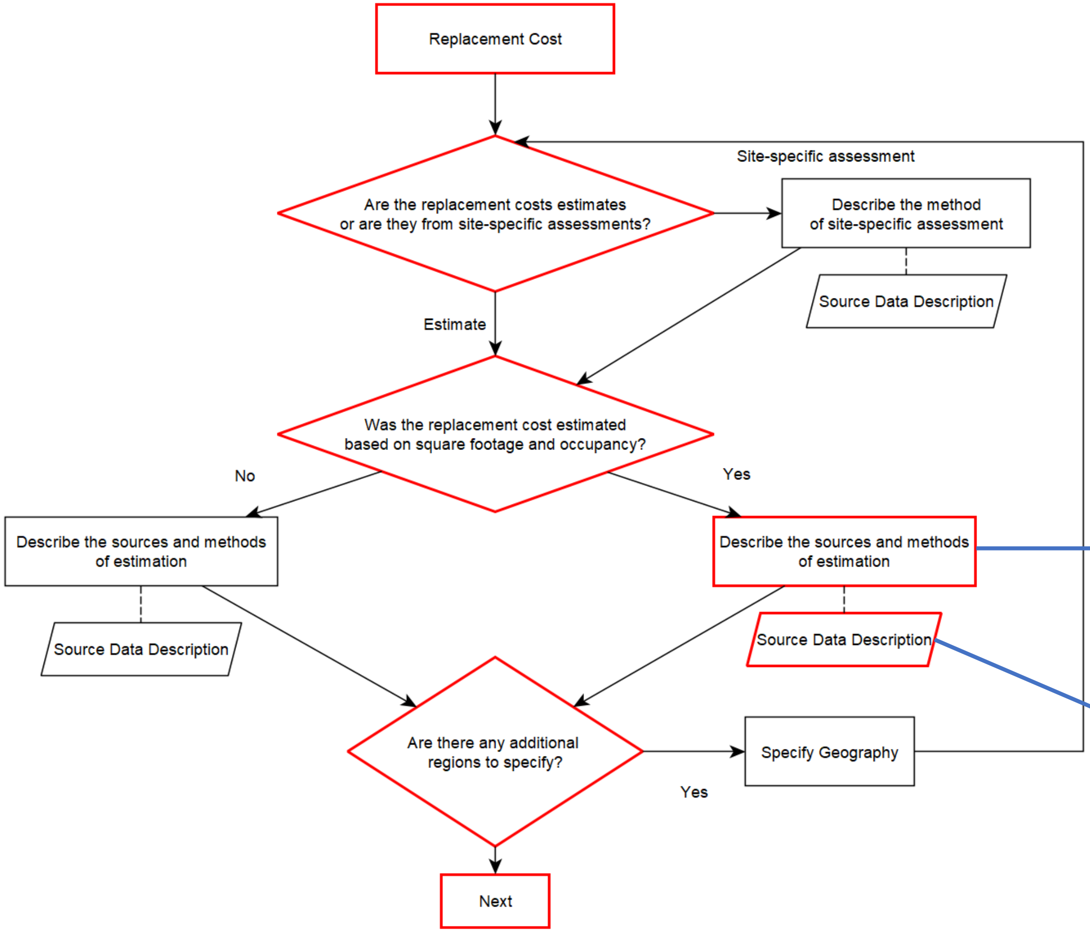





Replacement Cost
Are the replacement costs estimates or are they from site-specific assessments?
Site-specific assessment
Describe the method of site-specific assessment
Source Data Description
Estimate
Was the replacement cost estimated based on square footage and occupancy?
No
Yes
Describe the sources and methods of estimation
Source Data Description
Describe the sources and methods of estimation
Source Data Description
Are there any additional regions to specify?
Specify Geography
Yes
Next



These values were derived by an in-country survey by Kathmandu Living Labs and HOTOSM in the surrounding urban and rural regions of Kathmandu.



Adobe - $9.00

Reinforced Concrete Framed Building (RCC) with infill - $27.00

Engineered Reinforced Concrete Framed Building (RCC) - $32.00

Informal - $5.00

Light Steel Building - $16.00

Steel Frame Building w/ URM Infill - $24.00

Load Bearing Brick and Mud Mortar Masonry - $12.22

Load Bearing Brick and Cement Mortar Masonry - $19.74

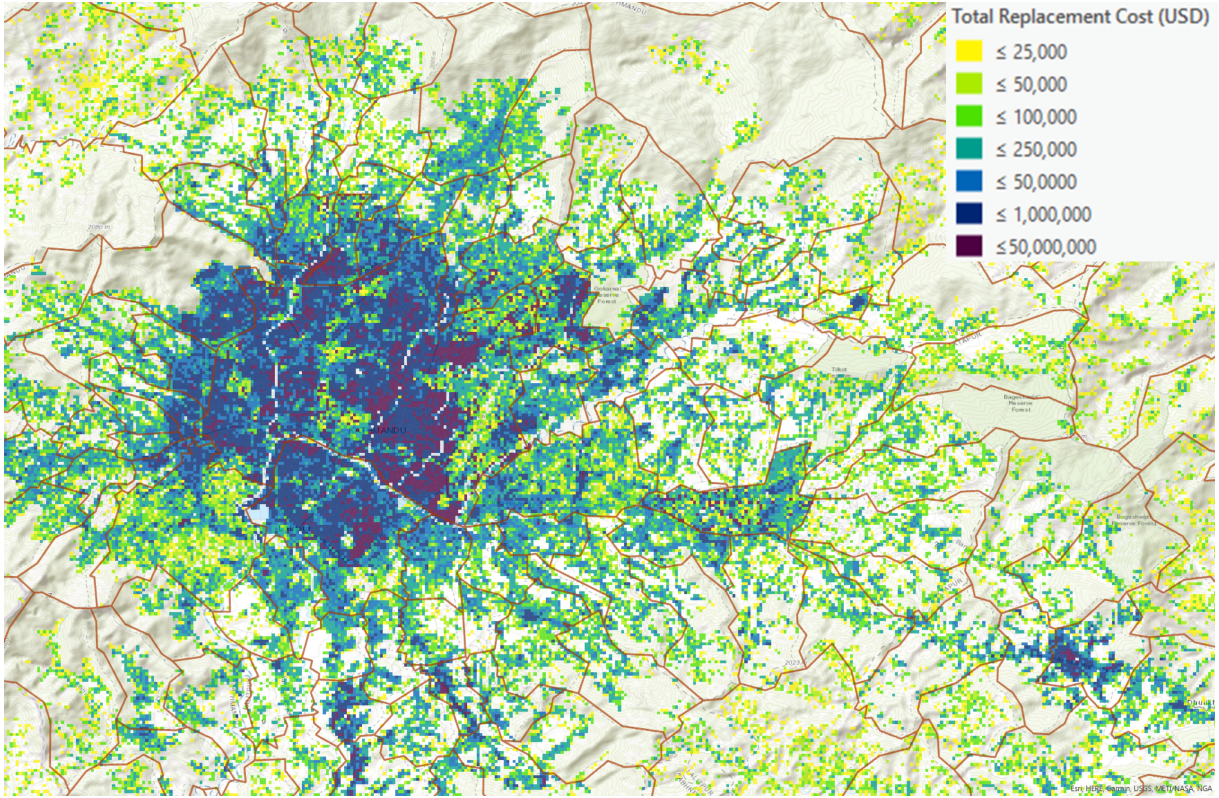
Load Bearing Stone and Mud Mortar Masonry - $9.40

Load Bearing Stone and Cement Mortar Masonry - $10.34

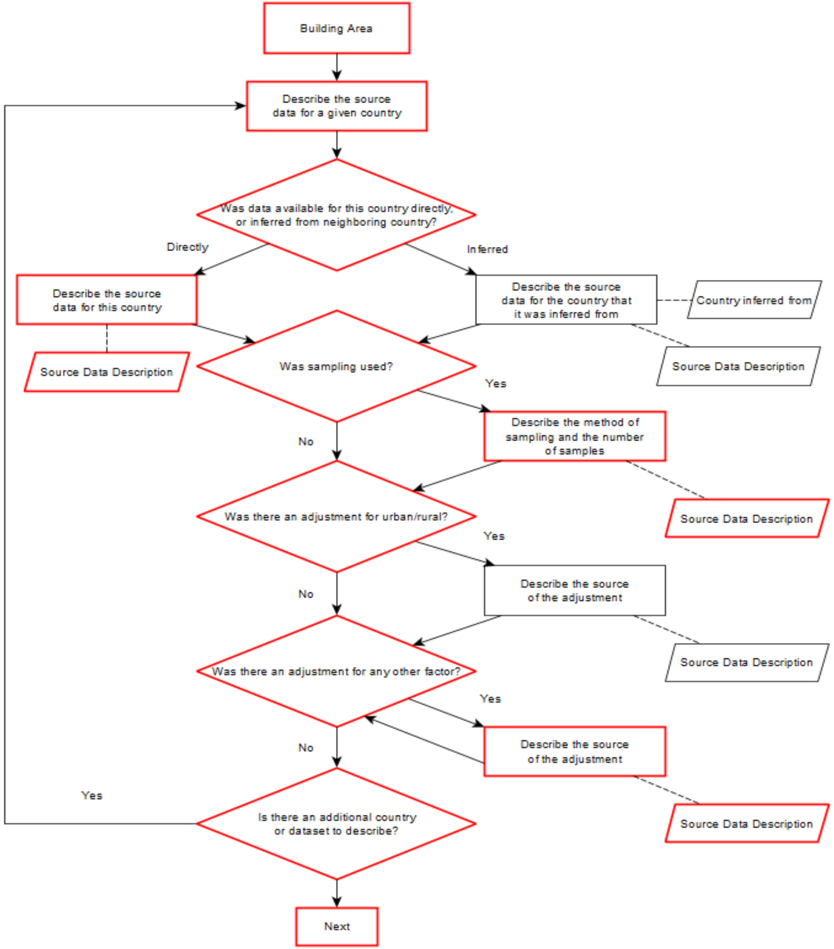
Wood and Timber - $8.00

National Society for Earthquake Technology (NSET). (2019) Unit replacement costs from NSET's building survey for Nepal. Provided by the National Society for Earthquake Technology – Nepal.

Kathmandu Region Replacement Cost in USD

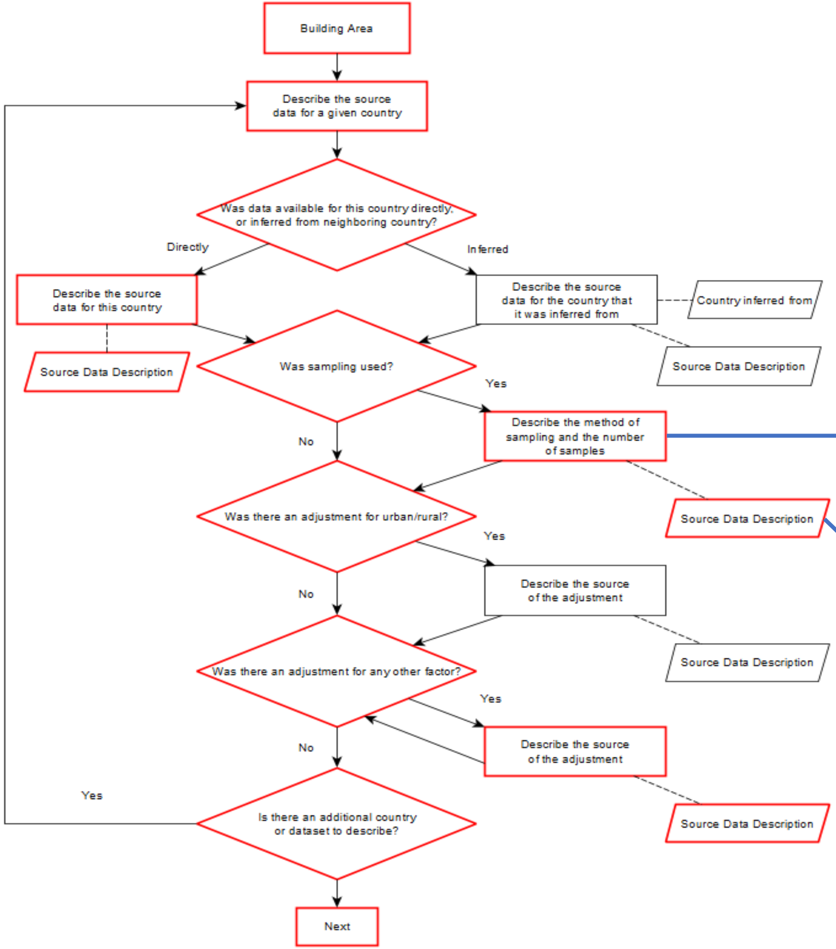


BGS British Geological Survey · FATHOM · GEM · HOT · ImageCat · NSET · Oxford Policy Management · METEOR



https://meteor-project.org

British Geological Survey



The total building area was calculated using a combination of IPUMS, Nepal census data, Humanitarian OpenStreetMap Team (HOTOSM) survey data (Humanitarian OpenStreetMap Team, 2019), and 3-arcsecond aggregated OSM building area raster data sets (ImageCat, Inc., 2019). For the rural development pattern types, the height distribution from IPUMS, specifically heights for unreinforced brick masonry UFB-1 and UFB-5, was used with the average building footprint area from 3-arcsecond aggregated OSM raster to determine the average total building area. For all other non-rural development pattern designated zones the Humanitarian OpenStreetMap Team (HOT) in-situ building survey was used to establish the total building area by structure type per development pattern type using the surveyed building footprint and height values.

Humanitarian OpenStreetMap Team (2019). In-situ structural building type, height, and footprint area sampling polygons of Nepal.

ImageCat, Inc. (2019). OSM building footprint data aggregation to 3-arcsecond raster grid

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British Geological Survey

Take-Aways

There is a great deal of information that goes into creating a building exposure database.

These flowcharts assist in organizing metadata collection and processing step review.

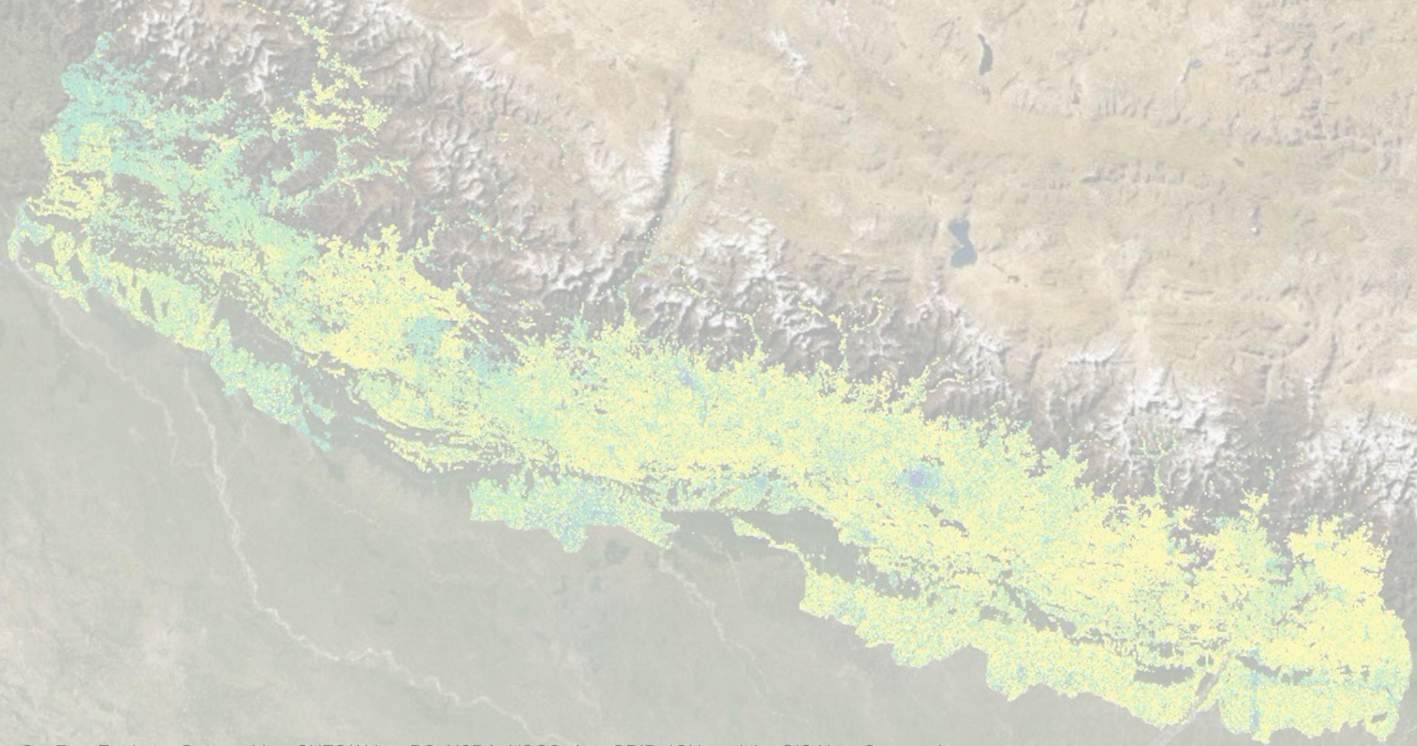
With these flow charts future researchers can update or refine the exposure database as a whole or finely tune an individual section with improved data.

We hope that these flowcharts assist future teams in updating or refining the exposure results.

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IG

Final Exposure



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

https://meteor-project.org

British Geological Survey

NSET

Oxford Policy Management

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IG

Thank You

Contact Information: gre@imagecatinc.com

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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