GIS analysis and optimization of faecal sludge logistics at city-wide scale in Kampala, Uganda

Supplementary information

Schoebitz, L., Bischoff, F., Lohri, C.R., Niwagaba, C.B., Siber, R., Strande, L.

Sandec
Sanitation, Water and
Solild Waste for Development

eawag...
aquatic research

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1. Introduction

The maps presented in this report were compiled as part of a collaborative project between Eawag/ Sandec and Makerere University. During this project a total of 34 faecal sludge collection and transport trucks were equipped with GPS trackers out of the 67 total operating in the city. The trackers were used to record all emptying events, and to analyze service delivery for Kampala. Municipal Kampala Capital City Authority (KCCA) trucks were equipped with trackers for a five week period, while all the other privately owned and operated trucks were equipped for twelve weeks. A total of 5,653 emptying events were recorded during the research period. This information in [Schoebitz et al., submitted] is based on this information, and the methods are fully reported there. This report is intended as supplementary information to the paper, and not as a standalone document. This paper and other information relevant to the research can be found on the Sandec website www.sandec. ch/fsm_tools.

The additional maps in this report were not included in the journal paper due to limited space. They are presented here for their usefulness in further identifying trends of collection and transport for stakeholders in Kampala, and practitioners working on faecal sludge management in other cities.

2. Maps

2.1 Kampala
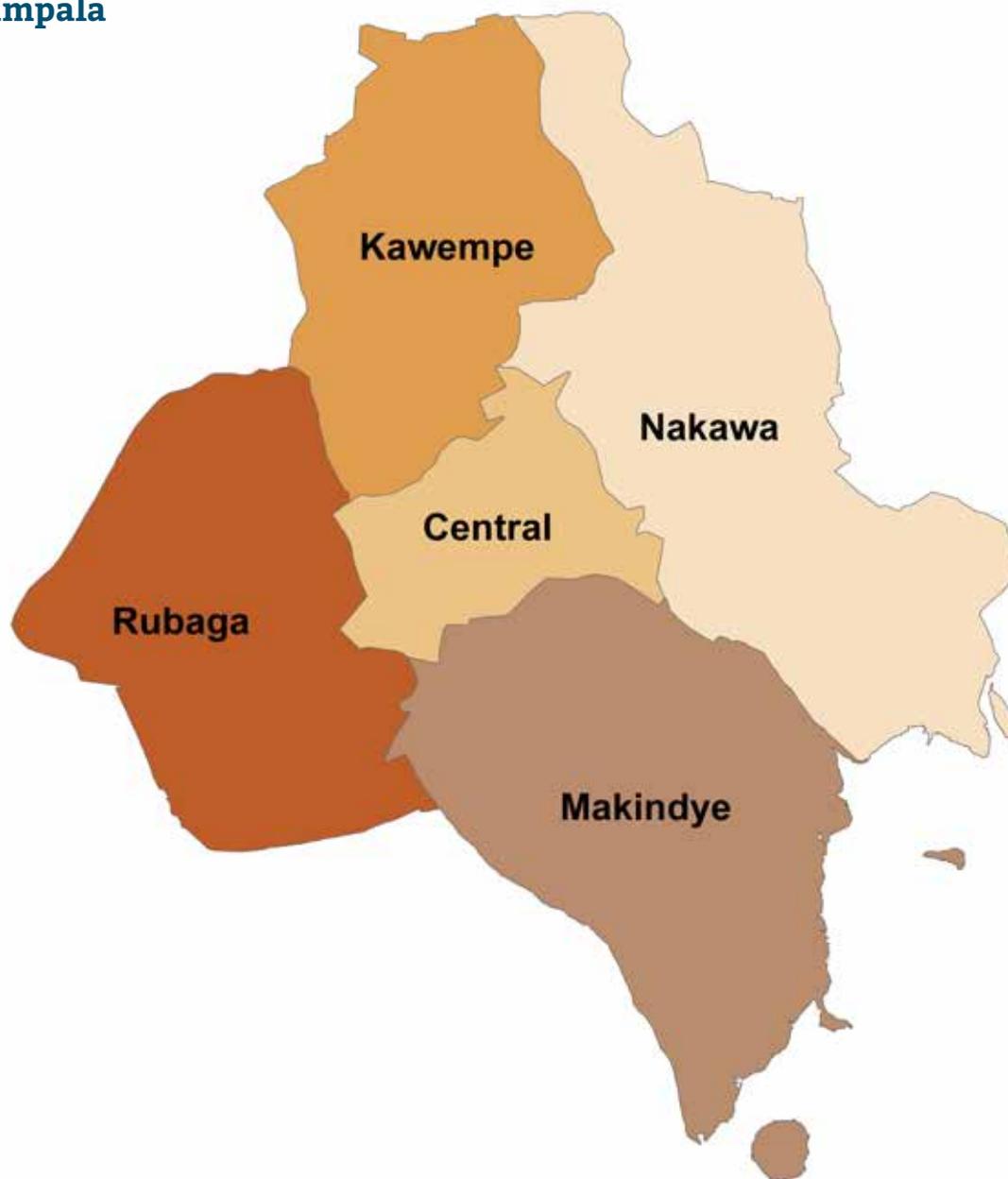
Kawempe, Nakawa, Central, Makindye and Rubaga are the
five municipal divisions within the Kampala boundaries.
Makindye is the largest division by area and population, with
395,276 residents, out of the total 1.5 million residents of
Kampala [*UBOS*, 2014].

Figure 2: Kampala parishes

The five divisions in Kampala are further divided into 99 parishes. Nabisunsa is the smallest by size with 0.01 km^2 and Kyanja the biggest with 7 km^2. The parishes are further divided into a total of 2,959 smaller "zones" (not shown here).
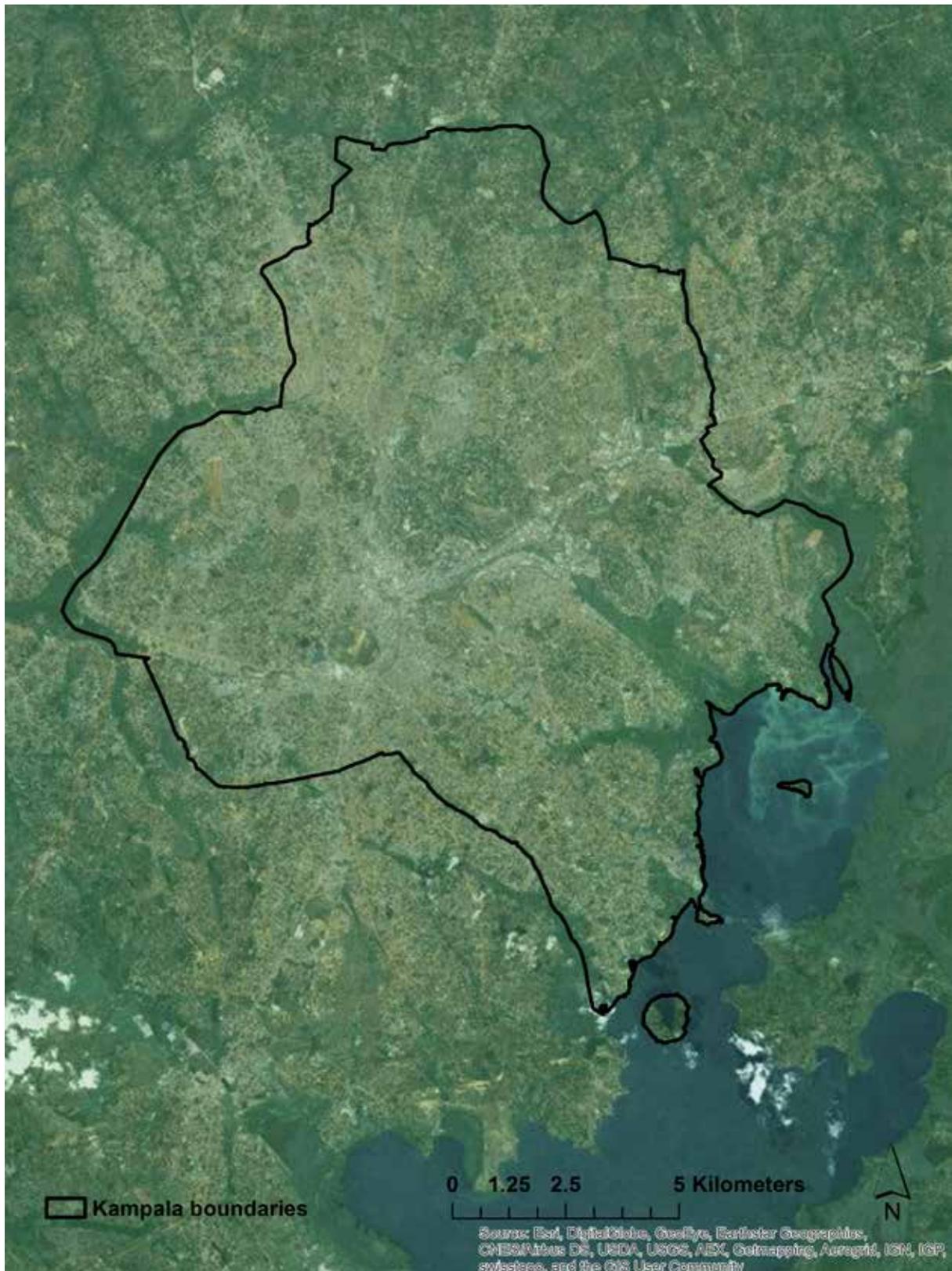
Figure 3: Kampala boundary

Boundaries of Kampala depicted on an open source satellite
picture, illustrating the level of development and population
outside the municipal boundaries of Kampala [ESRI].
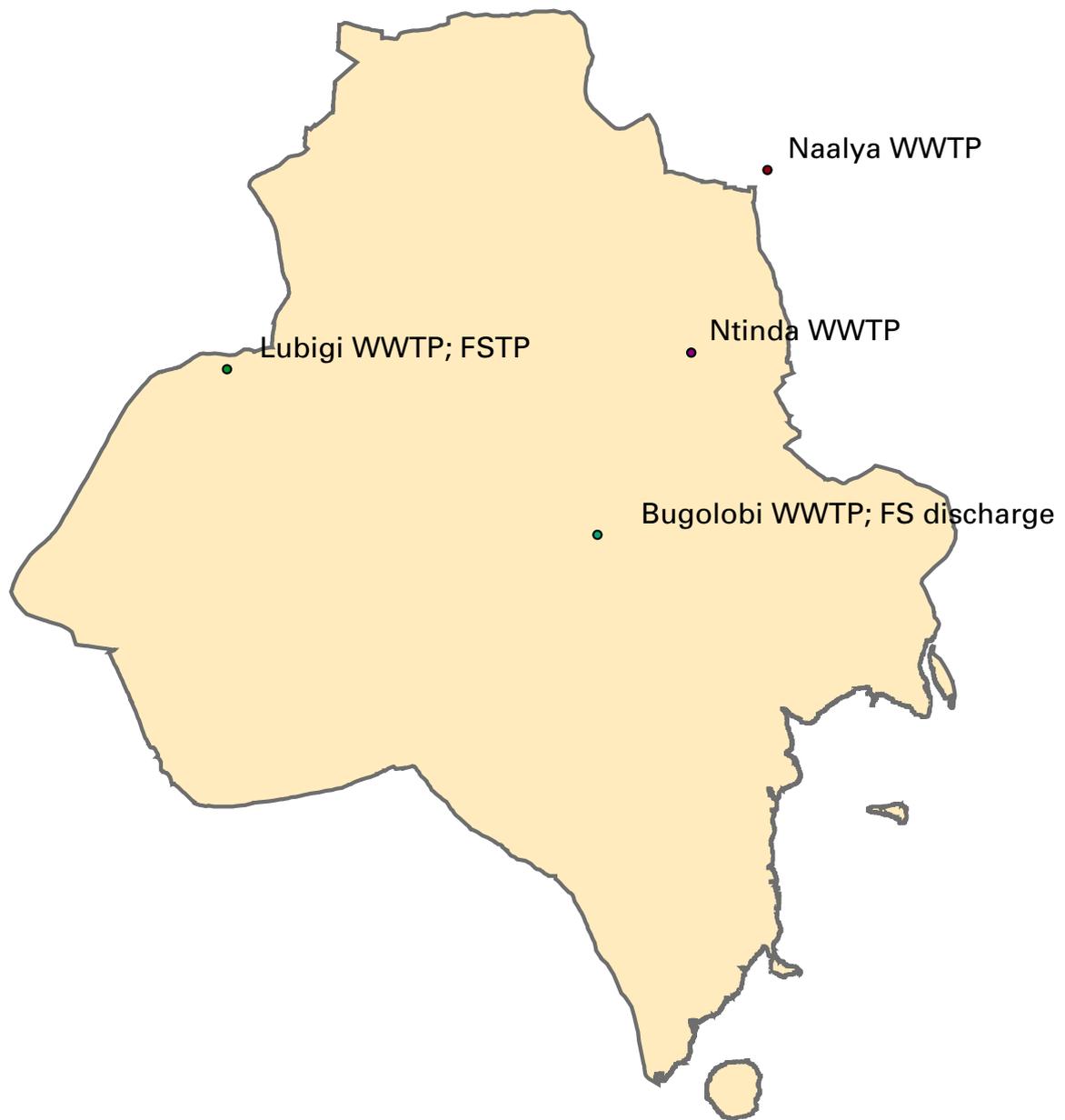
Figure 4: Treatment plant locations

Displayed are locations of current treatment plants in Kampala. The plants in Naalya and Ntinda are waste stabilization ponds designed to treat 1,000 m³ of wastewater per day. The Bugolobi wastewater treatment plant has a treatment capacity of up to 33,000 m³ wastewater per day. It is currently also used as faecal sludge discharge location but was not initially designed for the treatment of faecal sludge. Lubigi is a wastewater treatment plant and a faecal sludge treatment plant (FSTP) designed to treat 5,000 m³ wastewater and 400 m³ faecal sludge per day [*Schoebitz et al.*, 2014].

2.2   Methodology for data collection
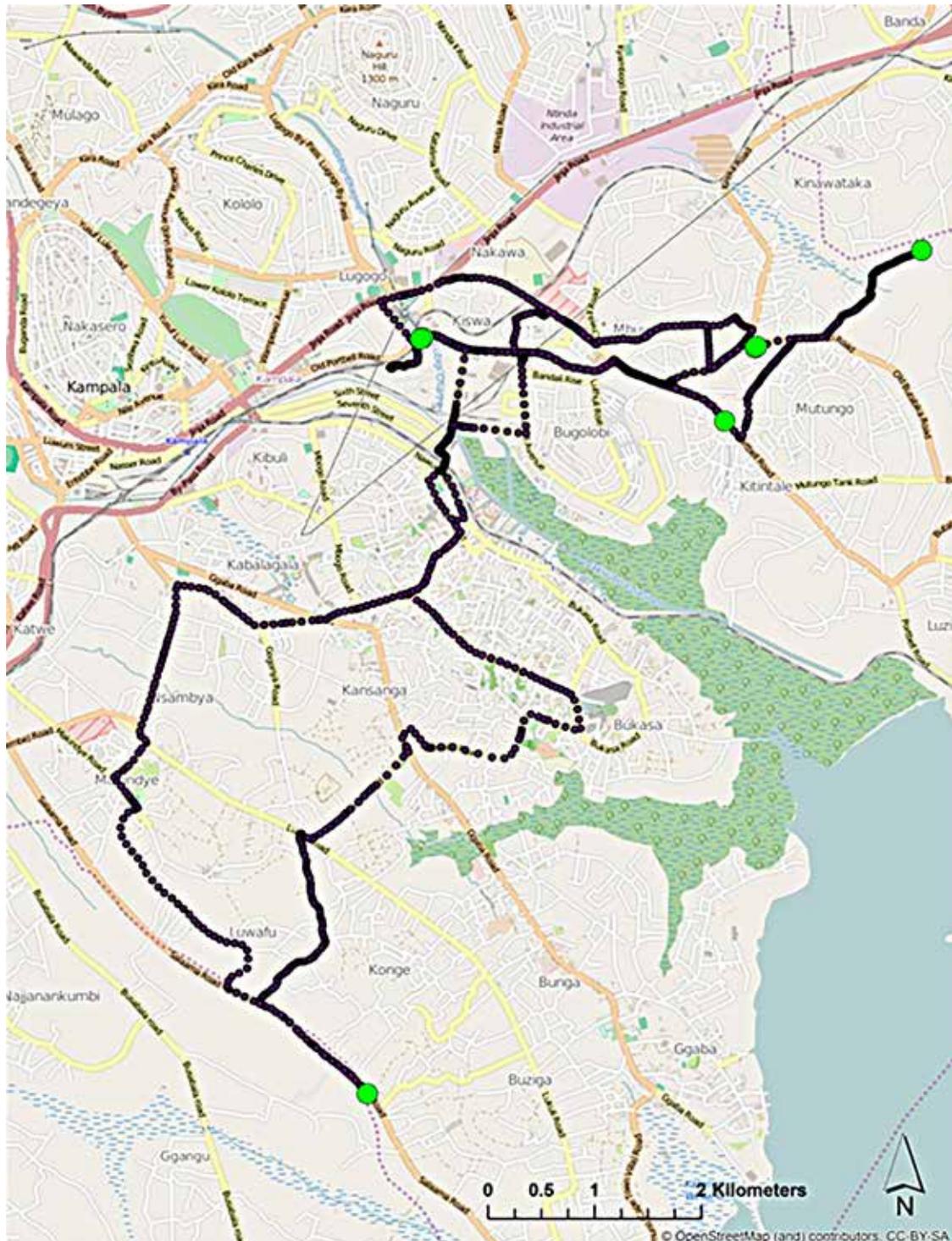
Figure 5: GPS methodology

Example of GPS track with identified emptying events for one privately operated truck that operates from the Bugolobi treatment plant over a period of 24 hours [Open Street Map]. The route driven by the truck is indicated by black circles (GPS coordinates recorded every 10 seconds). The green circles indicate identified emptying events. The events were identified using a python script. Emptying events were defined by a stop of the truck for up to three hours with a minimum of 20 minutes for private trucks and 15 minutes for KCCA owned trucks. For method description, see [*Schoebitz et a*l., submitted].

Legend:
— KCCA
— Private sector

0   1.25   2.5   5 Kilometers

N
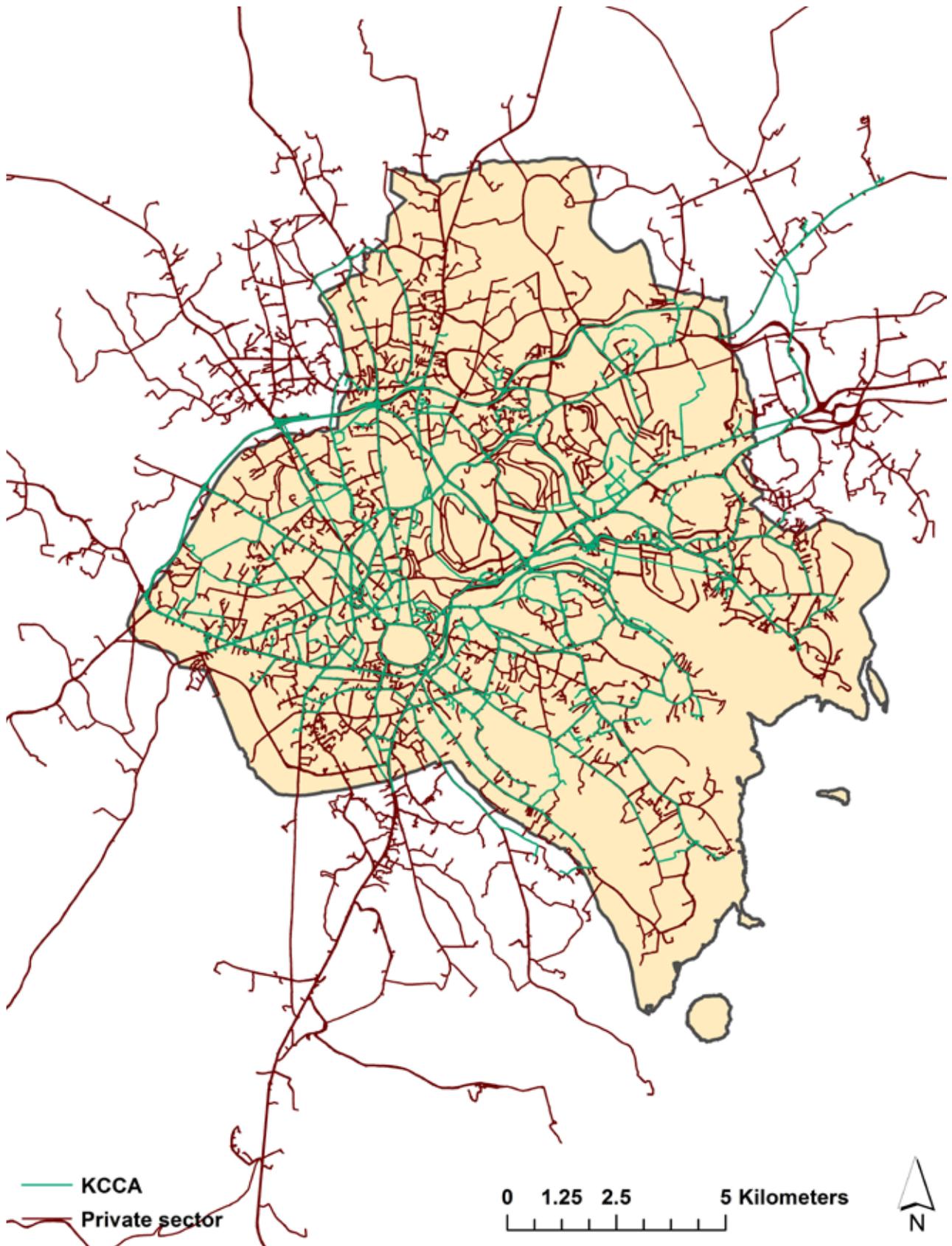
Figure 6: Recorded routes

Summary of all recorded routes over the research period.
Routes driven by the Kampala Capital City Authority (KCCA)
trucks are shown in green, and routes driven by privately
operated trucks are shown in brown.

2.3   Results and analyses
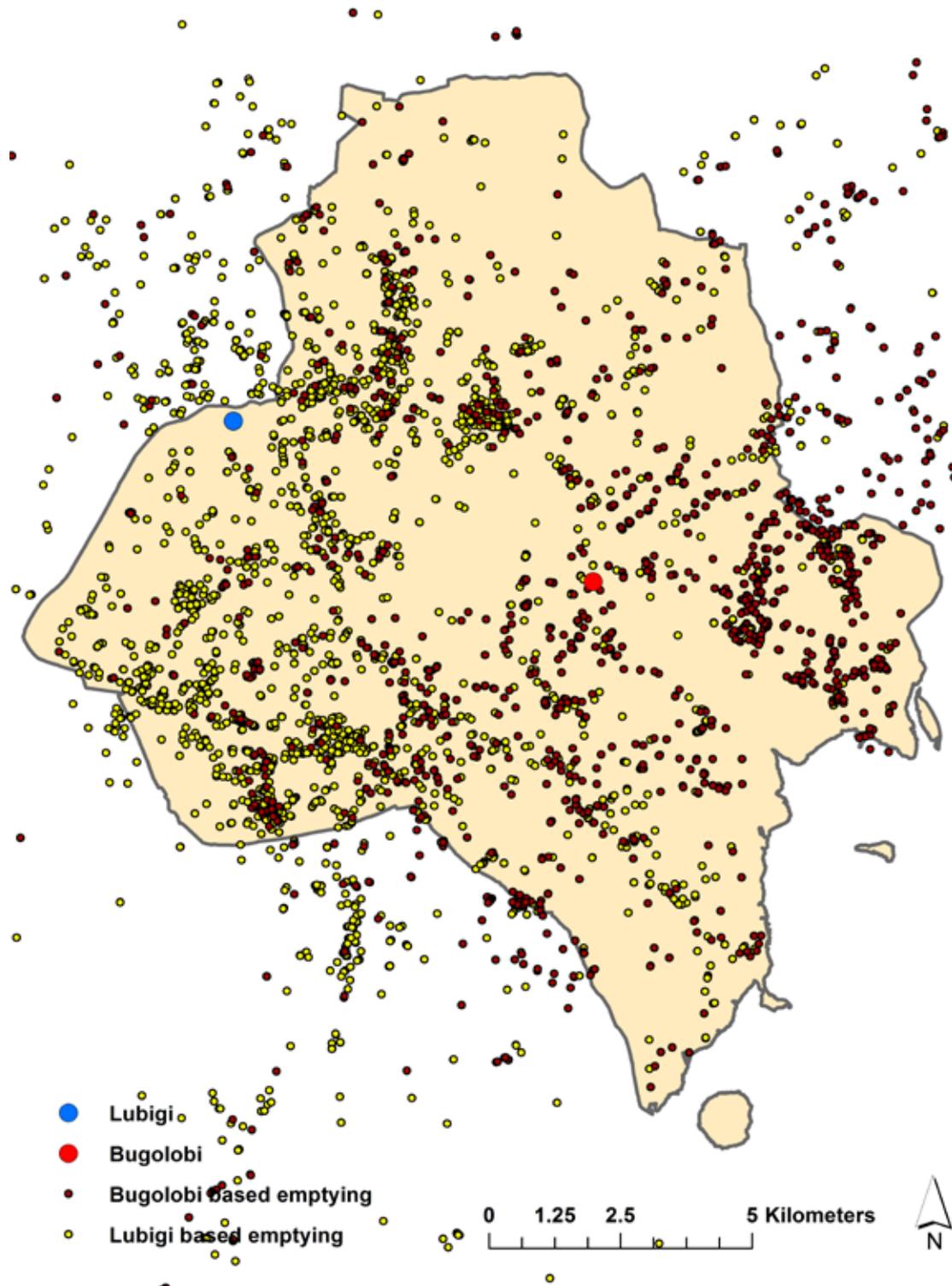
Figure 7: Emptying events from treatment plants

Distribution of emptying events over the research period of three months in the Kampala region. In this illustration it is distinguished between emptying conducted by trucks that that are based at either the Bugolobi (brown) or Lubigi (yellow) treatment plants in between emptying events. In general, trucks discharged at the treatment plant closest to the emptying event, then moved to the plant where they were based while waiting for additional customers.
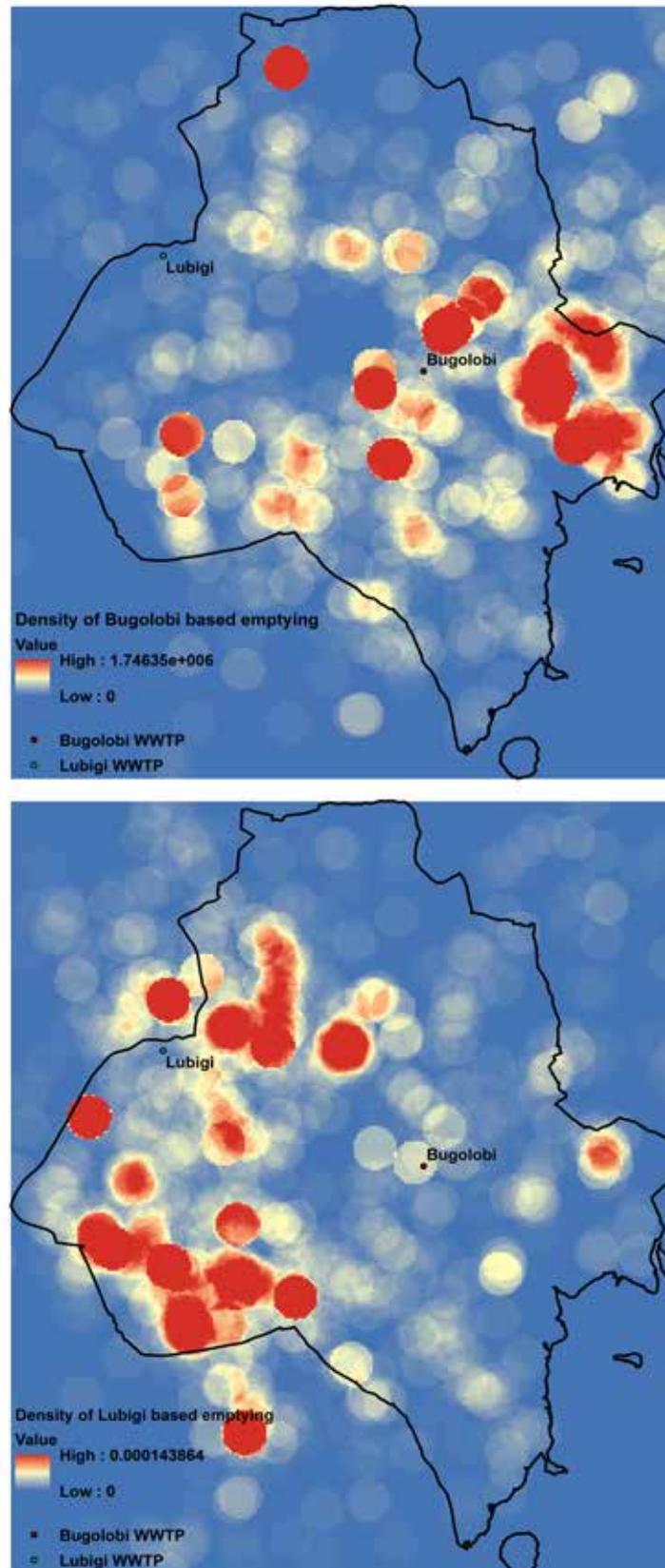
Figure 8: Density of emptying events by treatment plant base

Density analysis of emptying events of trucks that are based at Bugolobi (a) and Lubigi (b) treatment plants. The figure illustrates the same information as Figure 7. Red illustrates areas with a high density of emptying events per km², and blue with no emptying events. In general, trucks served customers located closer to where they are based, but not exclusively.
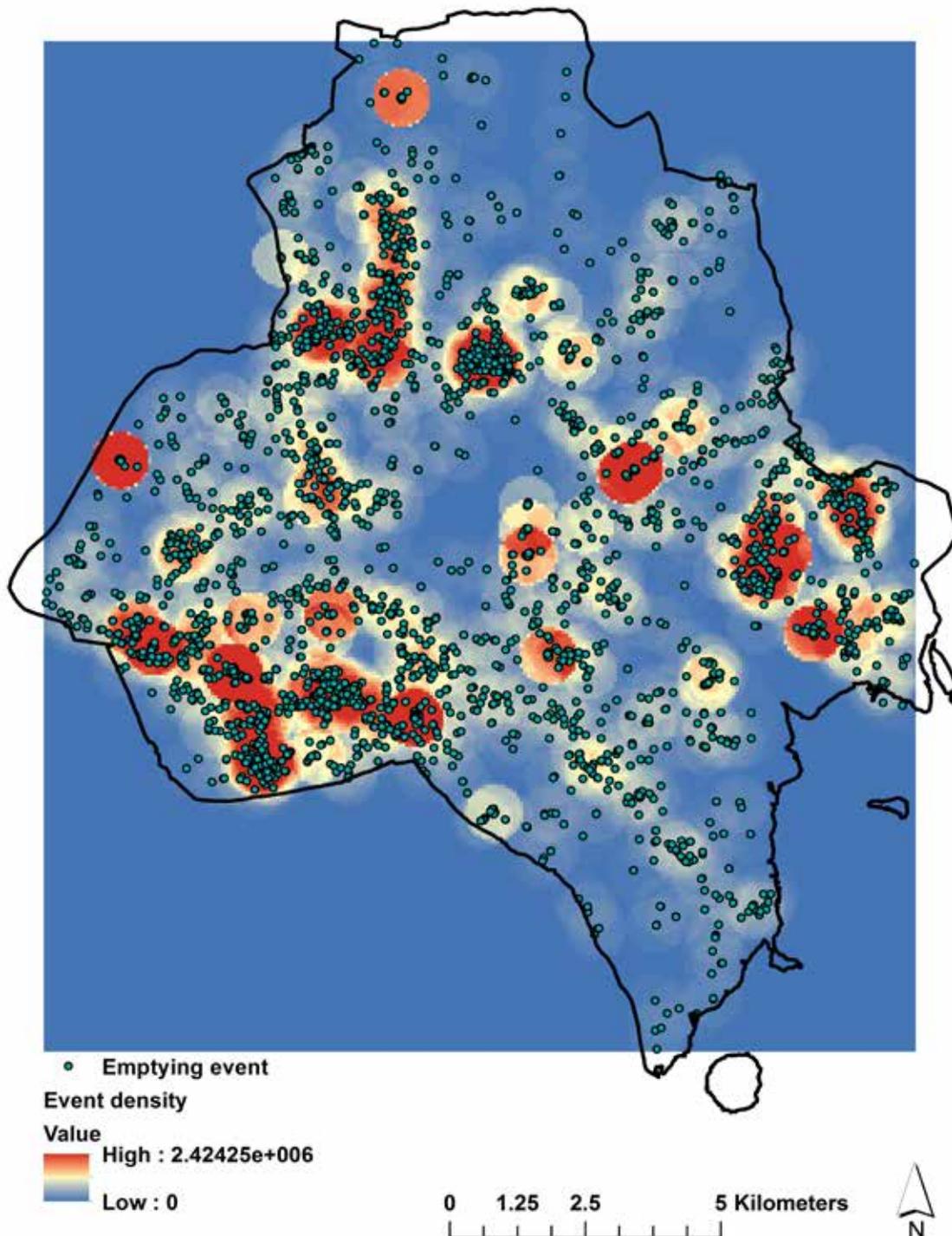
Figure 9: Density of emptying events in Kampala boundaries

Density analysis of emptying events per km² shown together with each individual event. Alternative presentation of the information in Figure 7 and 8, which illustrates that emptying events are not equally distributed throughout Kampala.
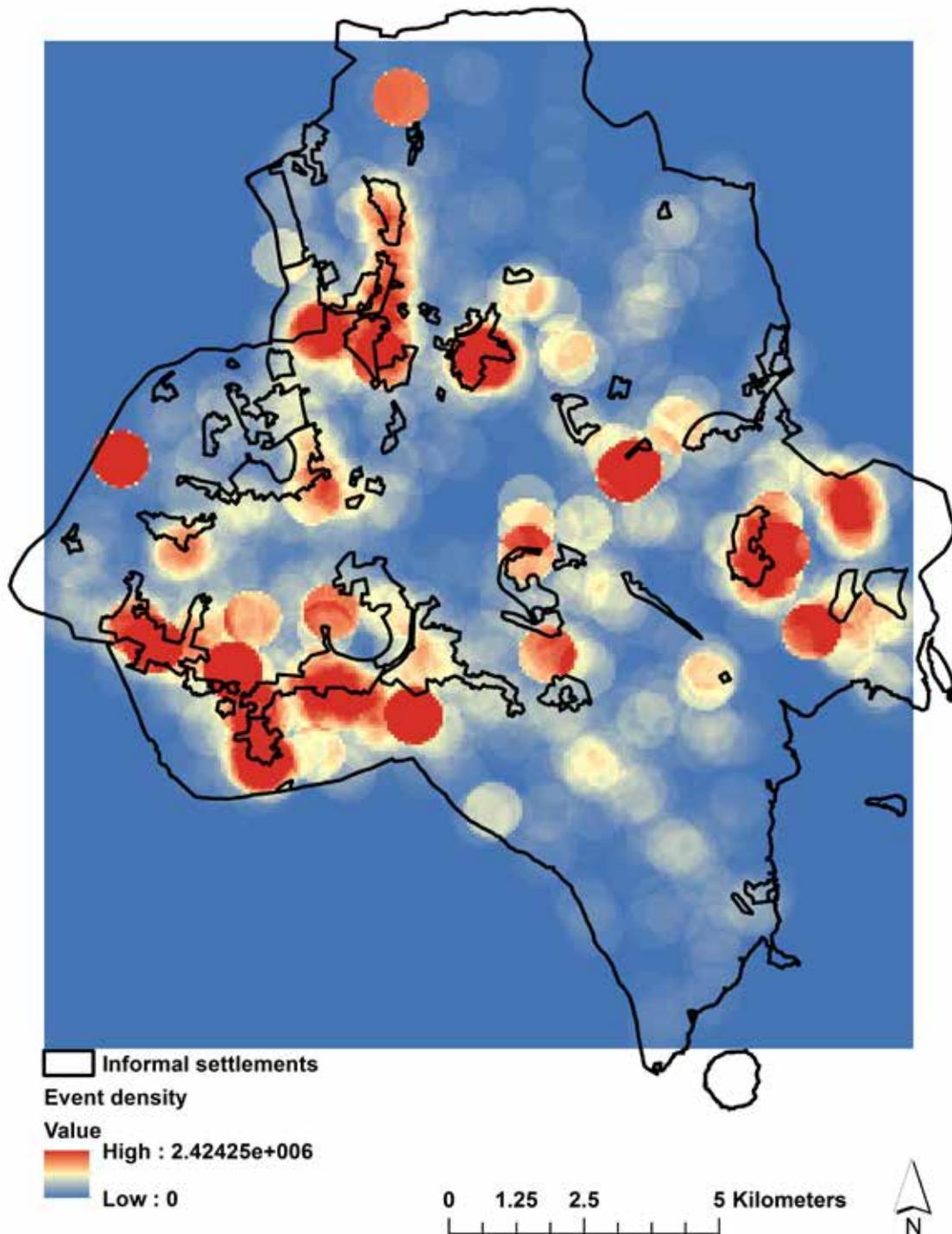
Figure 10: Density of emptying events with informal settlements

Density analysis of emptying events shown together with
locations of low-income informal settlements ("slums").
This figure illustrates similar information in color as Figure
2 in [*Schoebitz et al.*, submitted] with 37 % of emptying
events being located within informal settlements.
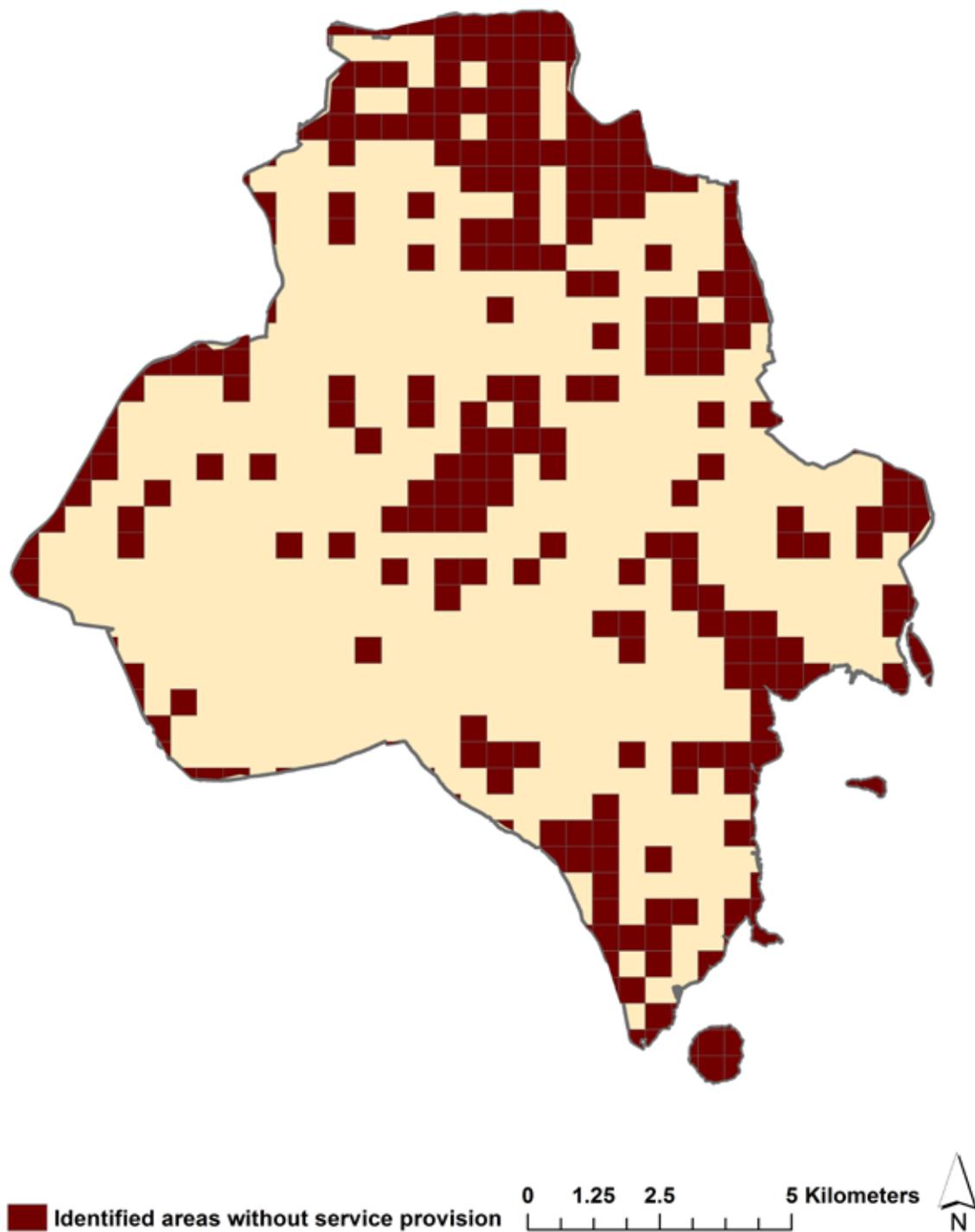
Figure 11: Identified areas without service provision

The displayed areas did not receive emptying services within the research period of three months and were therefore categorized as areas without service provision. For description of methodology see [*Schoebitz et a*l., submitted].

Events/parish

— **Sewer network**

▢ **0**
▢ **1 - 5**
▢ **6 - 10**
▢ **11 - 50**
▢ **51 - 100**
▢ **101 - 304**

0   1.25   2.5   5 Kilometers

N
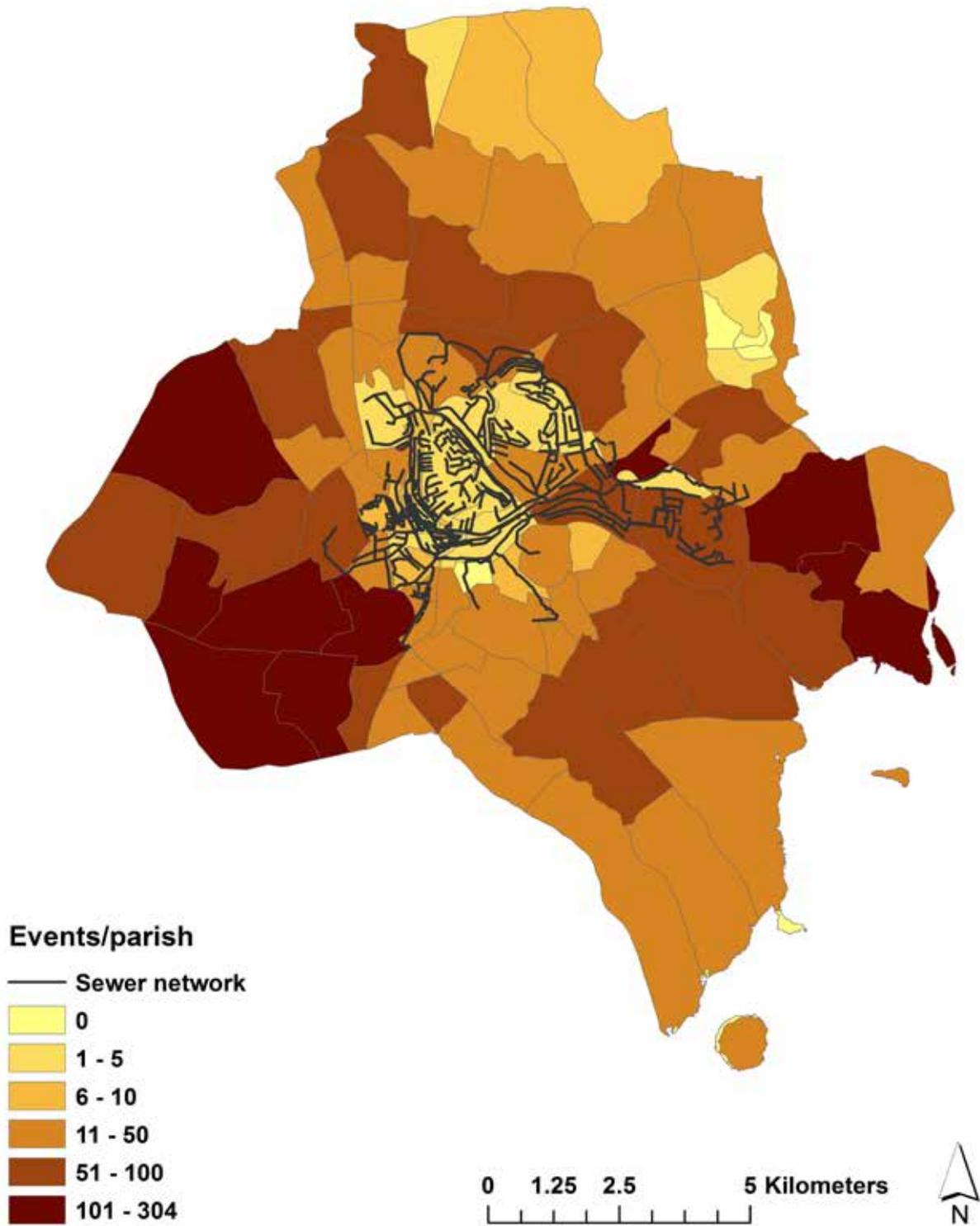
Figure 12: Emptying events per parish

The legend colors depict the number of emptying events
per parish, and the black line location of the existing sewer
network in 2008. These were the most recently available
maps of the sewer network.

Areas without service provision
Non residential
High income
Middle income
Low income
Very low income

0   1.25   2.5   5 Kilometers

N
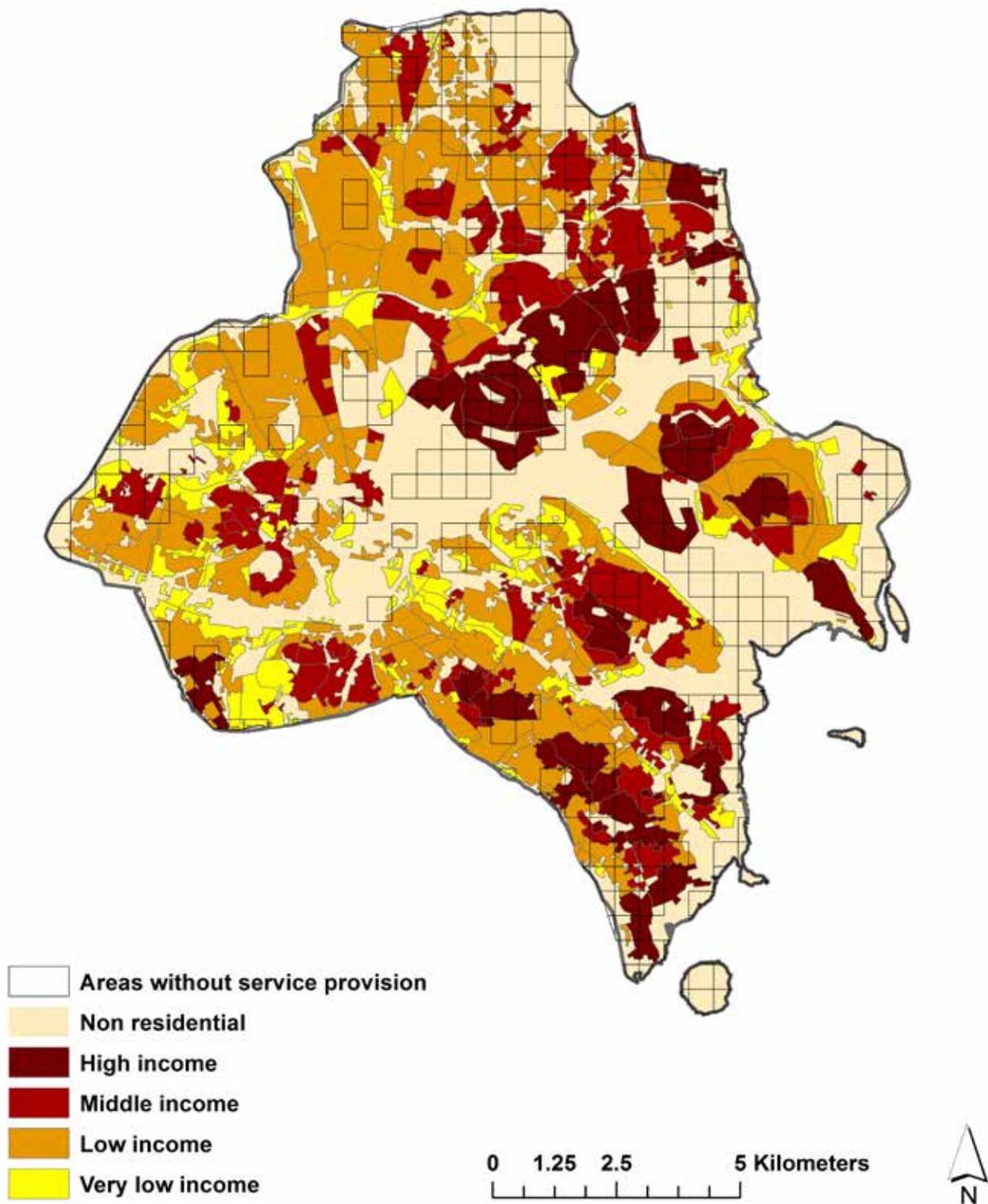
Figure 13: Income categories and areas without service provision

Categories of income as defined by KCCA and identified areas without service provision (squares). Low income areas represent the largest income category by size, additional information is presented in [*Schoebitz et al.*, submitted].

Legend:
- Areas without service provision
- Other
- Industrial
- Formal commercial and offices

0 1.25 2.5 5 Kilometers

N
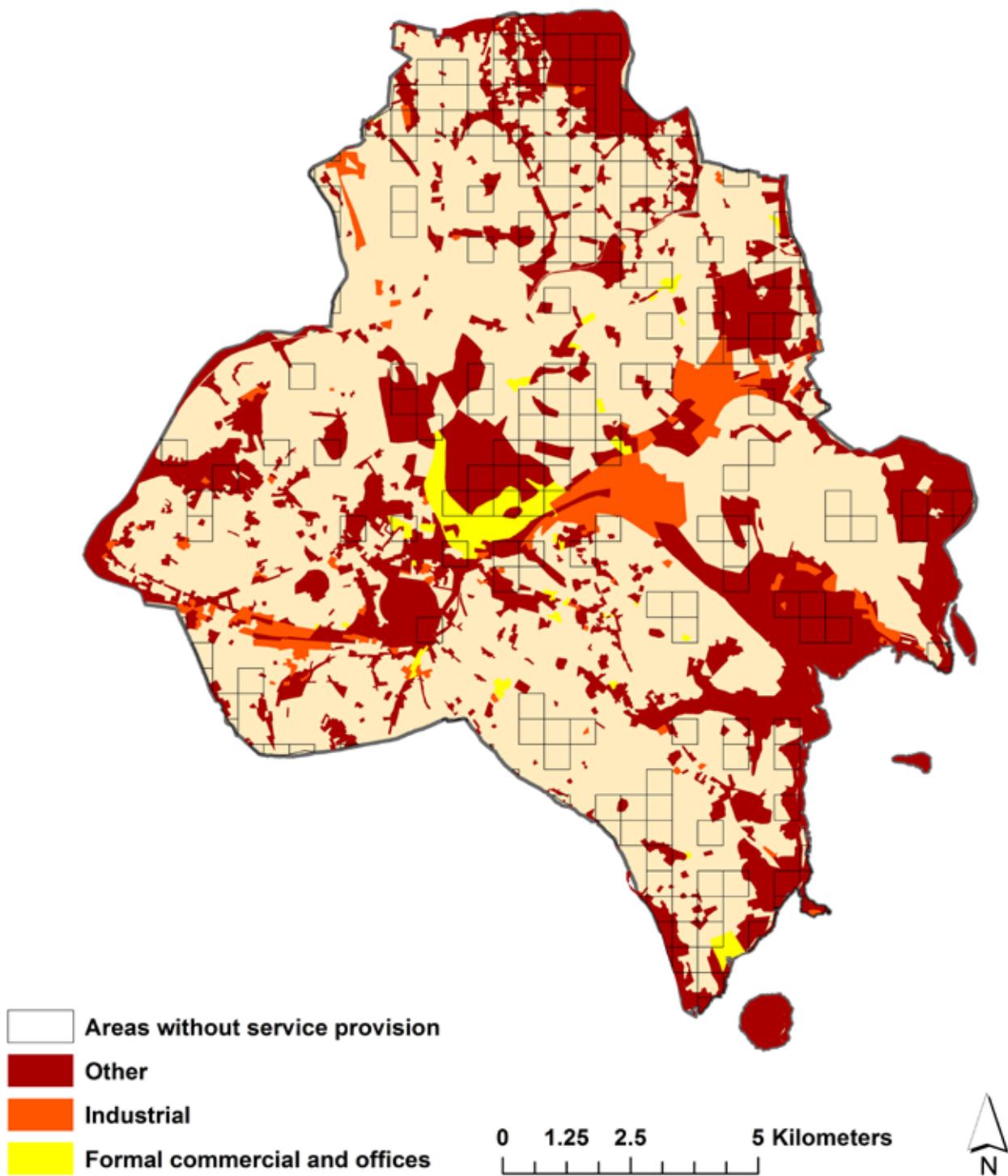
Figure 14: Non-residential and areas without service provision

Non-residential areas within the Kampala boundaries, including the illustration of areas without service provision (squares). "Other" includes vacant land, forests, community facilities or wetlands. This map combined with the sewer network was used to create Figure 22.

Population/km2

|	
☐	Areas without service provision
▨	418 - 5781
▨	5781 - 11669
▨	11669 - 19907
▨	19907 - 30229
▨	30229 - 46736

0   1.25   2.5   5 Kilometers

N
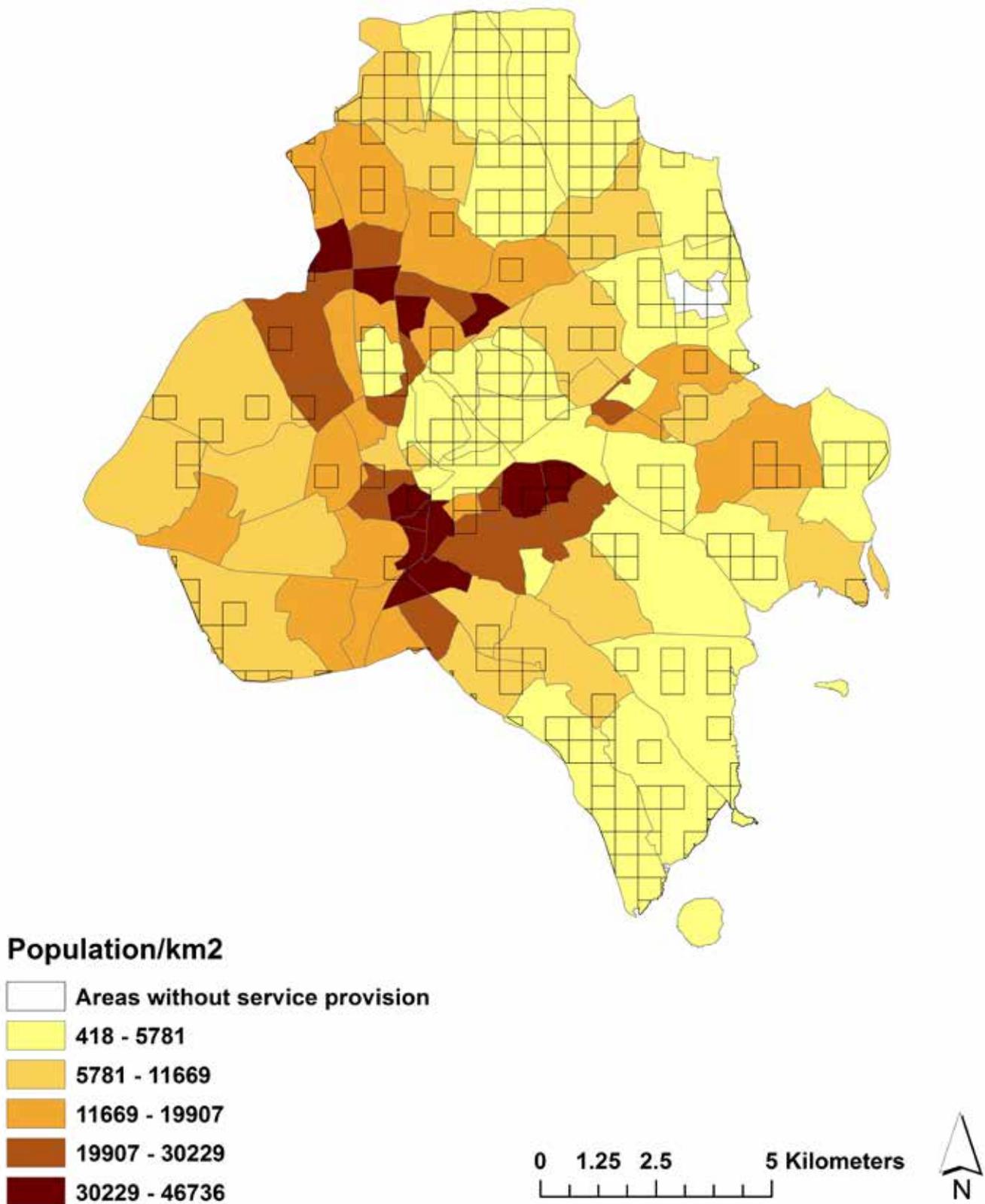
Figure 15: Population density and areas without service provision

2013 population density, including areas without service provision (squares). Areas without service provision typically but not exclusively occur in areas with low population densi-ties like northern or southern parishes, since less emptying services are required in those areas. For the white spaces displayed in the map no data on population was available.

Population using septic tanks

☐	Areas without service provision
☐	0 - 10 %
☐	10 - 25 %
☐	25 - 50 %
☐	> 50 %

0   1.25   2.5   5 Kilometers

N
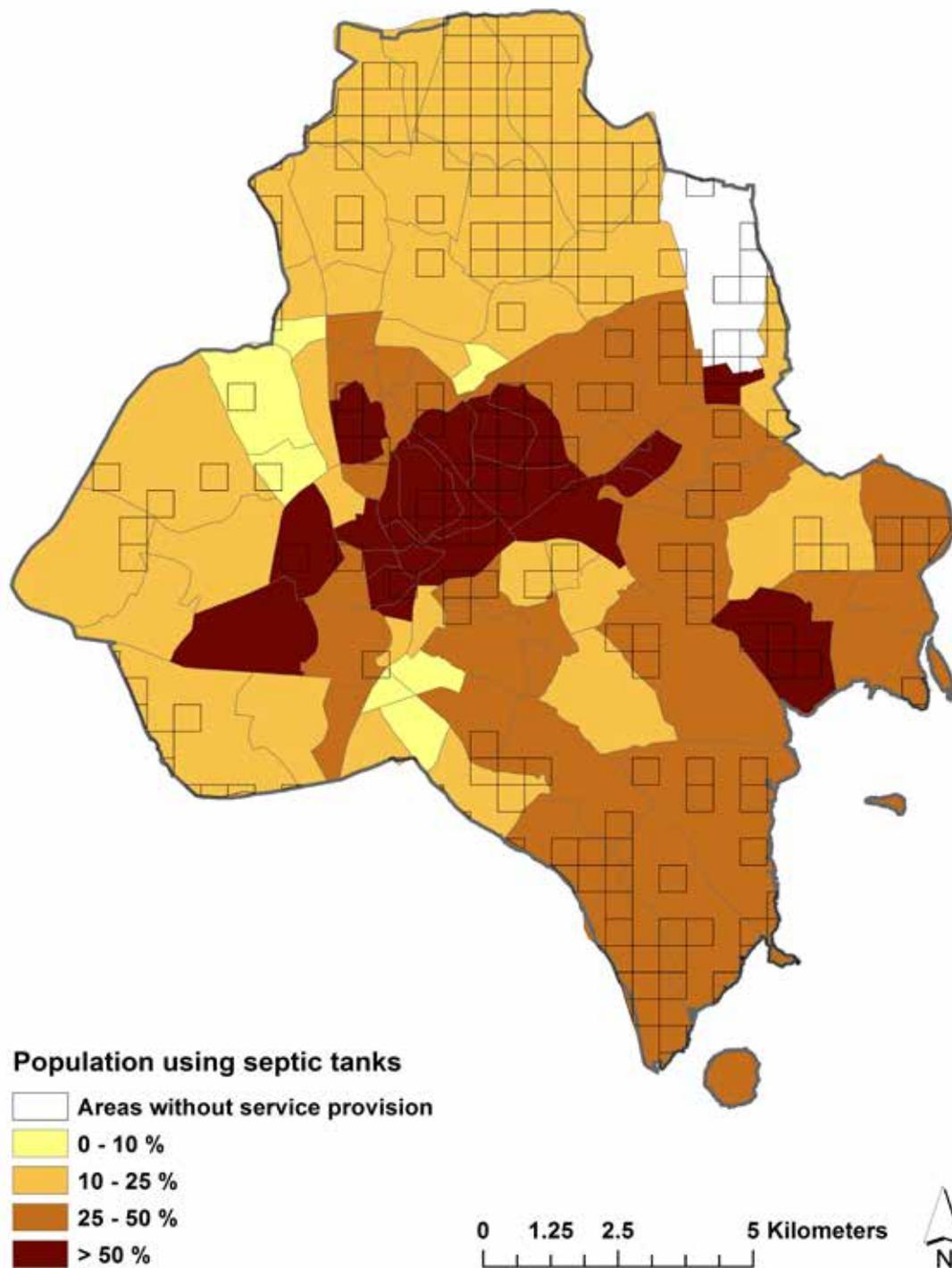
Figure 16: Usage of septic tanks

Percentage of septic tanks out of all onsite containment technologies in use. Septic tanks are the prevailing technology in high income areas (e.g. Kololo, Luzira). These areas are typically less populated in comparison to lower income areas and therefore demand less mechanical emptying services. No data was available for septic tank usage in the upper, right-hand portion of the map with no shading.

Paved roads
Unpaved roads

0   1.25   2.5   5 Kilometers

N

Figure 17: Road network

Existing road network within Kampala boundaries. It is visible that high income and industrial/commercial areas like Kololo, Nakasero and Bugolobi are characterized by the presence of paved roads, whereby low income areas like Bwaise typically remain unpaved.
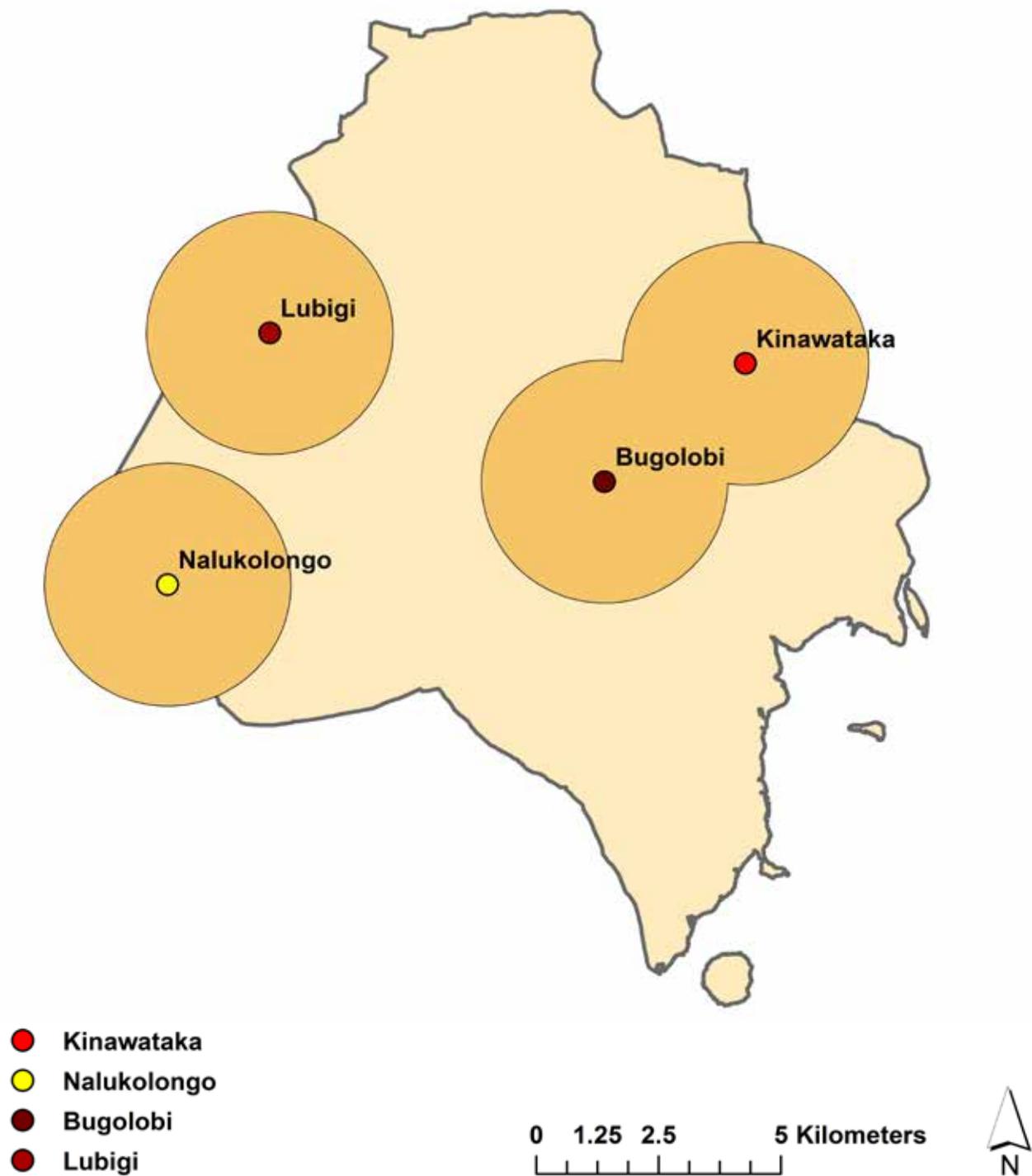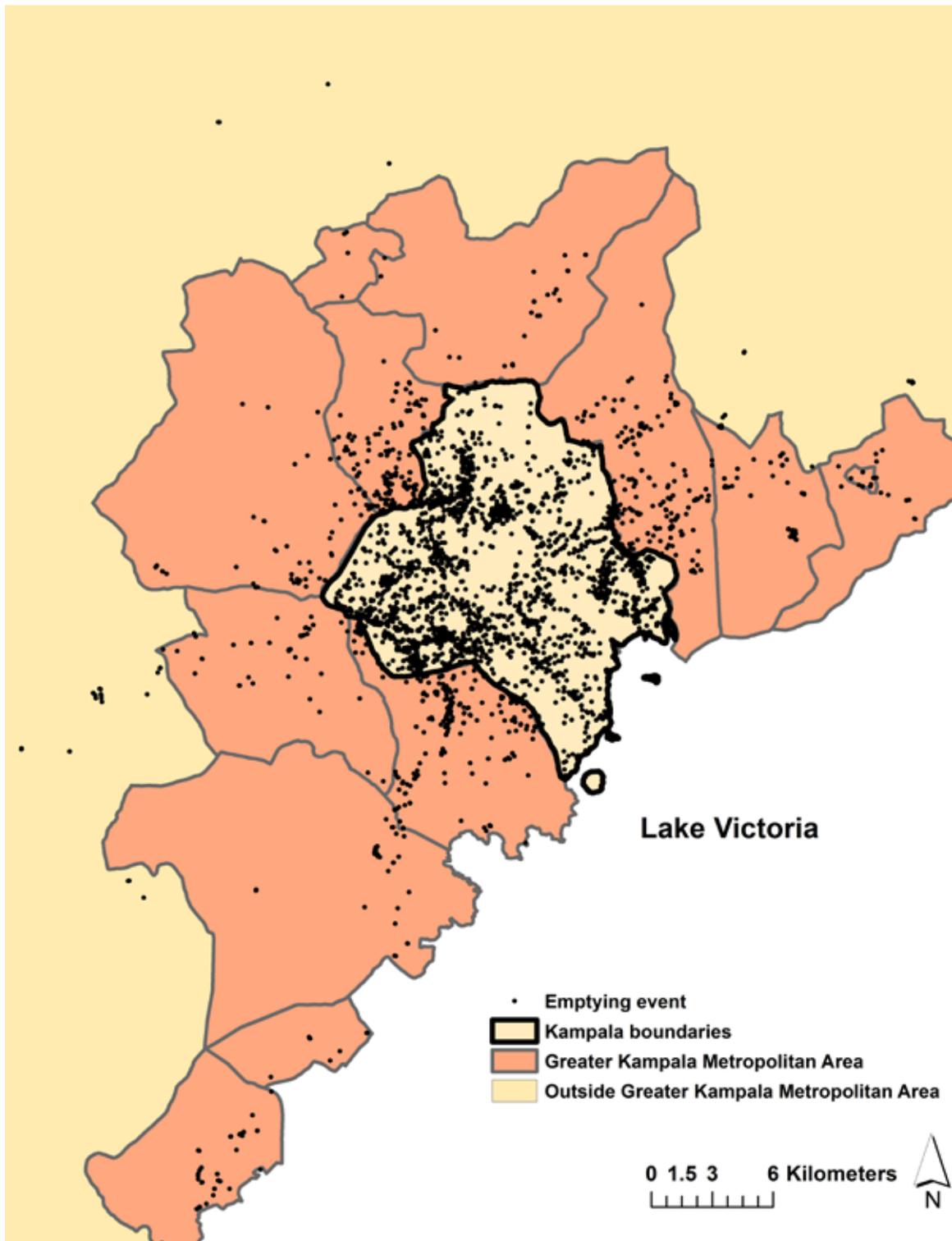
Figure 18: Treatment plant locations

Locations of planned treatment plants defined in the Kampala [*Beller Consult et al.*, KSMP, 2004]. Combined faecal sludge and wastewater treatment plants are planned at the Lubigi, Nalukolongo and Kinawataka locations. The Lubigi faecal sludge treatment plant was commissioned in 2014. In the future, the Bugolobi wastewater treatment plant will treat wastewater only. The circles depict a 2.5 km radius around the plants.

2.4 Color versions of maps in *Schoebitz et al.* (submitted)

Lake Victoria

- Emptying event
- ☐ Kampala boundaries
- Greater Kampala Metropolitan Area
- Outside Greater Kampala Metropolitan Area

0 1.5 3   6 Kilometers

N

Figure 19: Distribution of emptying events

Distribution of all emptying events recorded during this study, within Kampala boundaries, the Greater Kampala Metropolitan Area, and outside the Greater Kampala Metropolitan Area.
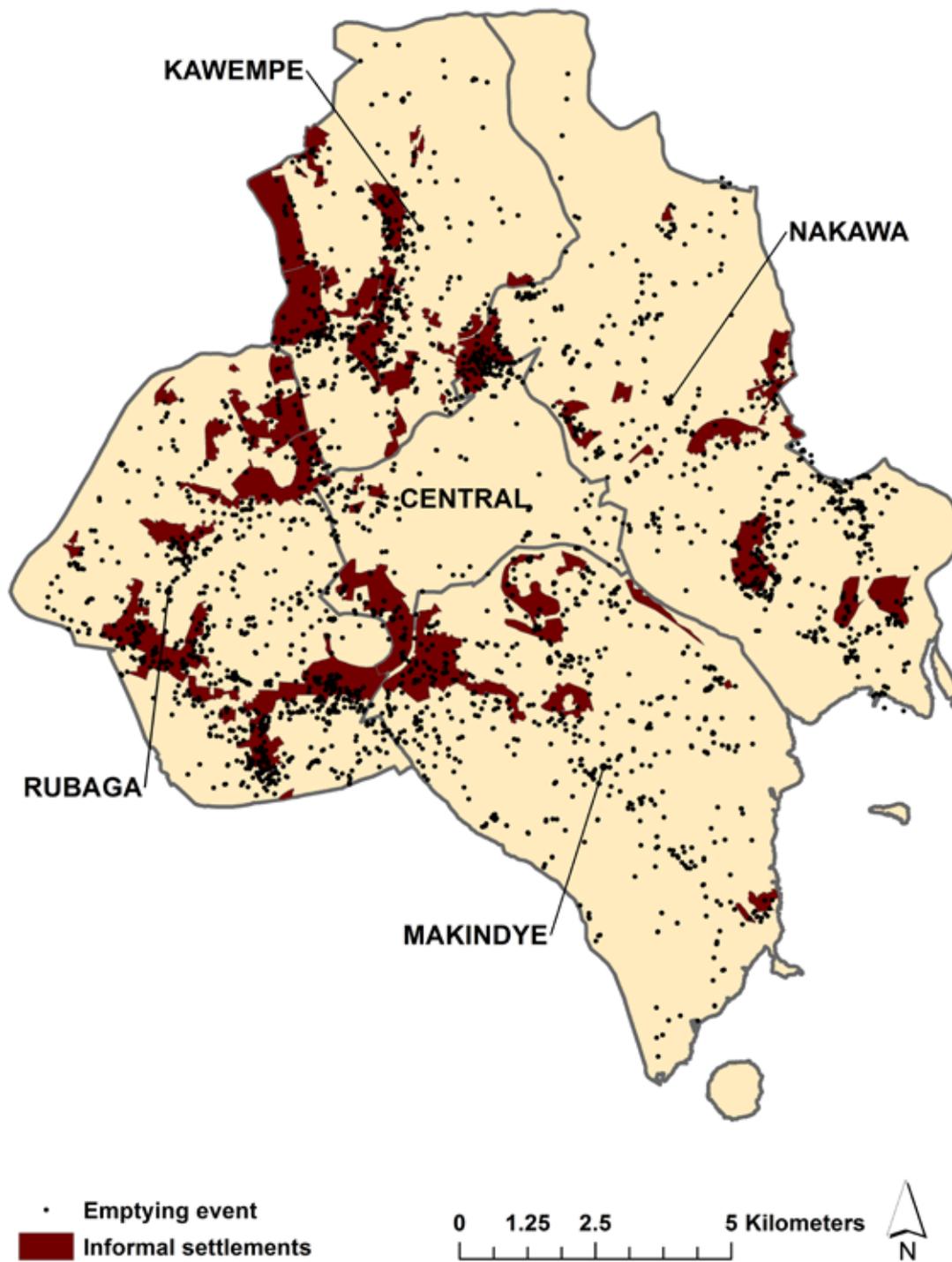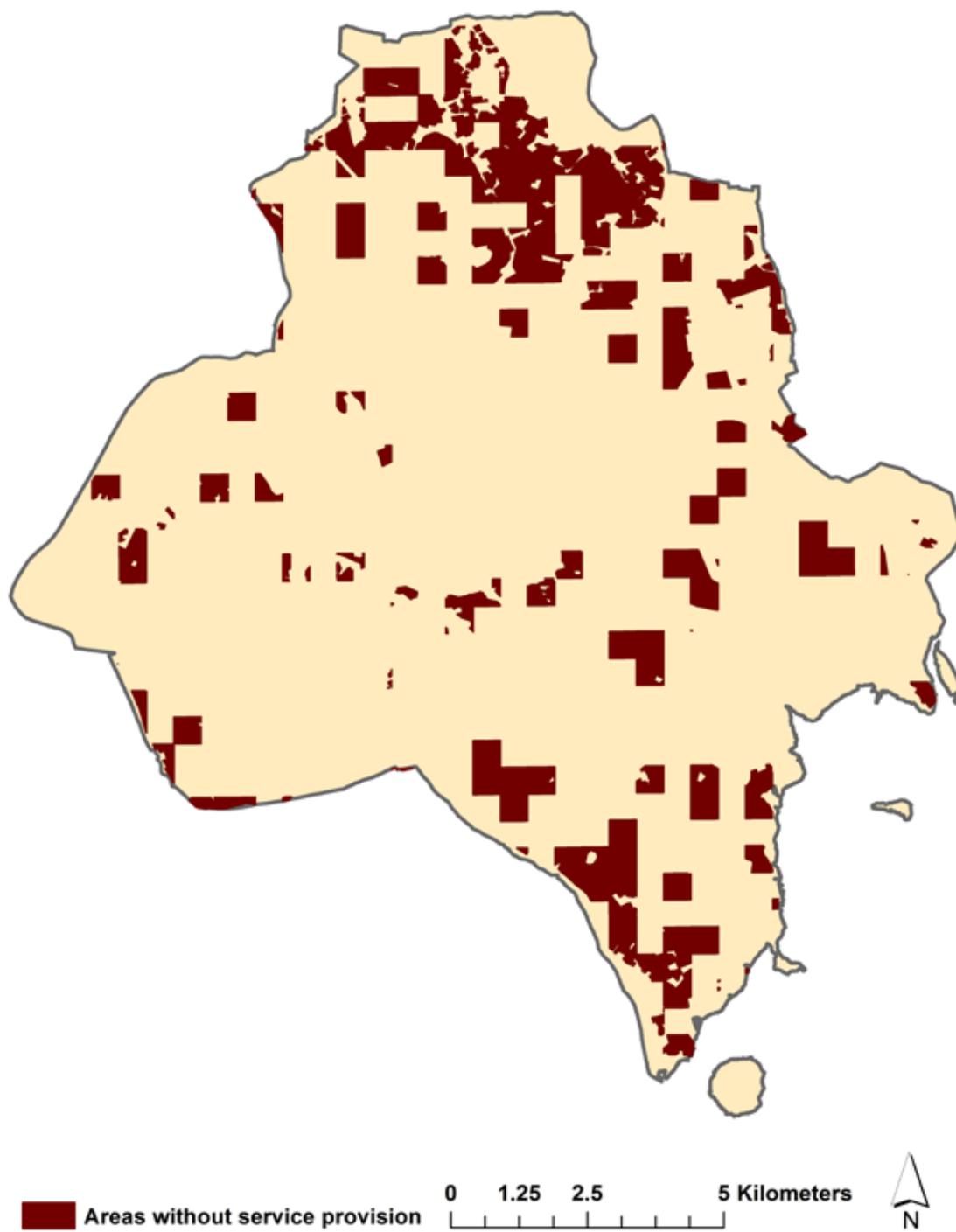
Figure 20: Emptying events

Emptying events within, and location of low-income infor-
mal settlements ("slums") (incl. 100 m buffer).

Events/0.25 km2

- 0
- 1 - 5
- 6 - 10
- 11 - 20
- 21 - 50
- 51 - 128

0   1.25   2.5   5 Kilometers

N
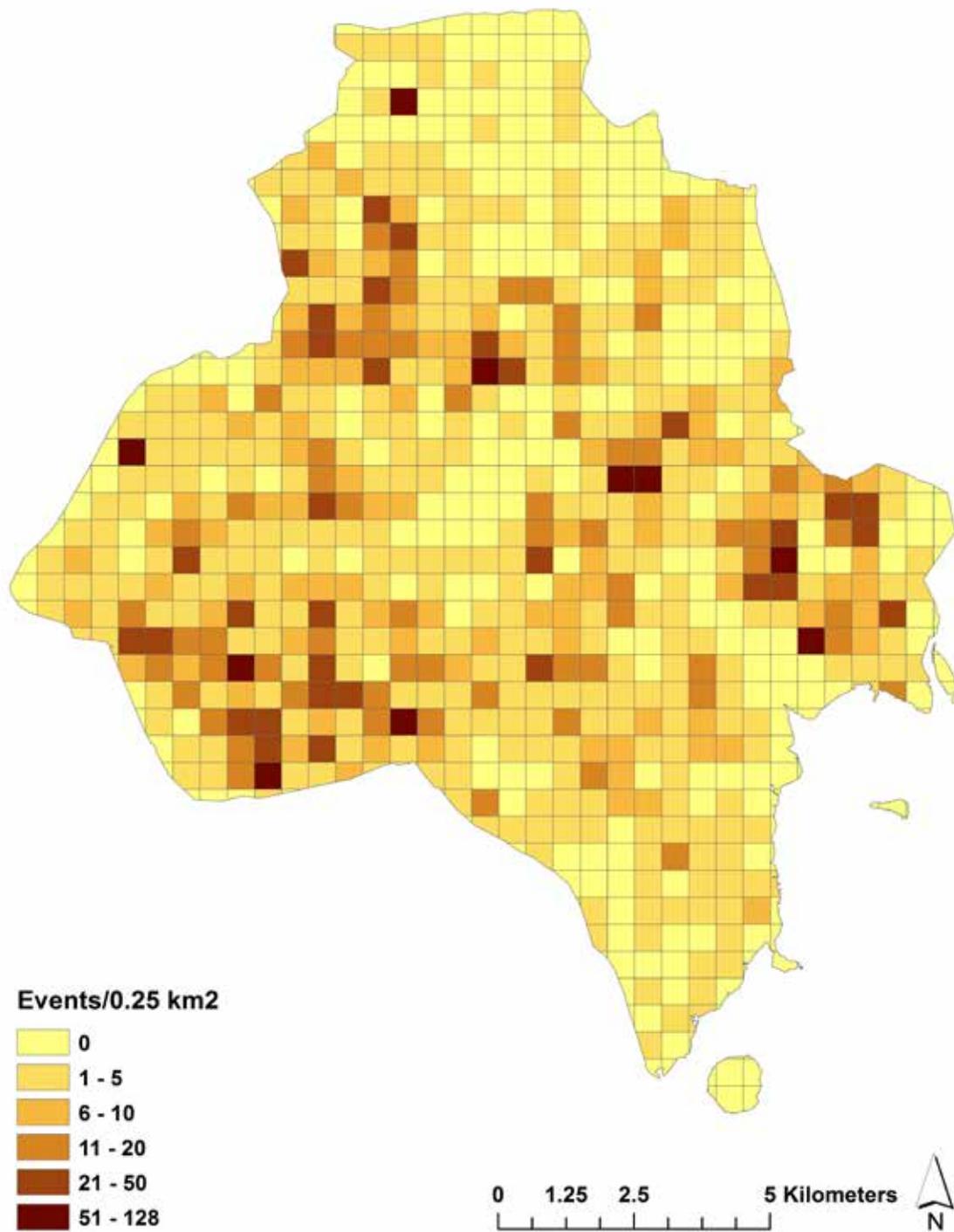
Figure 21: Emptying events

Distribution of identified emptying events in Kampala.

0   1.25   2.5   5 Kilometers

Areas without service provision

N

Figure 22: Areas without mechanical emptying

Areas without mechanical FS emptying service provision
in Kampala, excluding non-residential areas and areas with
access to sewer.
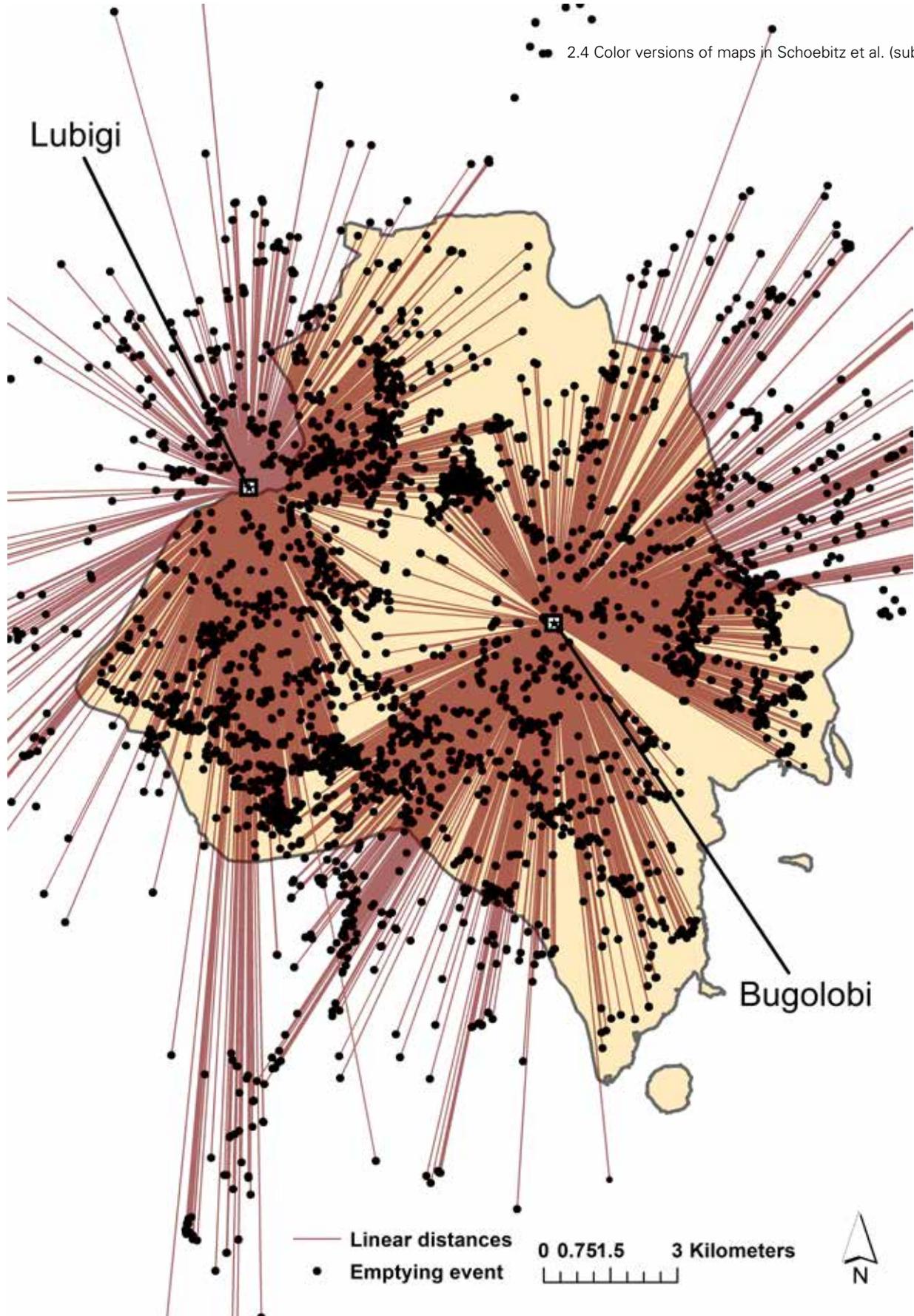
Figure 23: Emptying and discharge distances

Linear distances between emptying events and present
location of Lubigi and Bugolobi treatment plants.
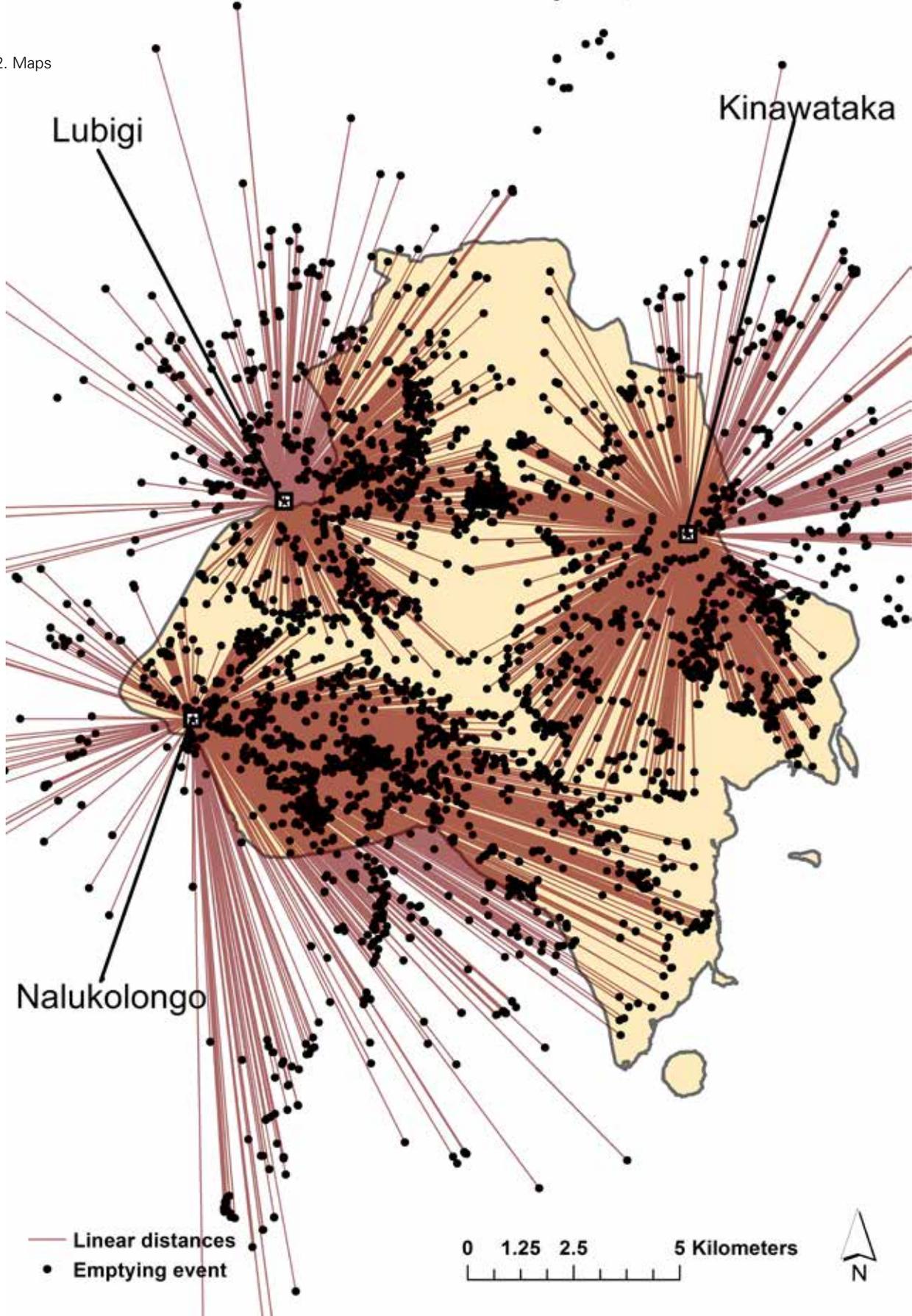
Figure 24: Emptying and discharge distances

Linear distances between emptying events and present
location of Lubigi treatment plans, and future location of
Kinawataka and Nalukolongo treatment plants.

3. References

Unless referenced differently, GIS layers used in the figures of this document were obtained from Fichtner Water & Transportation for population and areas and from KCCA for identification of low-income informal settlements.

Beller Consult, M. MacDonald, and M. E. Associates (2004). Sanitation Strategy and Master Plan for Kampala City.

Fichtner Water and Transportation (2008). Kampala Sanitation Program.

ESRI (2015). Digitalglobe, Geoeye, Earthstar Geographics, Cnes/Airbus, Usda, Usgs, Aex, Getmapping, Aerogrid Ign, Igp, Swisstopo and the Gis User Community.

KCCA (2012). Kampala Physical Development Plan.

Open Street Map. https://www.openstreetmap.org/ - map=5/51.500/-0.100

Schoebitz, L., Bischoff, F., Lohri, C.R., Niwagaba, C.B., Siber, R., and Strande, L.,. GIS analysis and optimization of faecal sludge logistics at city-wide scale in Kampala, Uganda, Submitted to Sustainability.

Schoebitz, L., Niwagaba, C., and Strande, L., (2014). RRR - Project: Waste Supply and Availability Report – Kampala.

UBOS (2014). National Population and Housing Census 2014, Uganda Bureau of Statistics.

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