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Localization of Urban Electricity Reliability Challenges Using Spatial Tools: A Case of Accra, Ghana

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Structure of the presentation

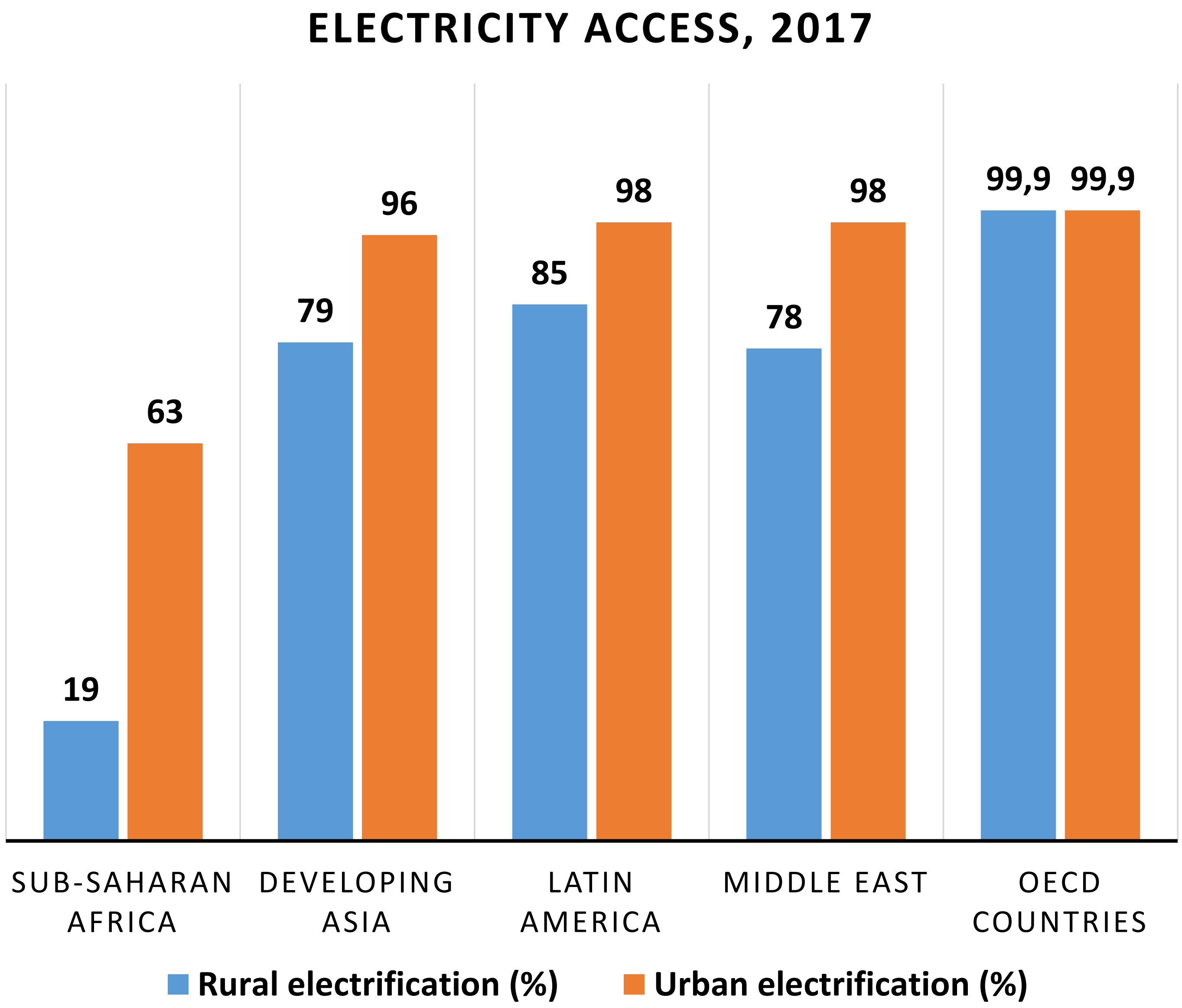
- Setting the stage (*what we already know*)
  - ❖ Electricity sector challenges in Africa
  - ❖ Electricity reliability challenges in Africa

- Emerging issues (*what we may not yet understand well, in a scientific sense*)
  - ❖ Electricity reliability issues in Accra, Ghana
  - ❖ Hypotheses and questions

- Study design and methods

- Results and discussion

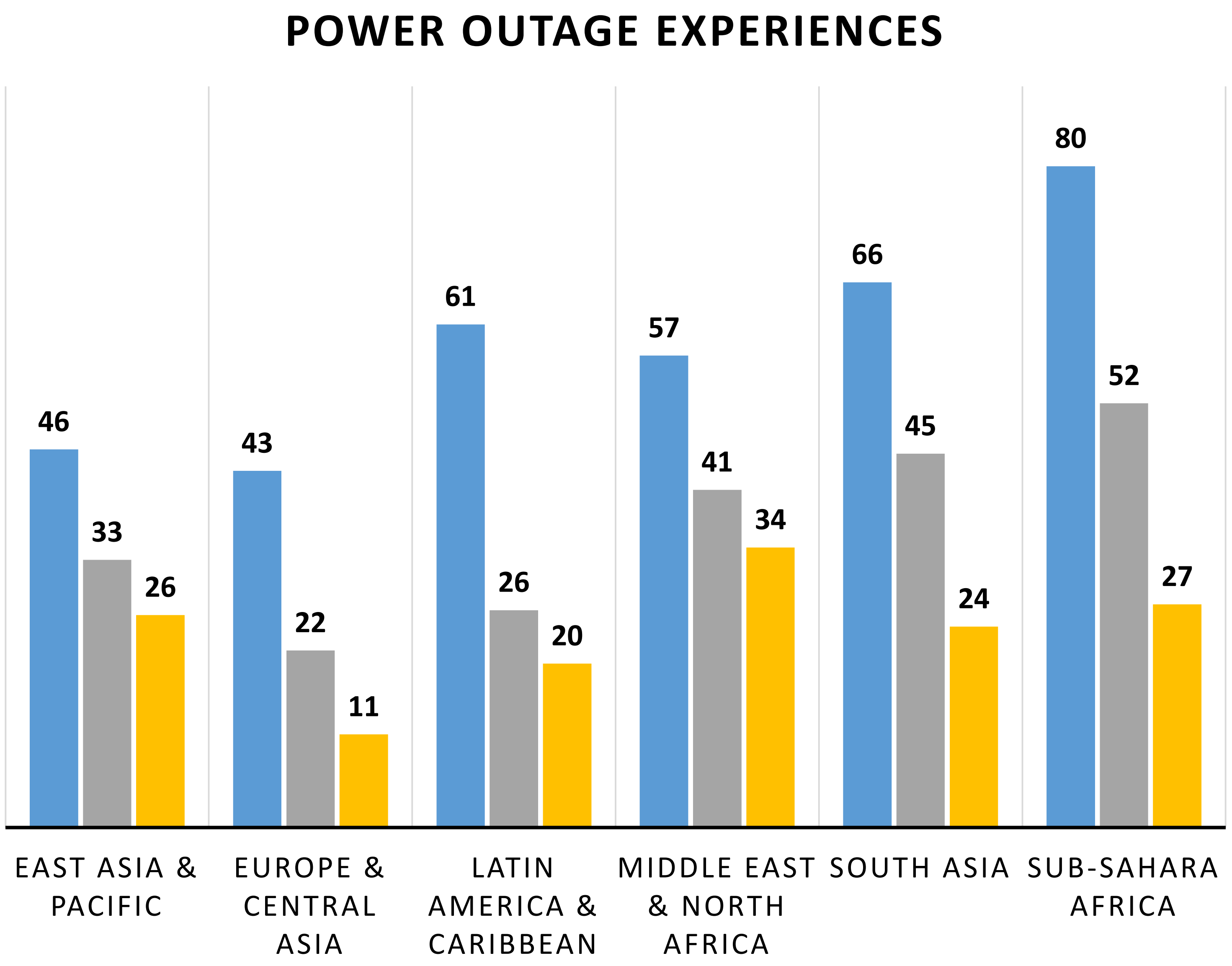
Electricity sector challenges in Africa – Low electrification



Source: International Energy Agency (IEA)

- Sub-Sahara Africa has lowest electrification rate compared to other world regions
- In most world regions, urban areas often have higher electricity access rates than rural areas.
- In Africa, the urban bias in electrification is even higher (>3 times).

Electricity sector challenges in Africa – High unreliability



Source: World Bank Enterprise surveys

Legend

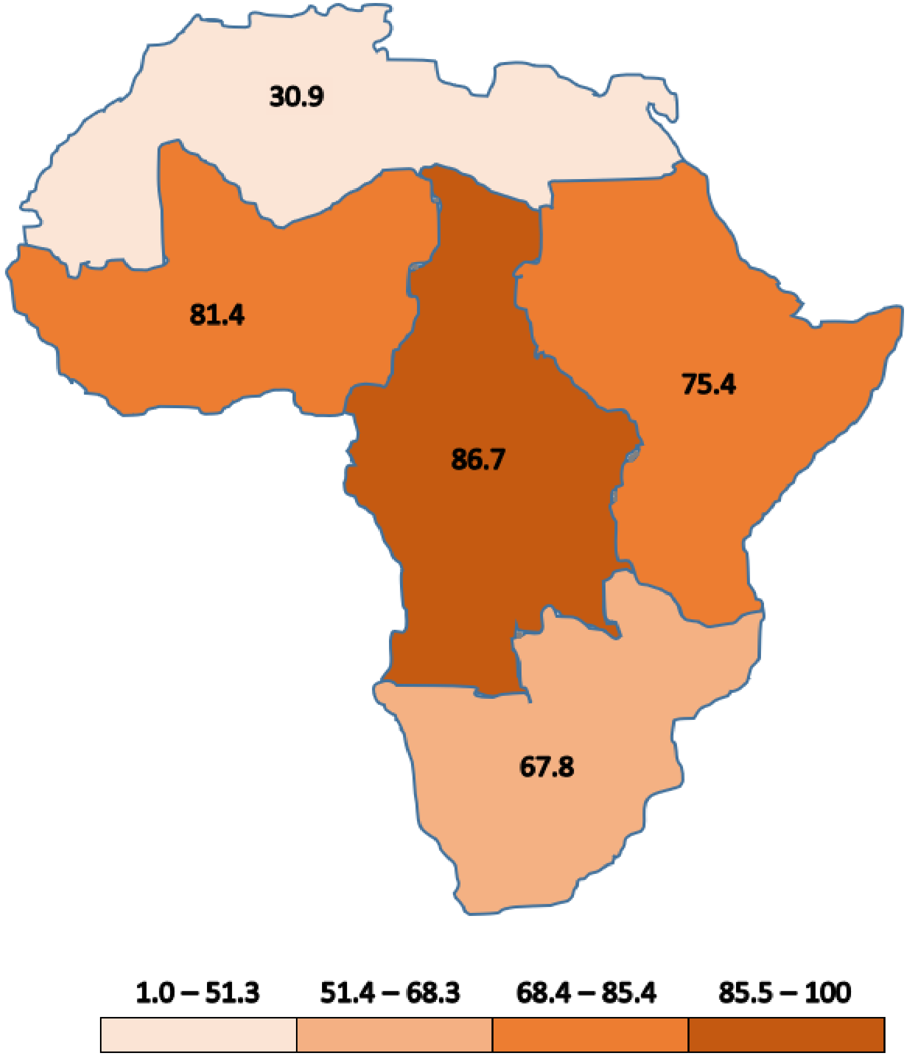
- Percent of firms experiencing power outages
- Percent of firms owning or sharing a generator
- Average proportion of electricity from a generator (%)

Sub-Sahara Africa characteristics:

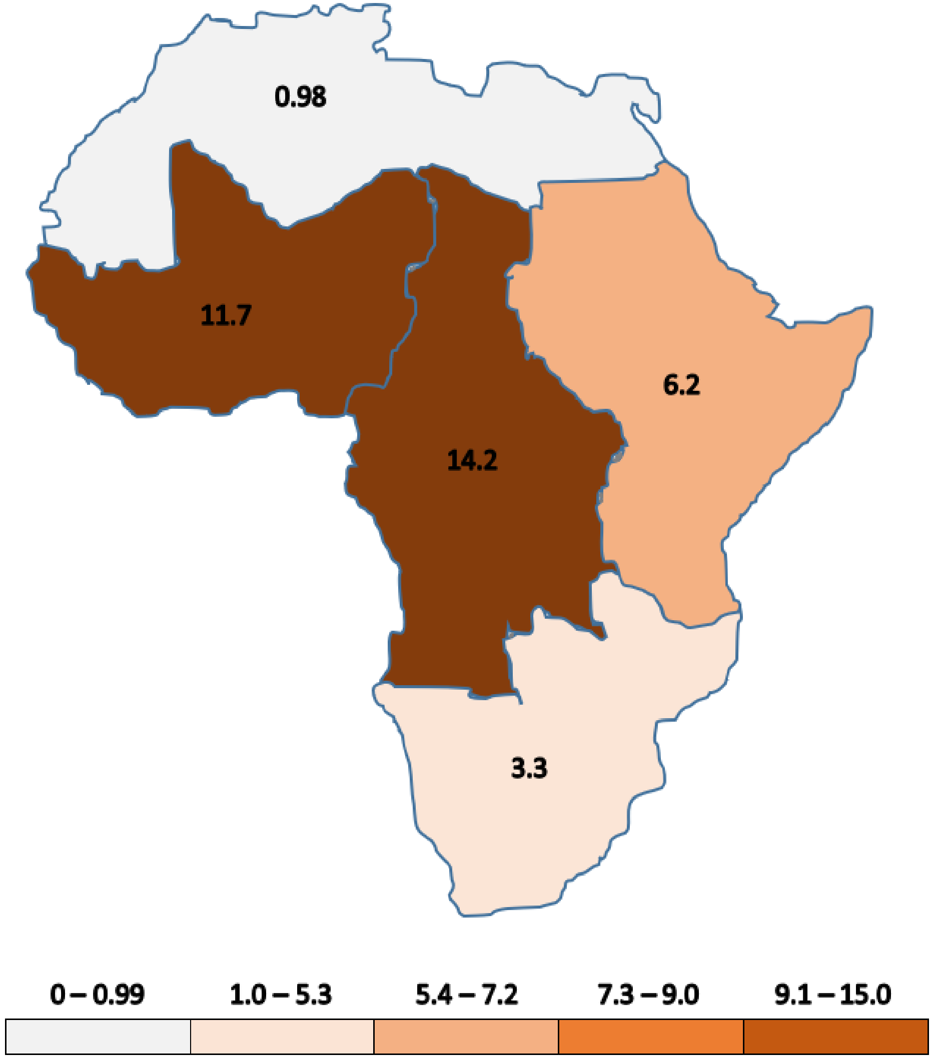
- Highest percent of firms experiencing outages as compared to other regions
- Highest generator ownership/usage as compared to other regions

Electricity reliability challenges in Africa – power outages

Map 1: Percent of firms experiencing power outages



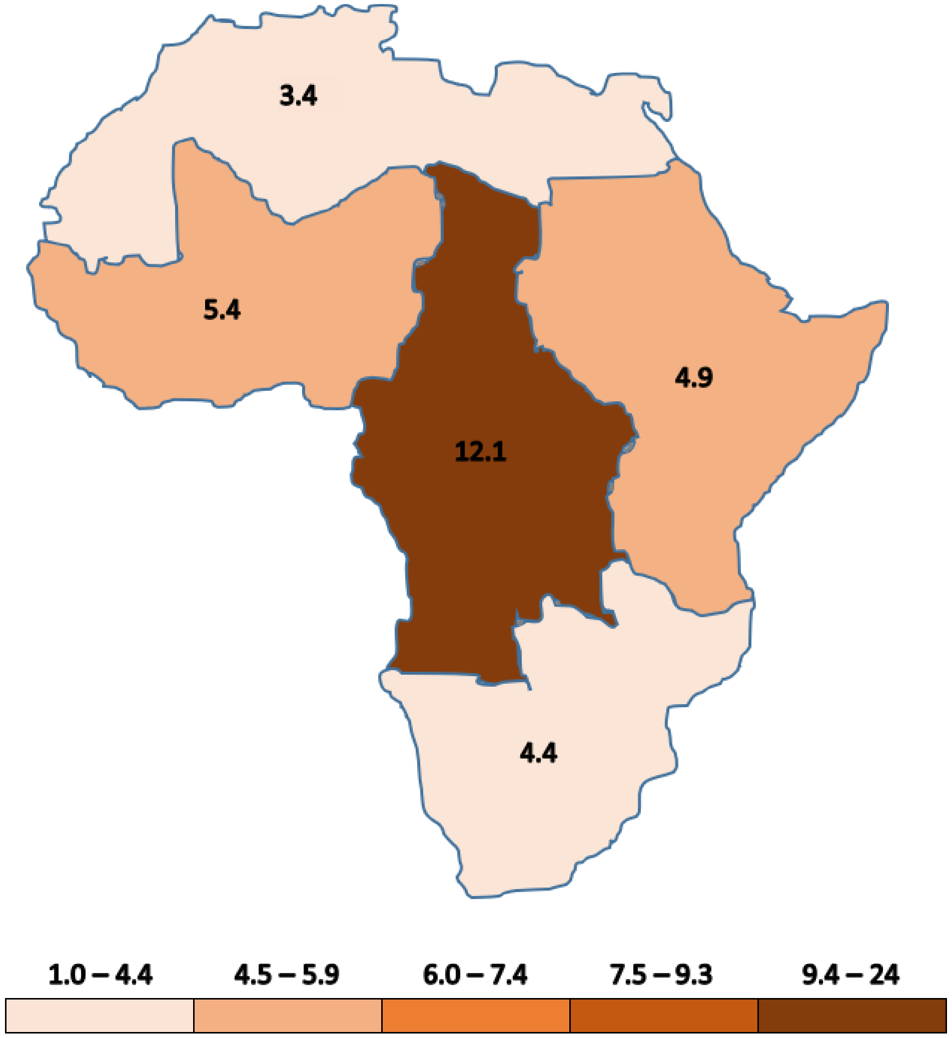
Map 2: Number of power outages in a typical month



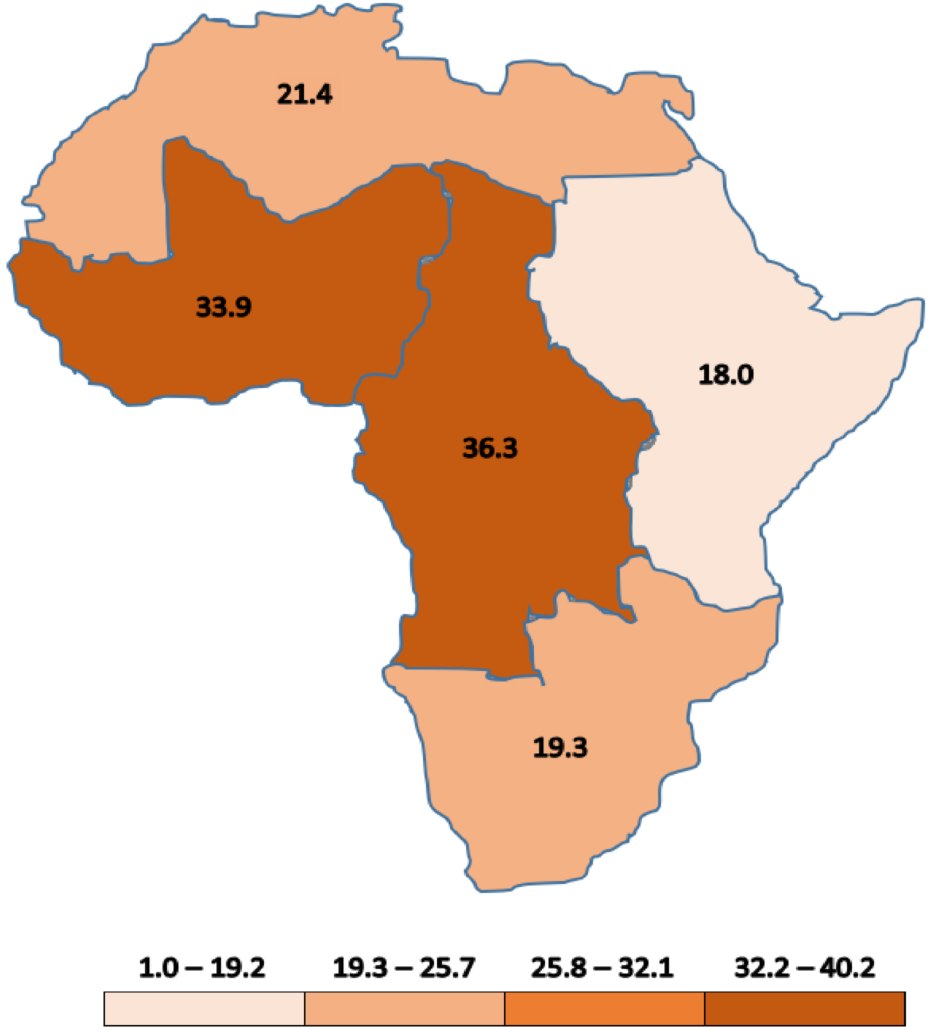
Source: World Bank Enterprise surveys

Electricity reliability challenges in Africa – power outages (cont'd)

Map 3: Average duration of a typical power outage (hrs)



Map 4: Average proportion of electricity from a generator (%)



Source: World Bank Enterprise surveys

Emerging issues – Electricity reliability issues in Accra, Ghana

General News of Thursday, 16 July 2015 — **Source:** Graphic.com.gh

ECG says load-shedding timetable cannot be followed

reasoning can be seen in the response of Dr. Charles Wereko-Brobby, former Chief Executive of Ghana's Volta River Authority, to early evidence that dumsor was favoring the wealthy: "The only schedule that matters is where ECG thinks it will get paid" (Aidoo 2015).[10] While prioritizing profit when targeting limited electricity is reasonable, it will have the effect of concentrating ... tarian bureau-

Underpowered: Rolling blackouts in Africa disproportionately hurt the poor

and especially ad... hborhoods (e.g., Cantonments, Ridge) have almost complete electricity coverage while other poor ones (e.g., Chorkor) receive a much lower and more uncertain supply.

"People who are ministers and government officials have electric running for them. [...] Ordinary people have constant blackouts. If you have political power, you have electricity." (Baker from Nkawkaw [Ghana], quoted in Rupp [2013:112])

Hypotheses and questions

Hypotheses

- Electricity unreliability across local communities in Accra, Ghana exhibits substantial spatial variation.

- The spatial patterns of unreliability are influenced by social, economic, and other factors.

Questions

- To what extent do levels of electricity unreliability (*herein measured as load shedding*) vary spatially across communities in Accra, Ghana?

a) How to disaggregate/localize electricity load shedding experiences to a neighborhood scale?

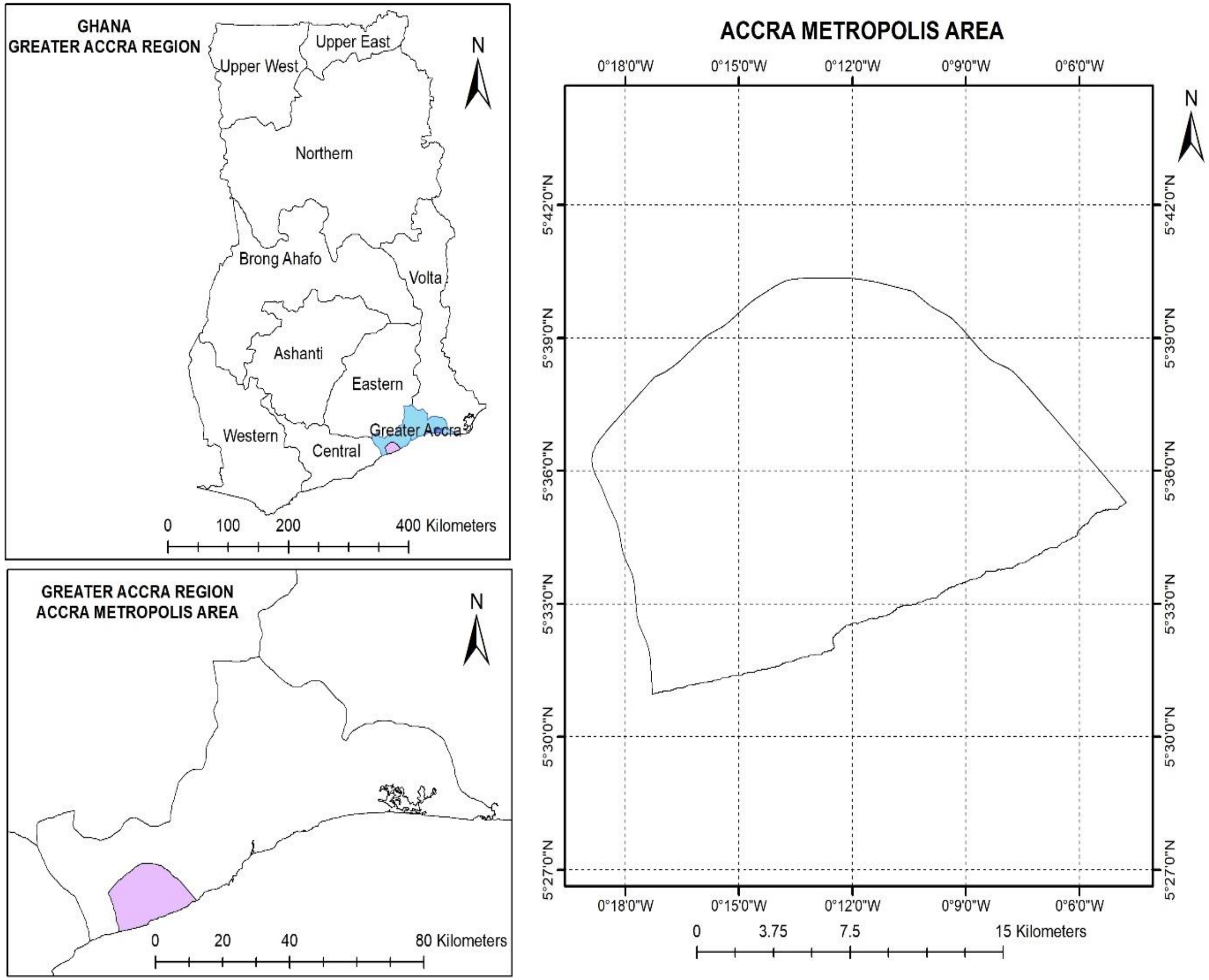
b) What variable is appropriate for quantifying neighborhood-level load shedding?

c) What are the spatial characteristics of load shedding experiences? Where are the hot/cold spots of electricity load shedding?

d) How does load shedding experience change with changing neighborhood characteristics?

Geographical Context of the study

Map 5: Location of Accra Metropolis Area in Ghana



General characteristics for Accra Metropolis

Accra Metropolis is Ghana's capital and largest city

Area: 225 sq. km (approx.)

Population: Over 2 million people in 2019

Sectors: Trade, Industrial; Government; Banking

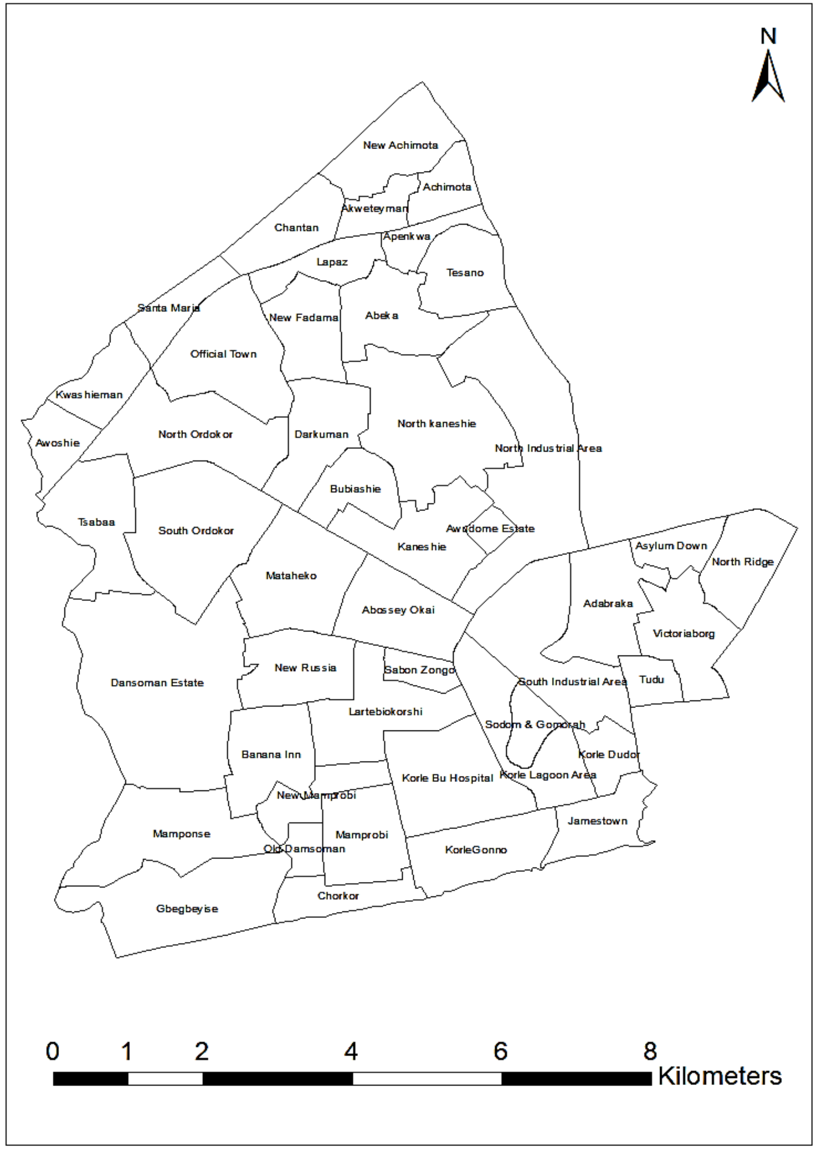
High levels of informality and inequalities

Electricity access rate: Over 95%

Recurrent electricity outage challenges

Study design

Map 6: Selected Accra Neighbourhoods



Study characteristics

- Study area– 47 communities in Accra Metropolis
- Data – Power network map; outage statistics; census data
- Target group – Residential sector (households)

Neighbourhood definition

- Neighbourhood is defined here as a spatial unit made up of geographically linked enumeration areas (EAs) with relative similarity in socioeconomic characteristics, and generally accepted as one social unit by the local population.

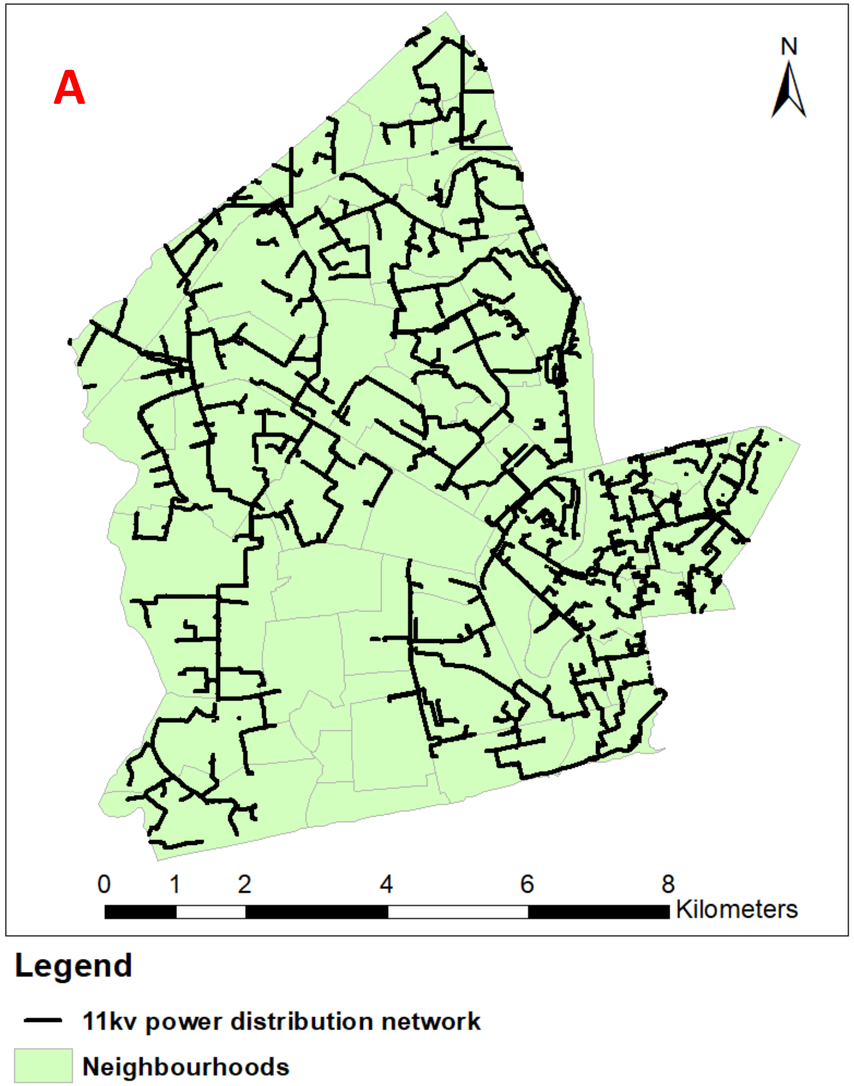
- Study area map used was extracted from Engstrom et al. (2013)

Electricity distribution network map

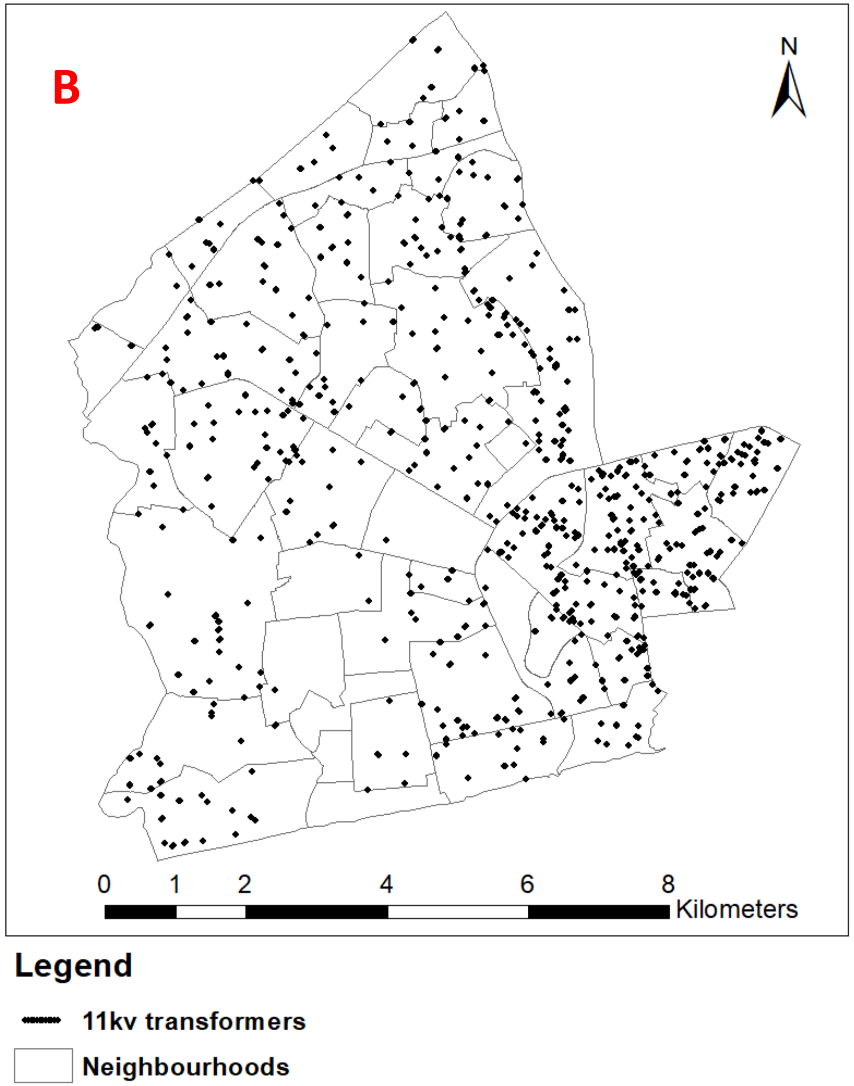
- The 11 kv electricity network (feeders and transformers) was most relevant for this study. The network map covering the study area was obtained as an AUTOCAD drawing. It was imported into ArcGIS and georeferenced.

Methods - Linking electricity load shedding to communities

Neighbourhoods and 11kv electricity feeders



Neighbourhoods and 11kv transformers



- 11kv electricity feeder map was overlaid onto the neighbourhood map within ArcMap 10.5.1.
- Presence of an 11kv step-down transformer in a neighbourhood was used to validate that a given feeder supplied electricity to that neighbourhood.

Map 7: Neighbourhoods and 11kv power distribution feeders (A); Neighbourhoods with 11kv step-down transformers (B)

Methods – Estimating neighborhood-level load shedding

Load shedding exposure, LS_e variable: Defined as the cumulative number of load shedding outage hours (or minutes) experienced on any single electricity feeder serving a given neighborhood.

$$LS_e = LS_f \times LS_d$$

$$LS_f = \frac{Total\ number\ of\ load\ shedding\ outages\ experienced\ on\ all\ feeders\ serving\ a\ neighbourhood}{Total\ number\ of\ electricity\ feeders\ serving\ the\ neighbourhood}$$

$$LS_d = \frac{Sum\ of\ the\ duration\ of\ all\ load\ shedding\ outages\ experienced\ in\ a\ given\ neighbourhood}{Total\ number\ of\ load\ shedding\ outages\ experienced\ in\ the\ neighbourhood}$$

Dealing with missing data:

- Geostatistical Analyst Tool and Areal Interpolation Layer to Polygons in ArcGIS

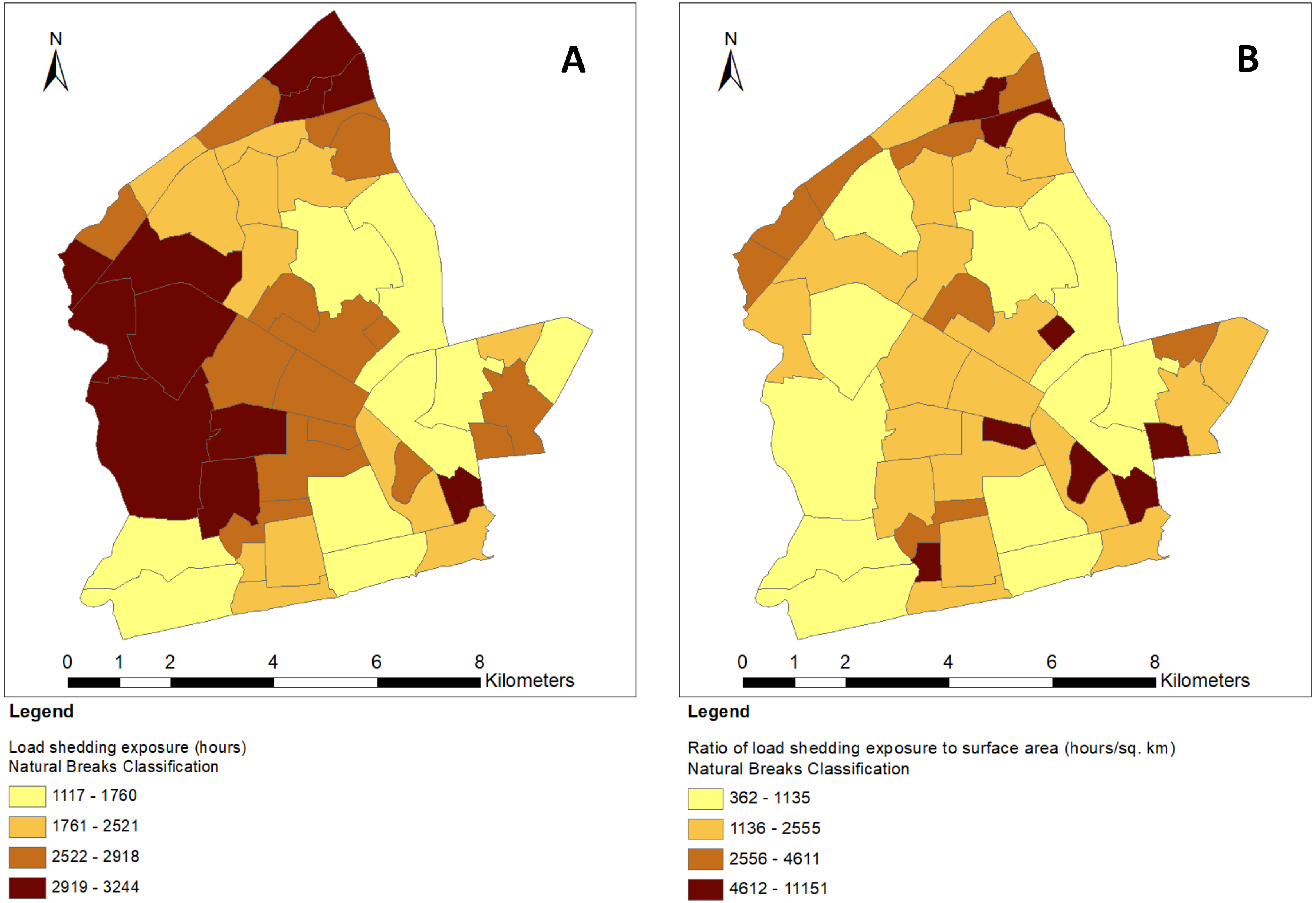
Normalization:

- Neighbourhood surface area, population and population density values were used to normalize of load shedding exposure values

Results – Visualized load shedding exposure and its normalizations

High exposure areas
- Awoshie
- Ordokor
- Dansoman
- Achimota

Low exposure areas
- Industrial Areas
- Korle Bu
- Adabraka
- Mamponse



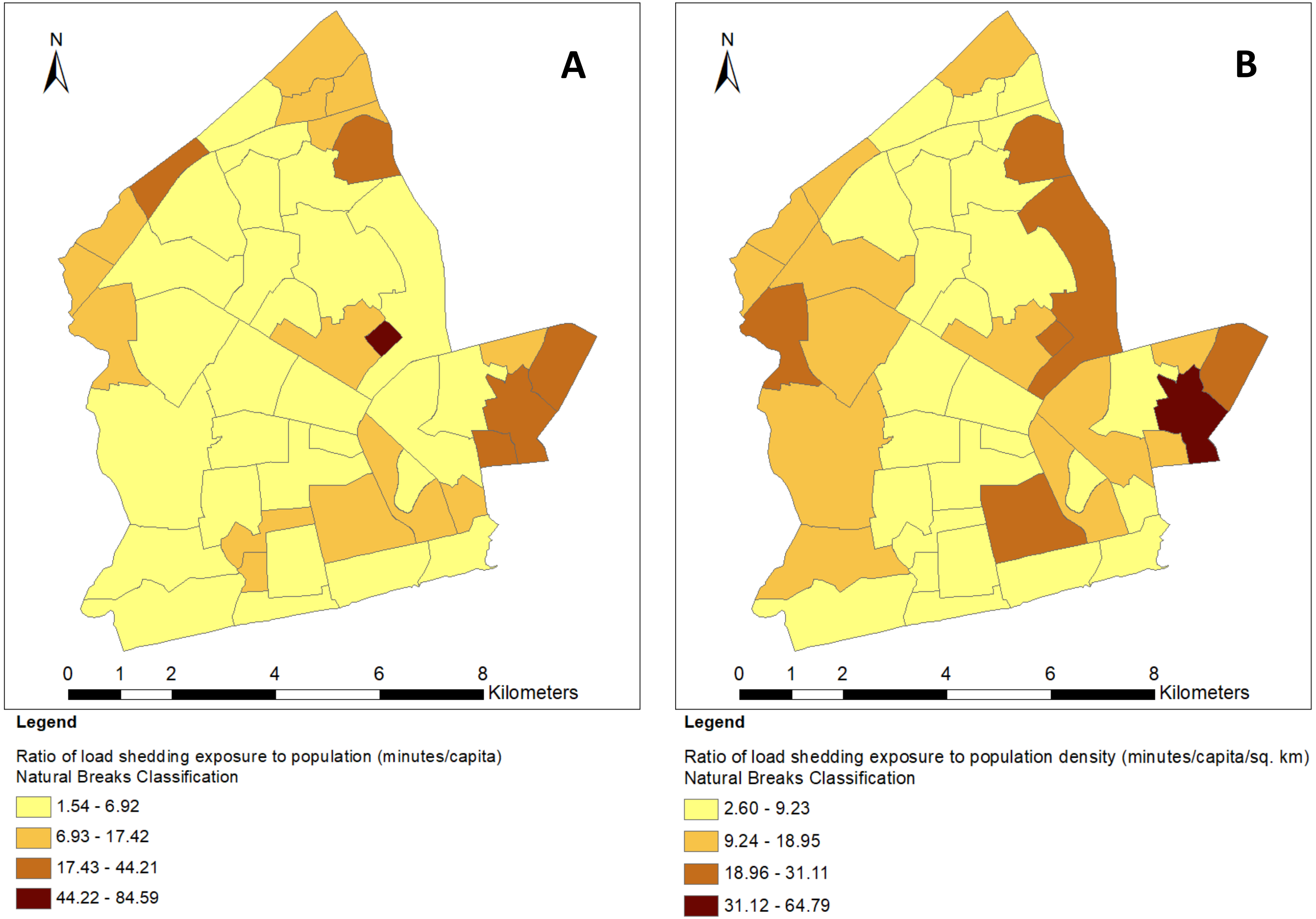
High exposure areas
- Sabon Zongo
- Tudu
- Old Dansoman
- Korle Dudor

Map 8: Neighbourhood load shedding exposure (A) and load shedding exposure per unit area (B)

Results – Visualized load shedding exposure and its normalizations (cont'd)

High exposure areas

- Awudome Estate
- Santa Maria
- Tesano
- North Ridge



High exposure areas

- Victoriaborg
- Tesano
- Tsaaba
- Korle Bu
- North Ridge

Map 9: Neighbourhood ratios of load shedding exposure to population (A) and load shedding exposure to population density (B)

Results – Spatial characteristics of load shedding exposure variables

Global spatial autocorrelation (GSA) analysis: Used global Moran's I statistic in ArcGIS to assess the level of similarity of one value relative to other values surrounding it. This tells us the overall spatial pattern of our values.

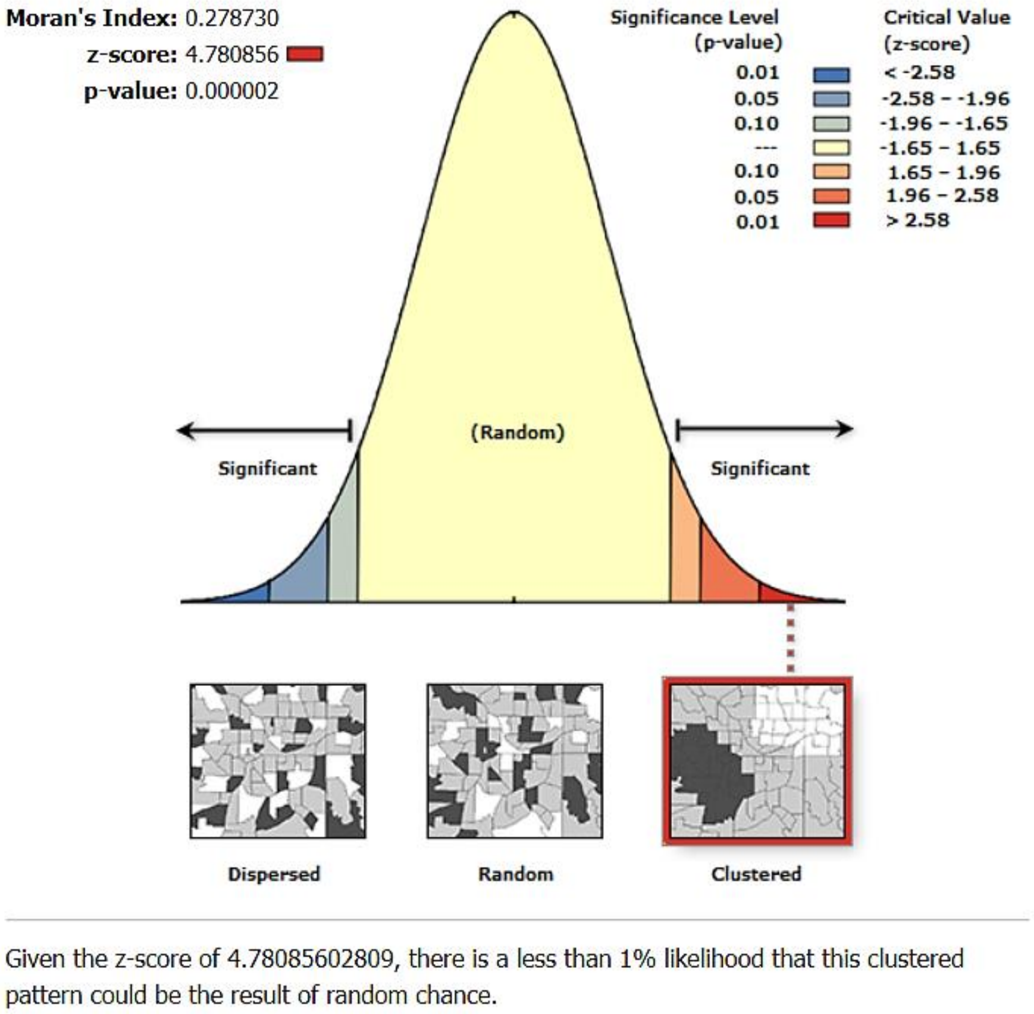
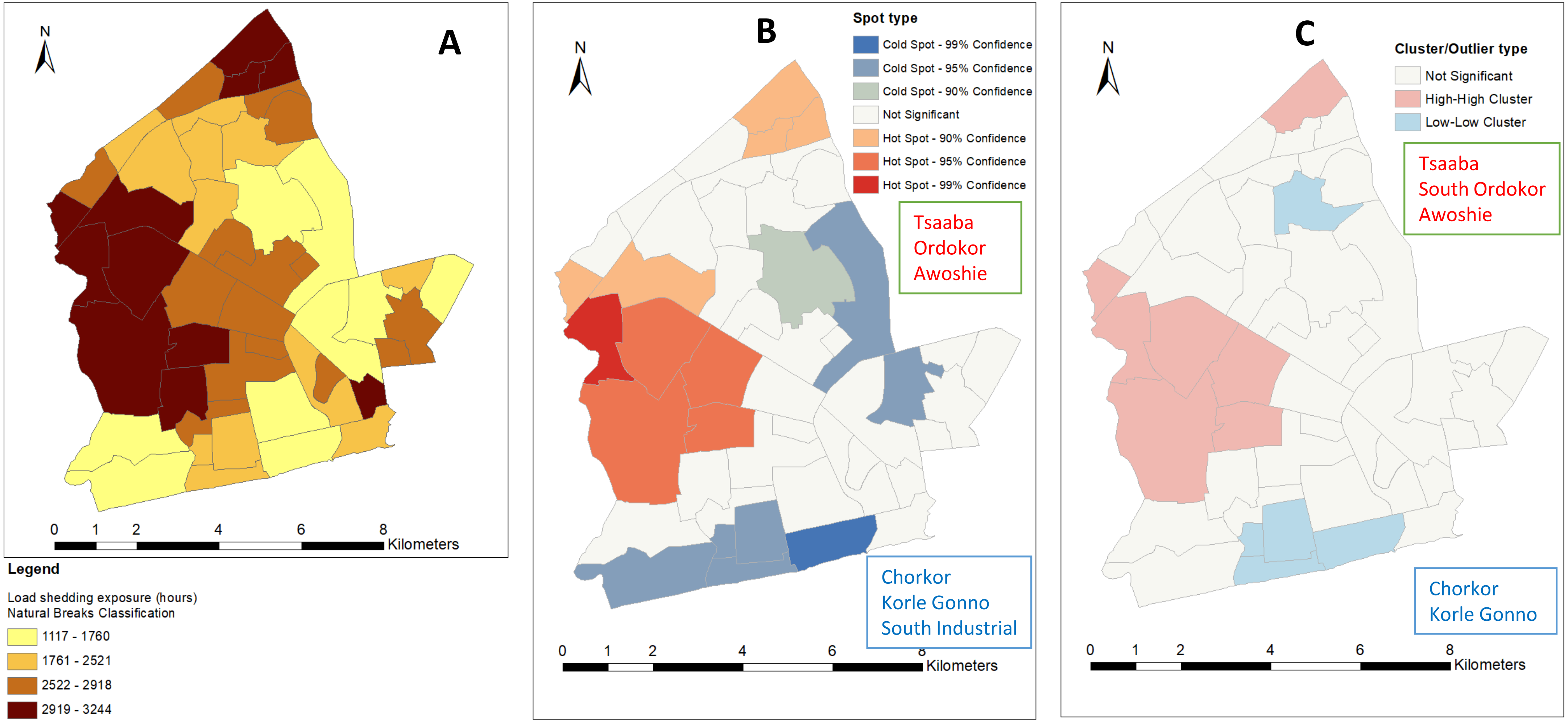


Fig: Spatial autocorrelation report for load shedding exposure

Variable	*Moran's Index*	*z-score*	*p-value*
Load shedding exposure	0.278730	4.780856	0.000002
Load shedding exposure per unit area	-0.076011	-0.616699	0.537433
Load shedding exposure to population ratio	0.089964	1.476733	0.139747
Ratio of load shedding exposure to population density	0.170645	2.363366	0.018110

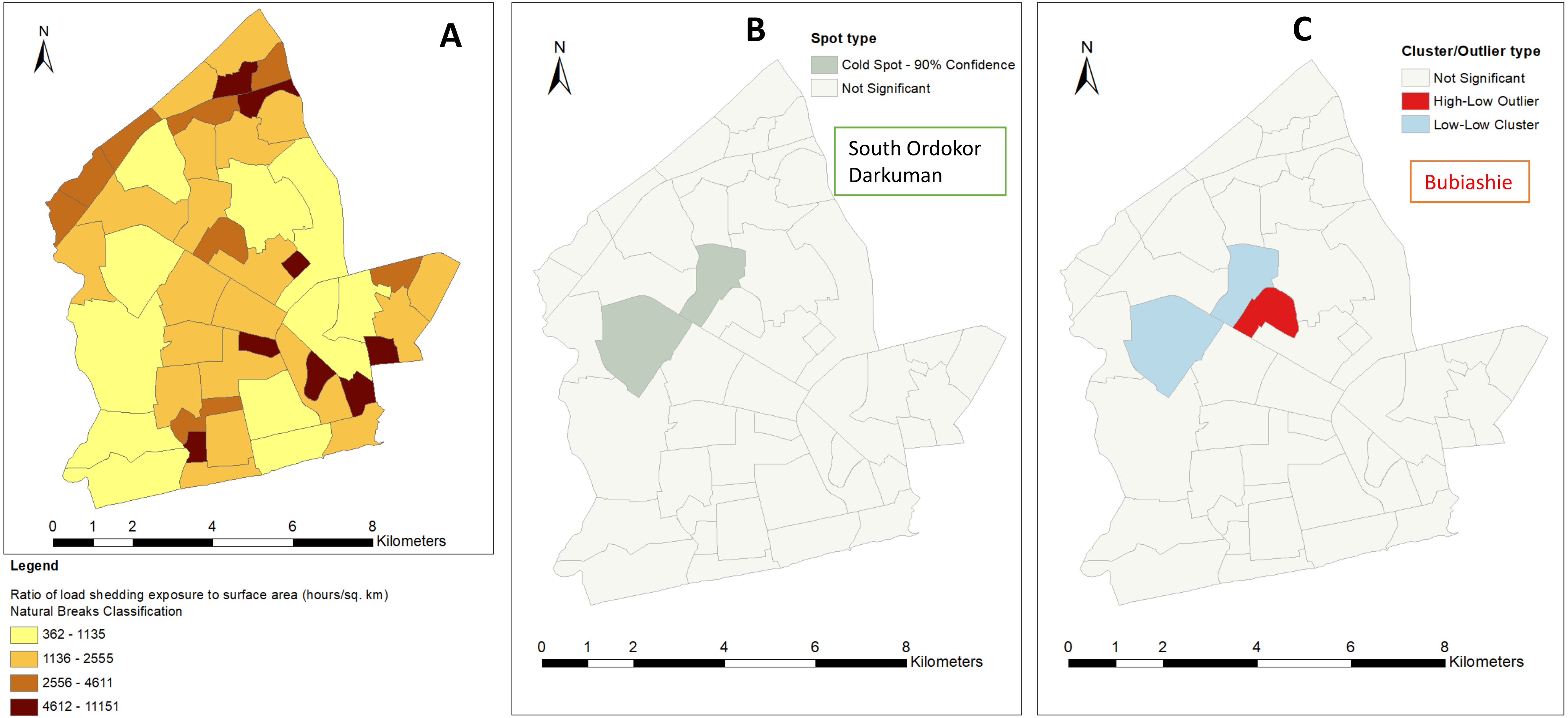
Results – Spatial characteristics of load shedding exposure variables

Local indicators of spatial autocorrelation (LISA) – Used the *Getis-Ord Gi* statistic* and *Anselin Local Moran's I statistic* also available in ArcGIS. These help to locate hot/cold spots and clusters or outliers respectively.



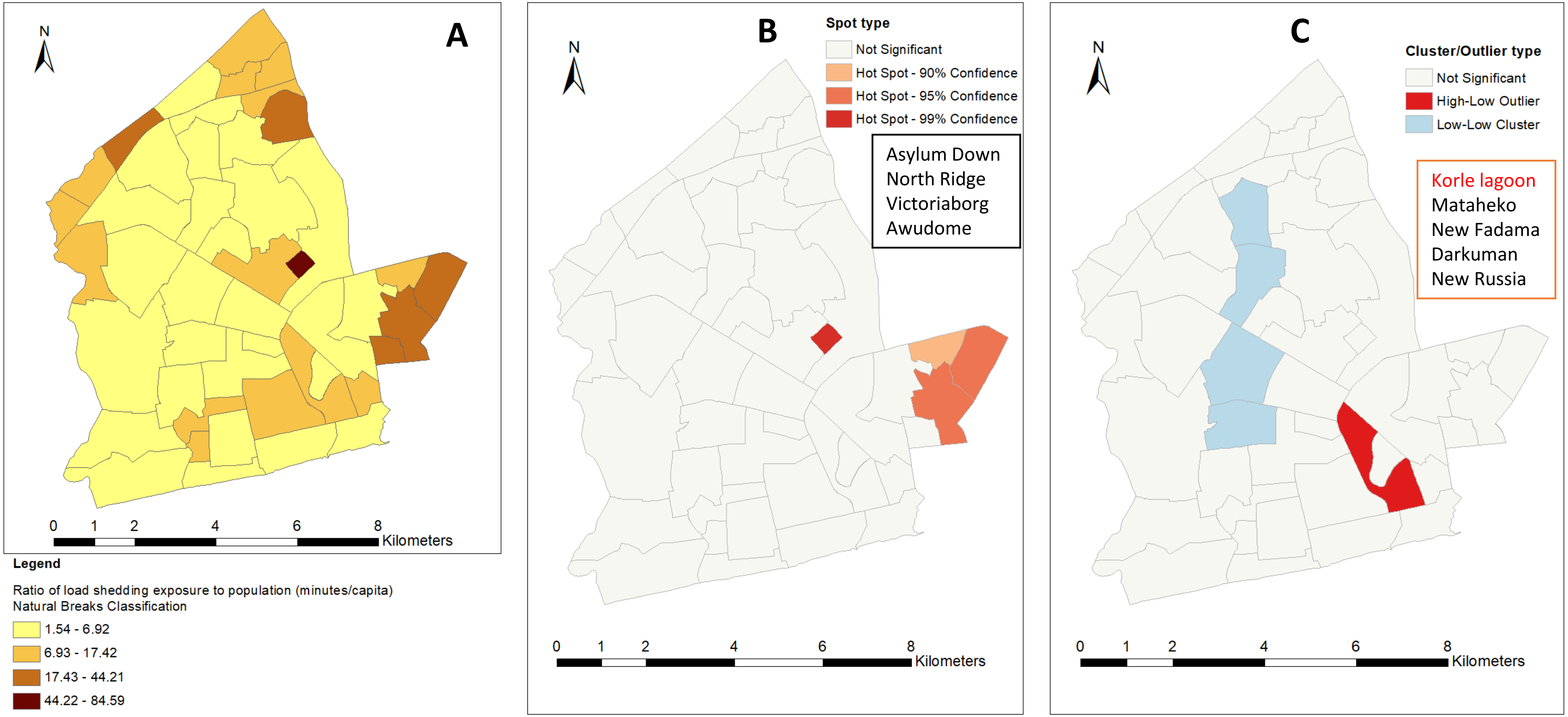
Map 10: Neighbourhood load shedding exposure (A) and corresponding Hot Spot analysis (B) and Cluster and Outlier analysis (C)

Results – Spatial characteristics of load shedding exposure per unit area



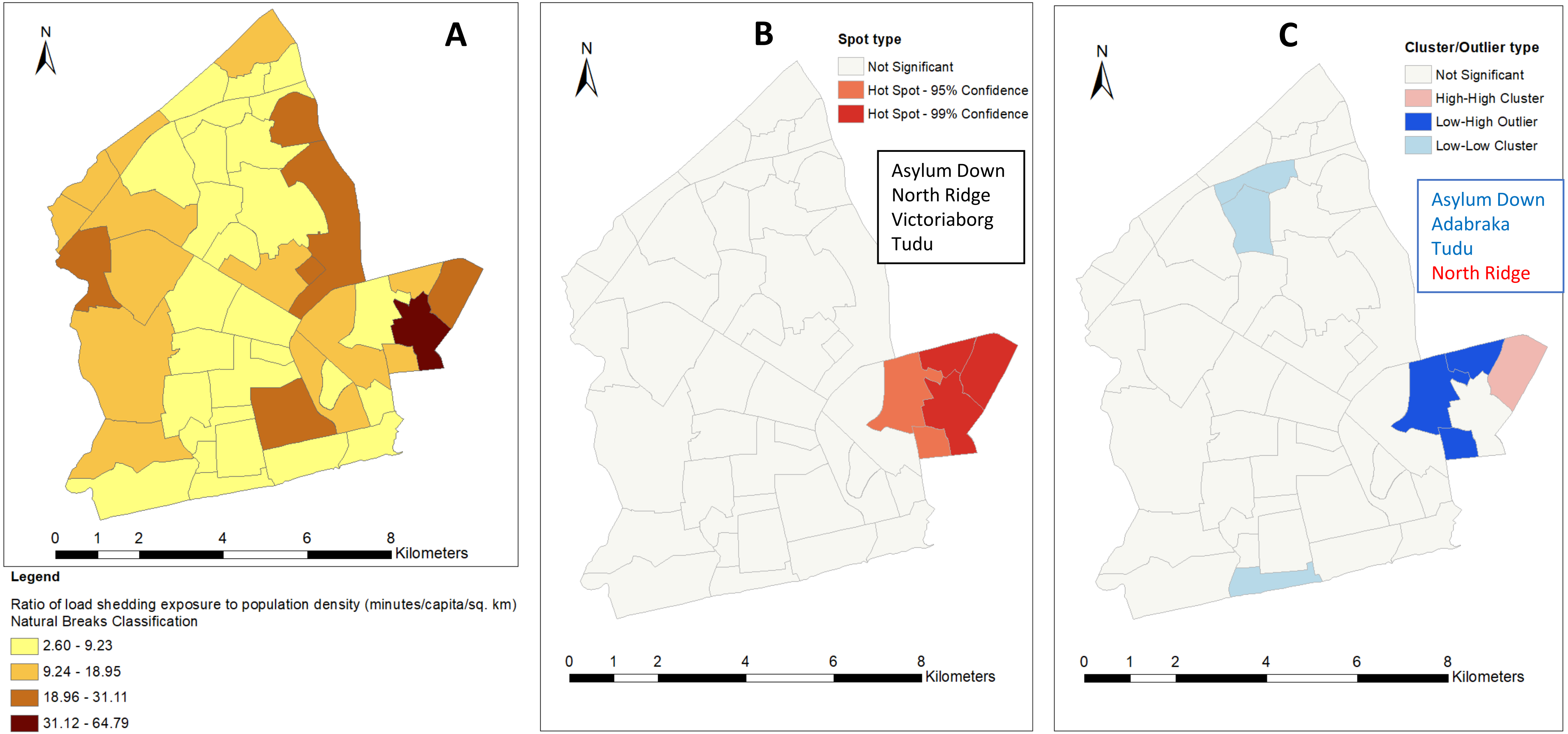
Map 11: Neighbourhood load shedding exposure per unit area (A) and corresponding Hot Spot analysis (B) and Cluster and Outlier analysis (C)

Results – Spatial characteristics of ratio of load shedding exposure to population



Map 12: Neighbourhood ratio of load shedding exposure to population (A) and corresponding Hot Spot analysis (B) and Cluster and Outlier analysis (C)

Results – Spatial characteristics of ratio of load shedding exposure to population density



Map 13: Neighbourhood ratio of load shedding exposure to population density (A) and corresponding Hot Spot analysis (B) and Cluster and Outlier analysis (C)

Results - Load shedding and socioeconomic factors

How load shedding exposure relates to select neighbourhood-level socioeconomic factors

		Area	Population	Population density	Housing Quality Indicator	Level of charcoal use	Use of modern sewerage services
Load shedding exposure, LS_e	Correlation	-.245	.056	.250	-.002	.046	-.064
	Significance	.097	.707	.090	.987	.757	.667
$LS_e/area$	Correlation	-.707**	-.423**	.356*	-.039	.041	-.022
	Significance	.000	.003	.014	.794	.784	.884
$LS_e/population$	Correlation	-.349*	-.616**	-.361*	.540**	-.482**	.476**
	Significance	.016	.000	.013	.000	.001	.001
$LS_e/population\ density$	Correlation	.169	-.508**	-.645**	.579**	-.567**	.575**
	Significance	.257	.000	.000	.000	.000	.000

*. Correlation is significant at 0.05 level (2-tailed); **. Correlation is significant at 0.01 level (2-tailed). Correlation based on Pearson correlation coefficient.

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