THE UNIVERSITY OF MELBOURNE

MELBOURNE SCHOOL OF POPULATION AND GLOBAL HEALTH

Applications of GIS in public health

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Melbourne School of Population and Global Health

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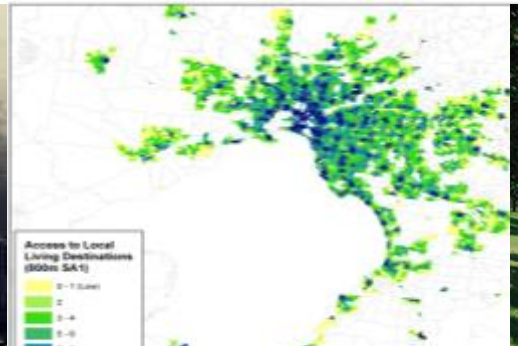



Outline

1. Introduction to public health
2. Examples of GIS applications in public health
3. Data challenges

Public health

“the art and science of preventing disease, prolonging life and promoting health through the organized efforts of society”

Acheson, D (1988) Public Health in England: The Report of the Committee of Inquiry into the Future Development of the Public Health Function. London: HMSO

Public health

Disease surveillance/monitoring
Risk assessment
Health service access
Community health
Health promotion
Health programs and interventions

planning, monitoring, implementing, advocating/promoting, policy making, researching…

Epidemiology

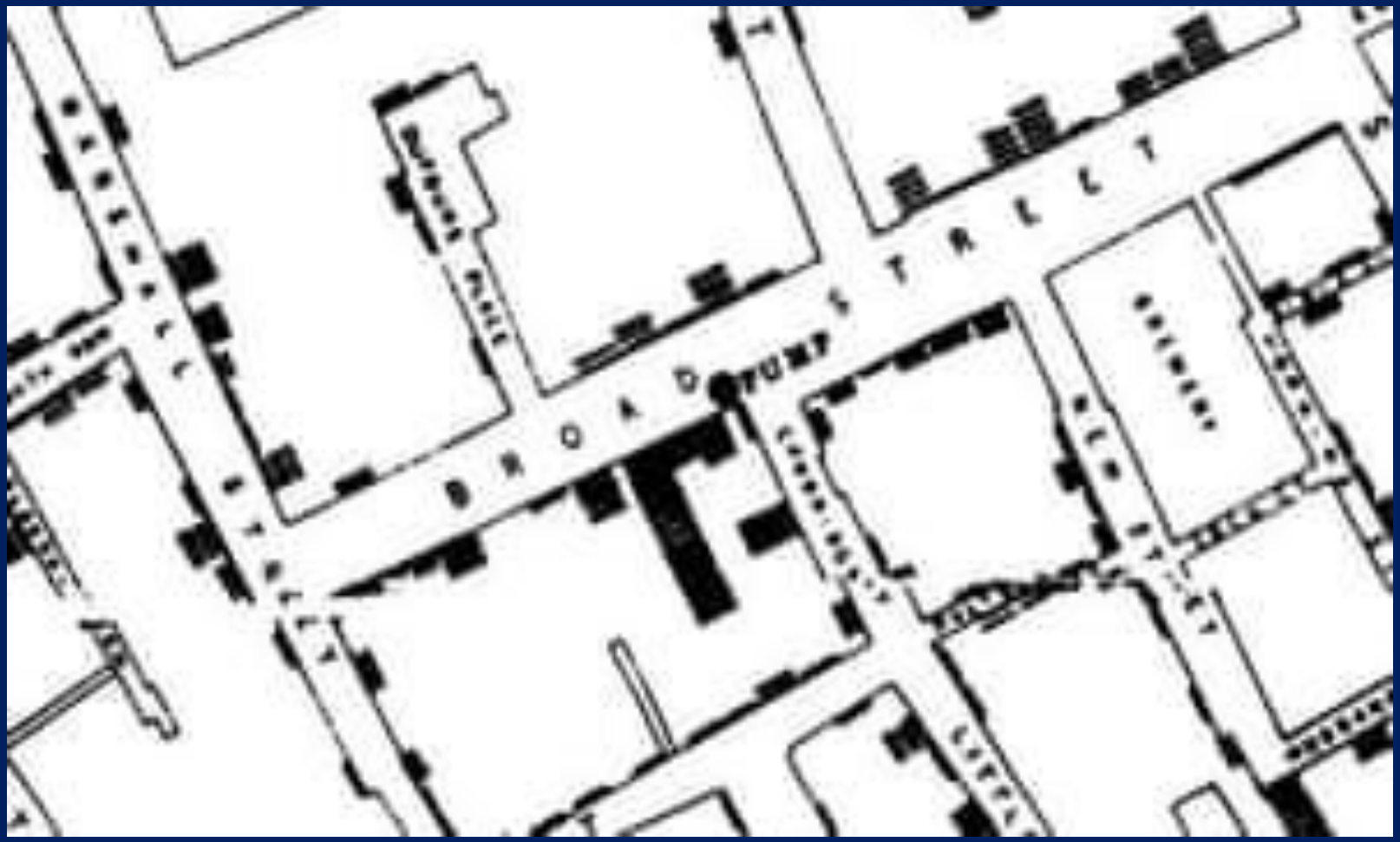
"Epidemiology is the study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to the control of health problem"

Last JM, editor. Dictionary of epidemiology. 4th ed. New York: Oxford University Press; 2001. p. 61.

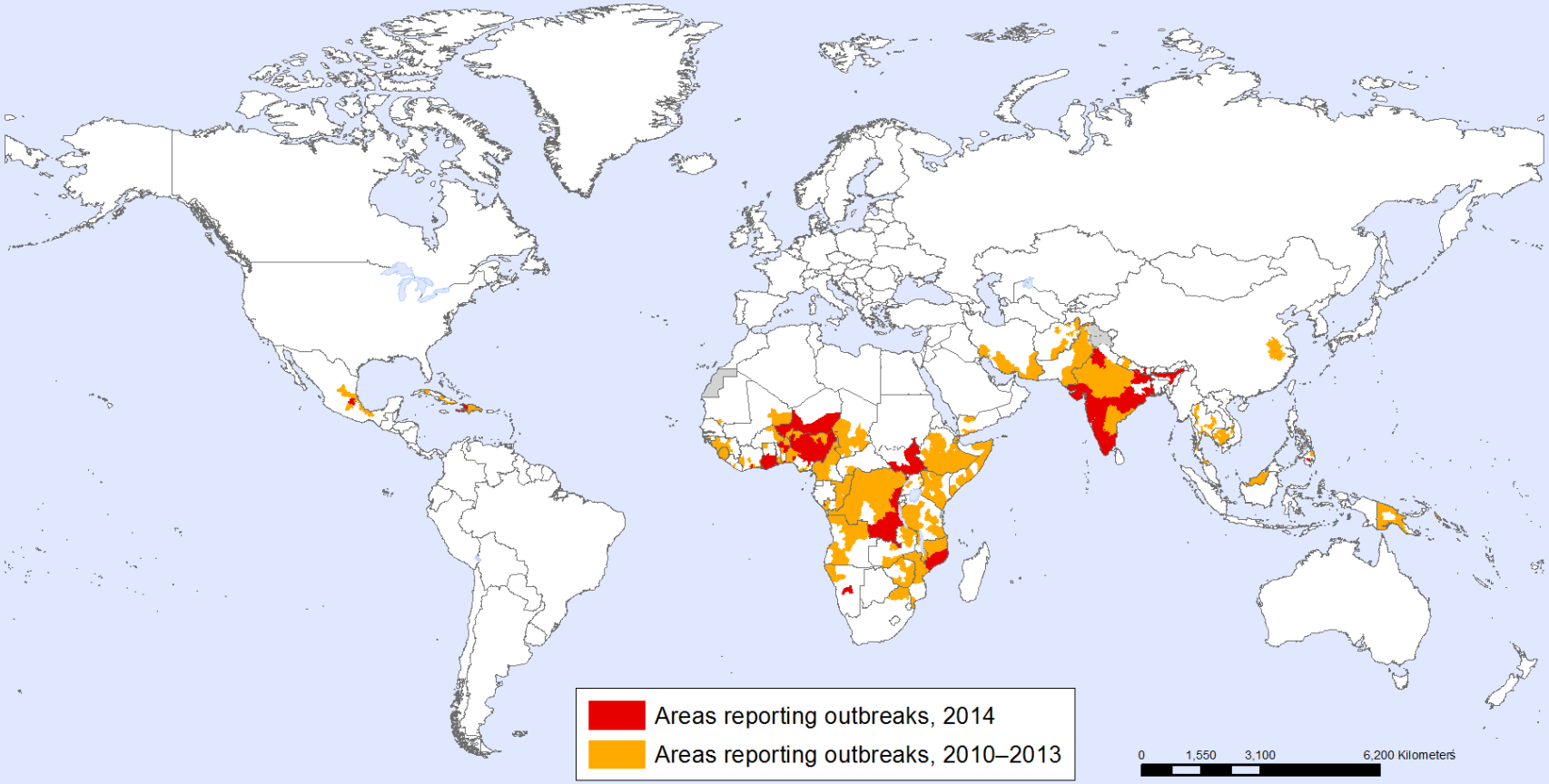
Focus on health and place underpins the roots of public health

Fig. 1. Snow's dot-map of cholera deaths, 1854 cholera outbreak, Golden Square, detail (in Frost, 1936, between pp. 44–45).

Snow, John (1855). *On the Mode of Communication of Cholera* (2nd ed.). London: John Churchill.


BROAD PUMP STREET

Cholera, areas reporting outbreaks, 2010–2014

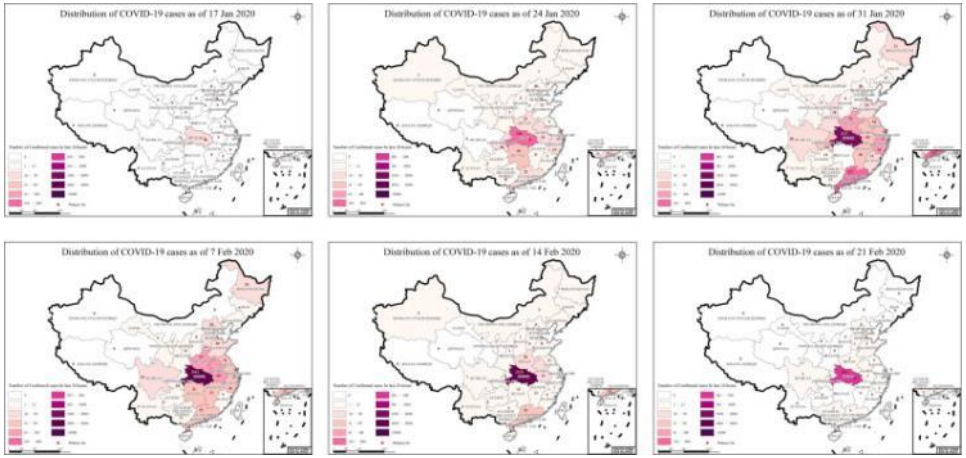


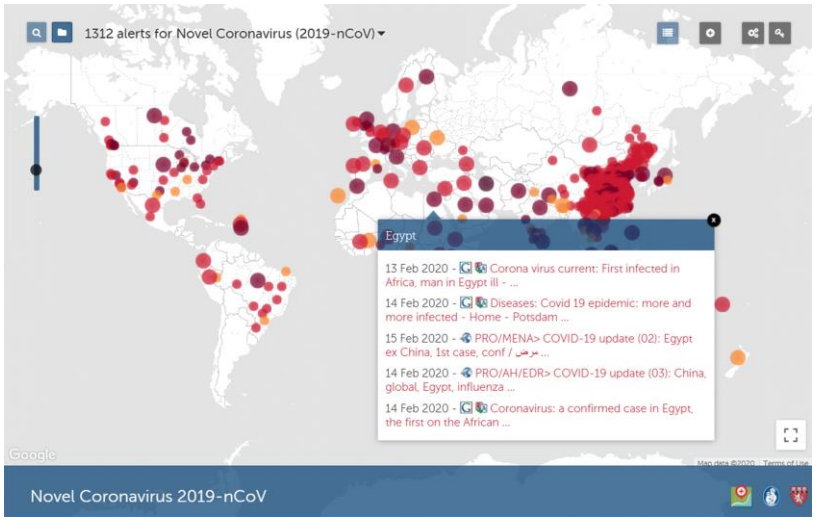
The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted and dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

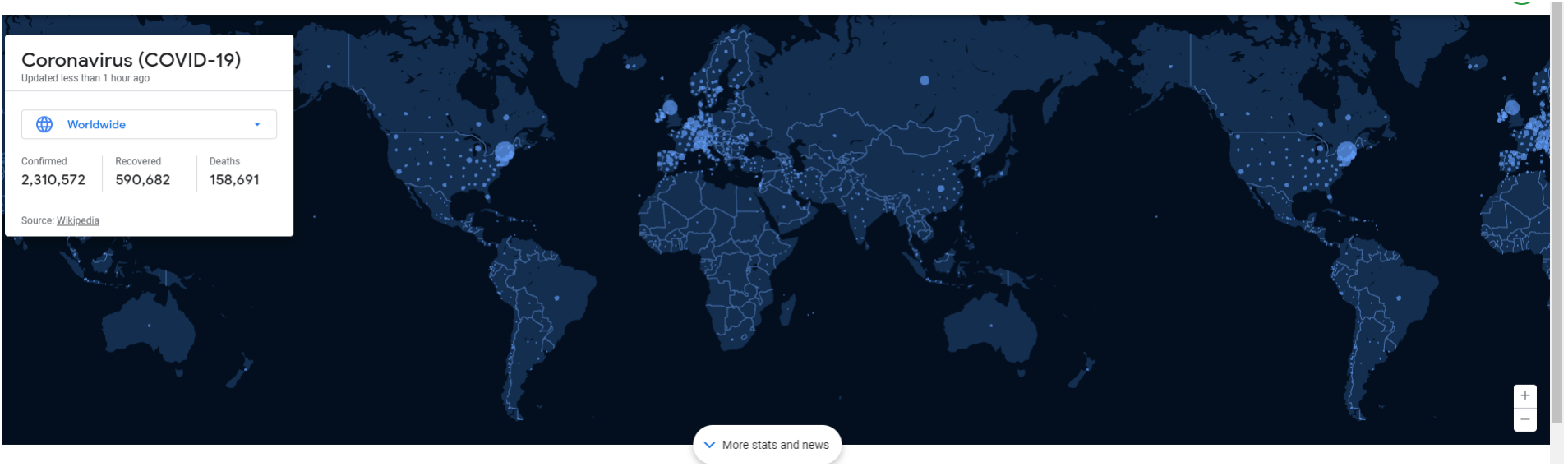
Data Source: World Health Organization
Map Production: Health Statistics and Information Systems (HSI)
World Health Organization

World Health Organization

COVID-19







Images sourced from:
Boulos, M.N.K. and Geraghty, E.M., 2020. Geographical tracking and mapping of coronavirus disease COVID-19/severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) epidemic and associated events around the world: how 21st century GIS technologies are supporting the global fight against outbreaks and epidemics.
Zhou, C., Su, F., Pei, T., Zhang, A., Du, Y., Luo, B., Cao, Z., Wang, J., Yuan, W., Zhu, Y. and Song, C., 2020. COVID-19: challenges to GIS with big data. *Geography and Sustainability*.
Google.

Determinants of health

Individual

Social

Environmental

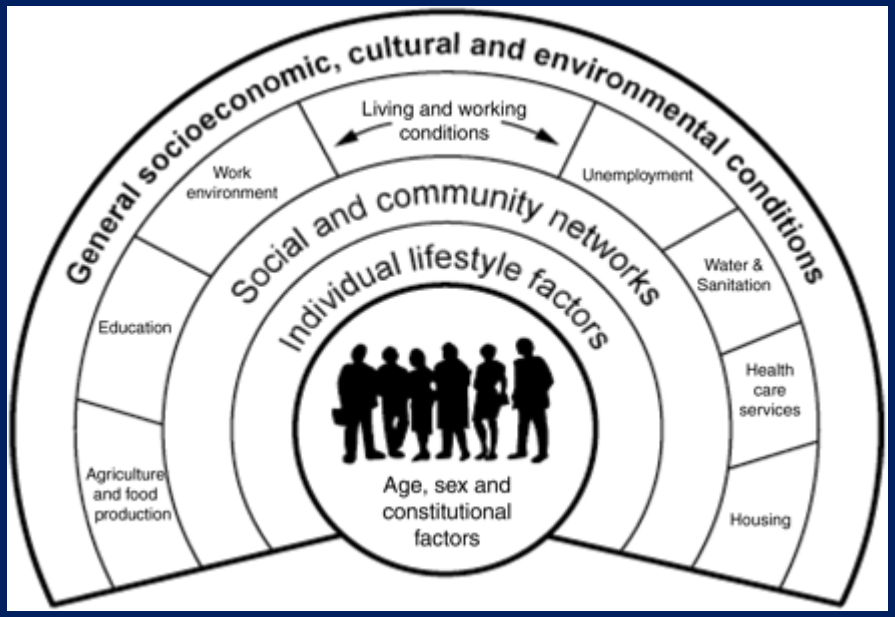
Determinants of health

Individual Social Environmental

biology behaviour

Determinants of health

Individual Social Environmental



Source: Dahlgren G, Whitehead M. , *Policies and strategies to promote social equity in health.*, 1991 Stockholm Institute for Future Studies

Determinants of health

Individual Social Environmental

chemicals/pollutants

built environment

natural environment

(Geo)spatial questions related to health

Where are the disease outbreaks? Where are the clusters/hotspots of disease?

Where are the at risk populations? Where should we intervene?

What health services are available in different areas of a city/country?

Where are the gaps in health services?

Are the habitats/climate that X species needs present in this environment?

How well do different neighbourhoods enable walking/physical activity?

What healthy food is available in different neighbourhoods?

What characteristics of environments determine health?

Where are people spending time? What environments are they exposed to?

A GIS/geospatial toolbox for public health

Collect/create data

Map/visualise

Spatial analysis

GIS applications in health – part 1

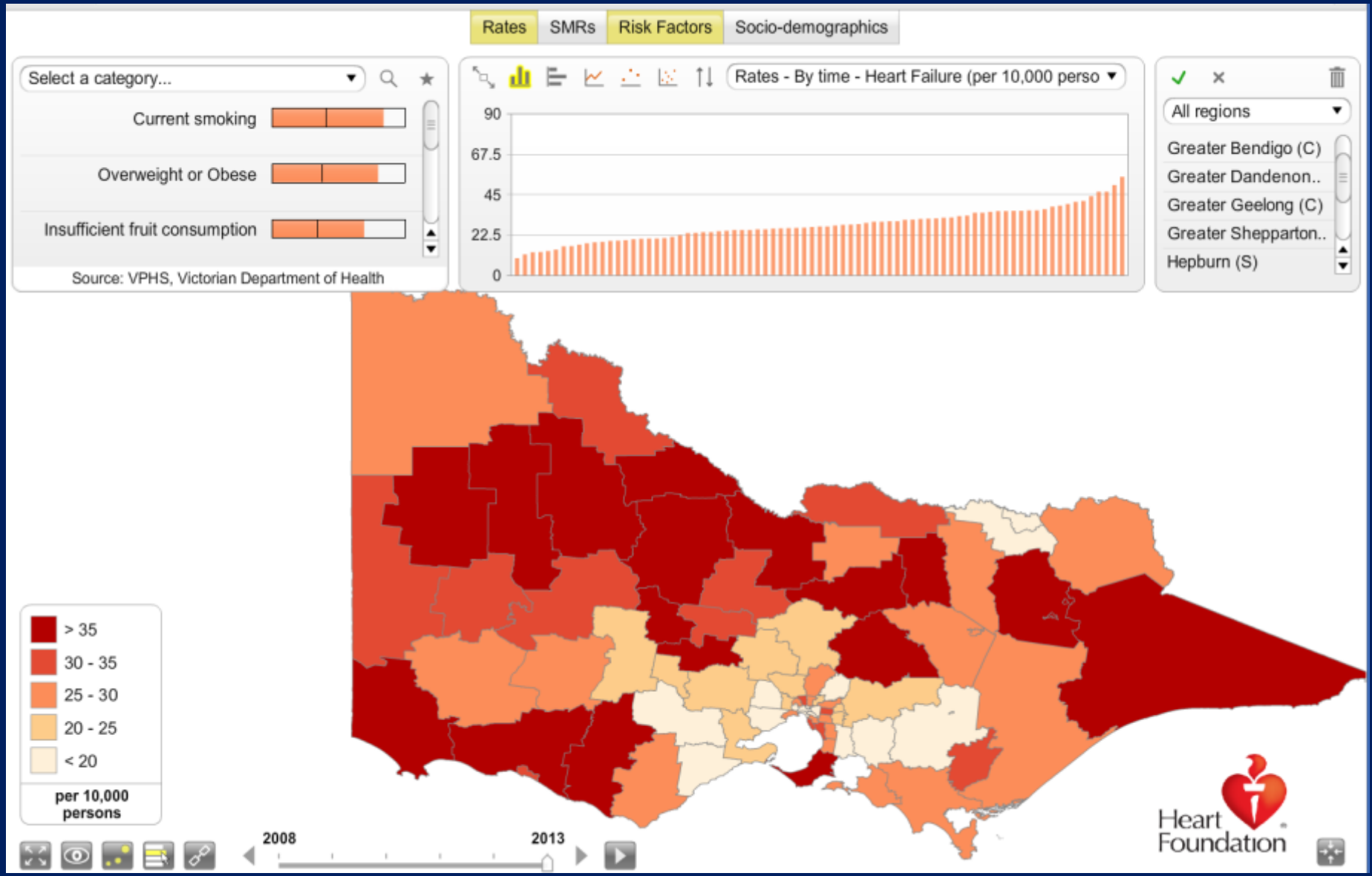
- Geographic distribution and variation of disease (incidence/prevalence)
- Surveillance and monitoring of disease (infectious and chronic)
- Identifying at risk populations
- Identifying spatial patterns, e.g. clusters of disease
- Spatial statistics, spatial regression, spatial interpolation
- Measure the environment (generate/test hypotheses)
- Assess resource allocation/accessibility (e.g., health services, schools, water)
- Estimate exposure to the environment (e.g, using GPS)

GIS applications in health – part 2

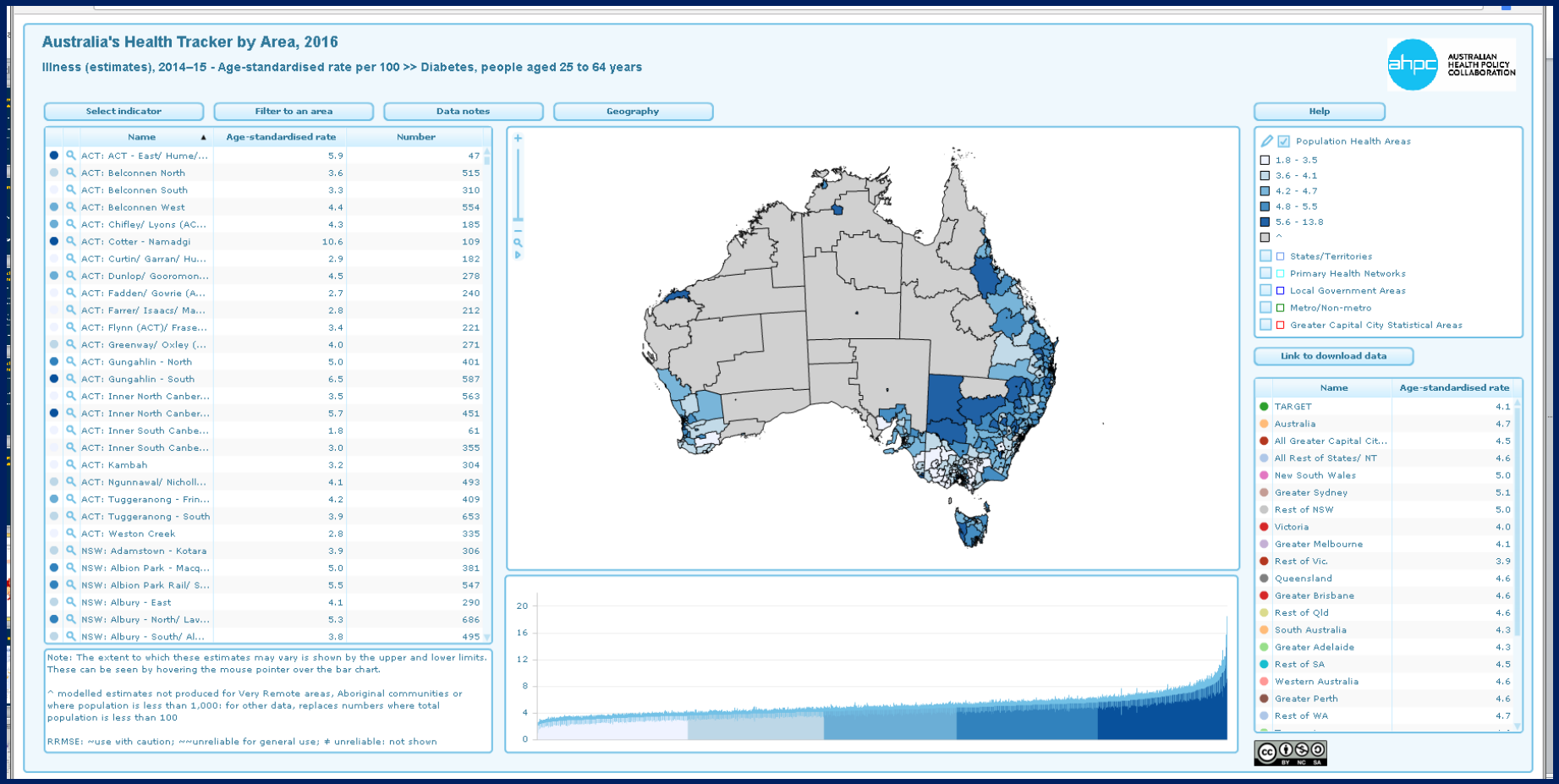
- Mapping perceptions/qualitative data
- Simulating spatial behaviour (e.g, disease transmission, walking)
- Measuring health-related policy implementation
- Targeting interventions
- Assessing the impact of interventions
- Assisting in research design and data collection (e.g., identifying study area, design of sample frames)
- Communication/knowledge translation/community engagement

GIS applications in health– part 1

- Geographic distribution and variation of disease (incidence/prevalence)
- Surveillance and monitoring of disease (infectious and chronic)



www.heartfoundation.org.au



Australia Health Tracker (Australian Health Policy Collaboration):
http://www.atlasesaustralia.com.au/ahpc/atlas/atlas.html?indicator=i18

GIS applications in health – part 1

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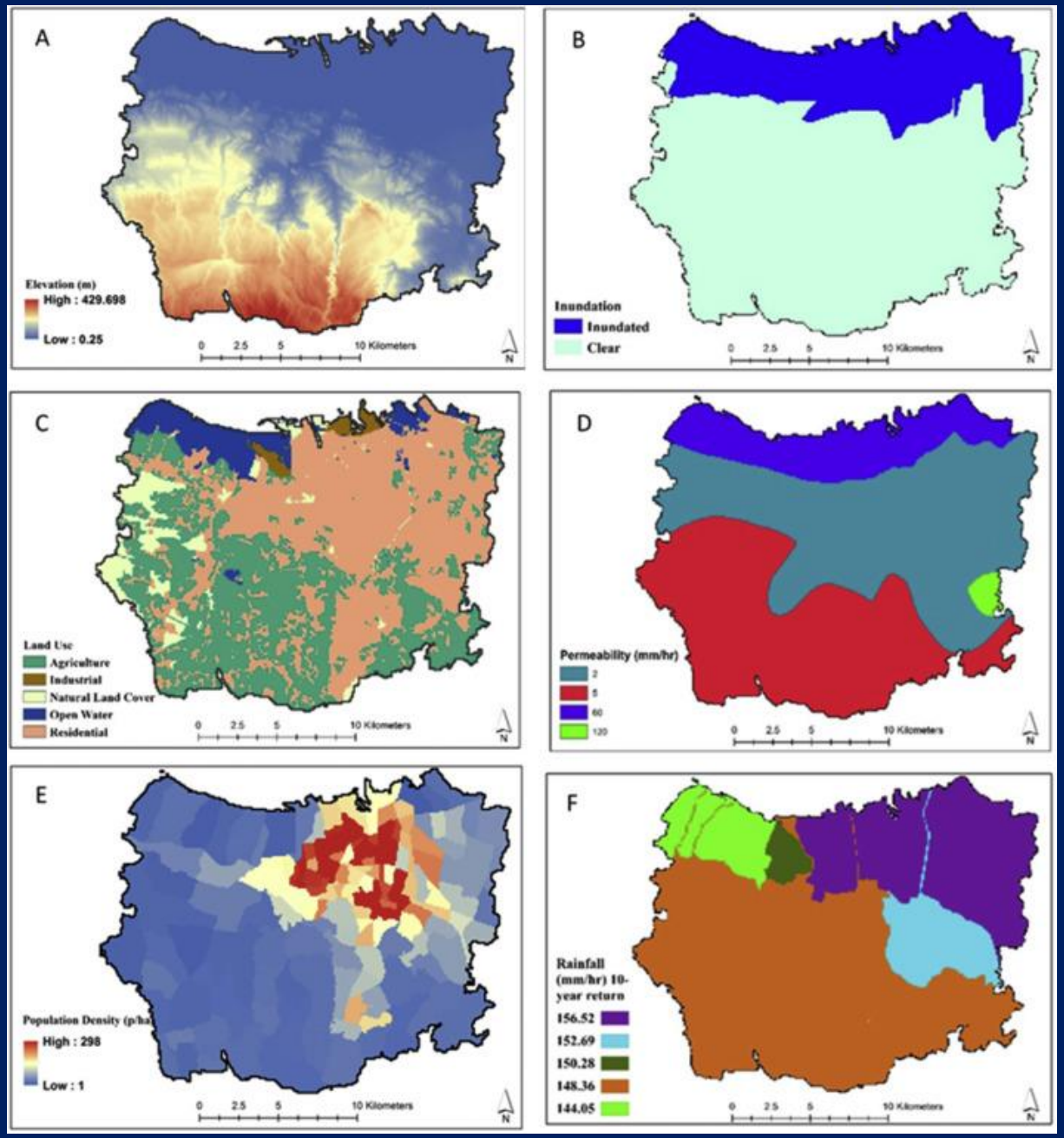
- Surveillance and monitoring of disease (infectious and chronic)
- **Identifying at risk populations**

Deilami, K., Hayes, J.F., McGree, J. and Goonetilleke, A., 2017. **Application of landscape epidemiology to assess potential public health risk due to poor sanitation**. *Journal of Environmental Management*, *192*, pp.124-133.



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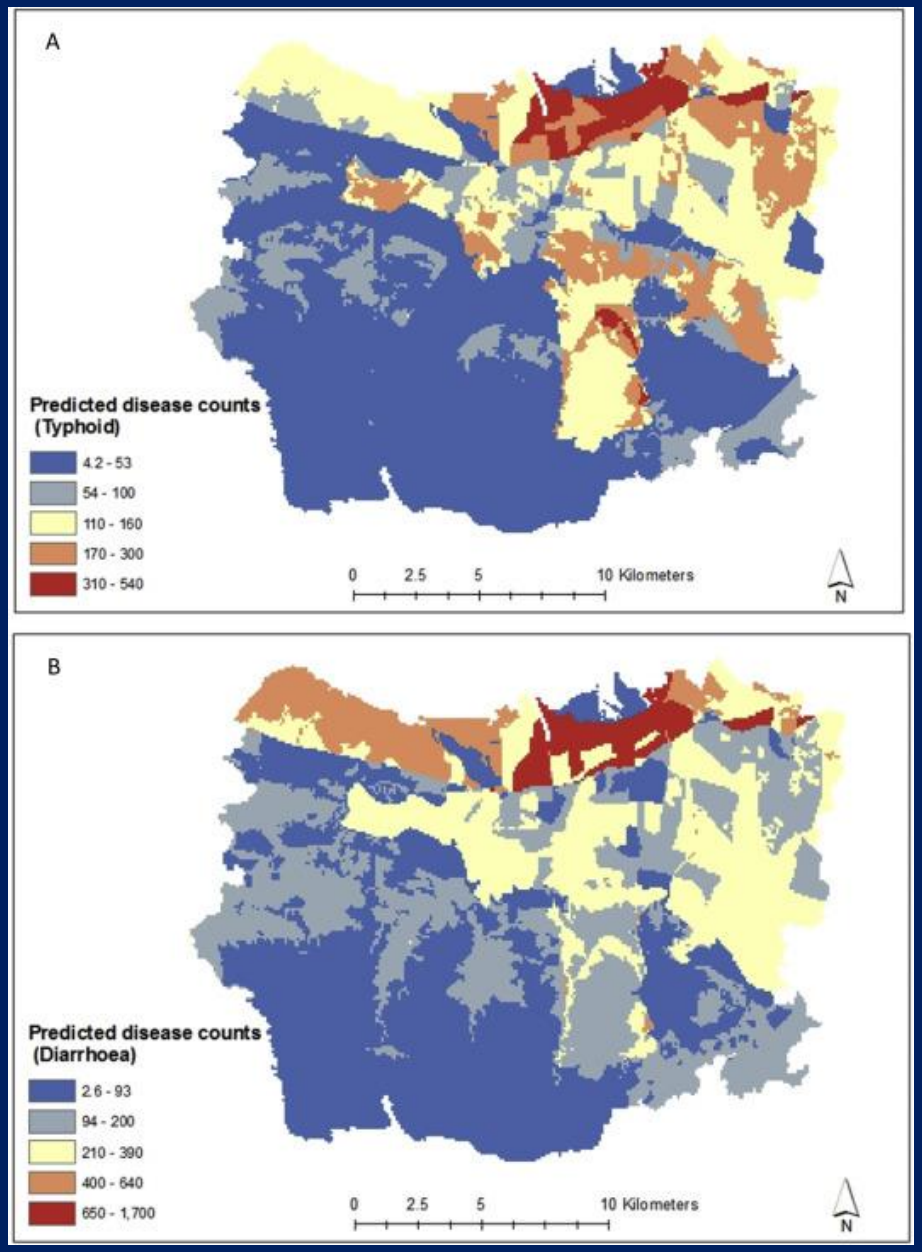

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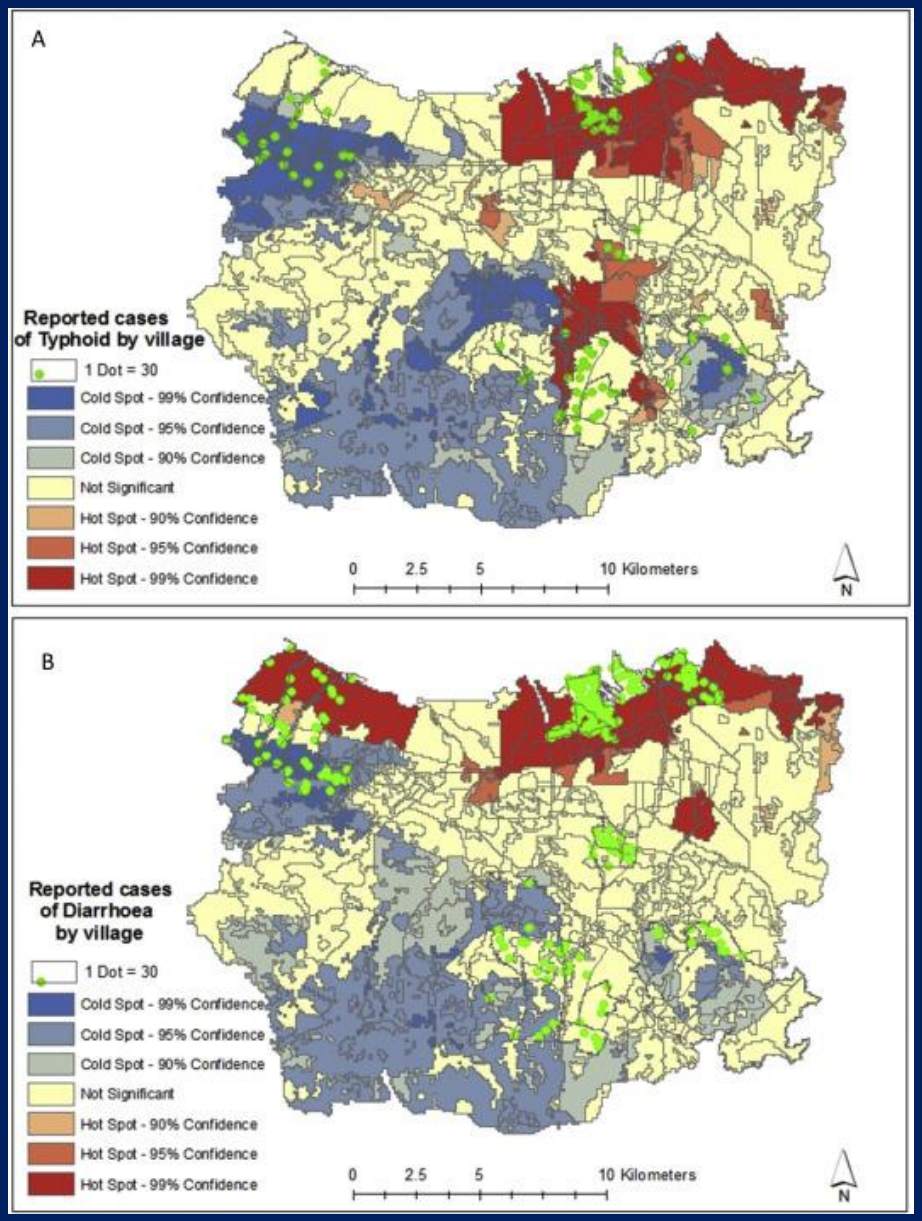

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GIS applications in health – part 1

- Geographic distribution and variation of disease (incidence/prevalence)
- Surveillance and monitoring of disease (infectious and chronic)
- Identifying at risk populations
- **Identifying spatial patterns, e.g. clusters of disease**

Lyme disease cluster analysis

Lantos, P.M., Tsao, J., Nigrovic, L.E., Auwaerter, P.G., Fowler, V., Ruffin, F., Foster, E. and Hickling, G., 2017, January. **Geographic Expansion of Lyme disease in Michigan, 2000-2014**. In *Open Forum Infectious Diseases* (p. ofw269). Oxford University Press.

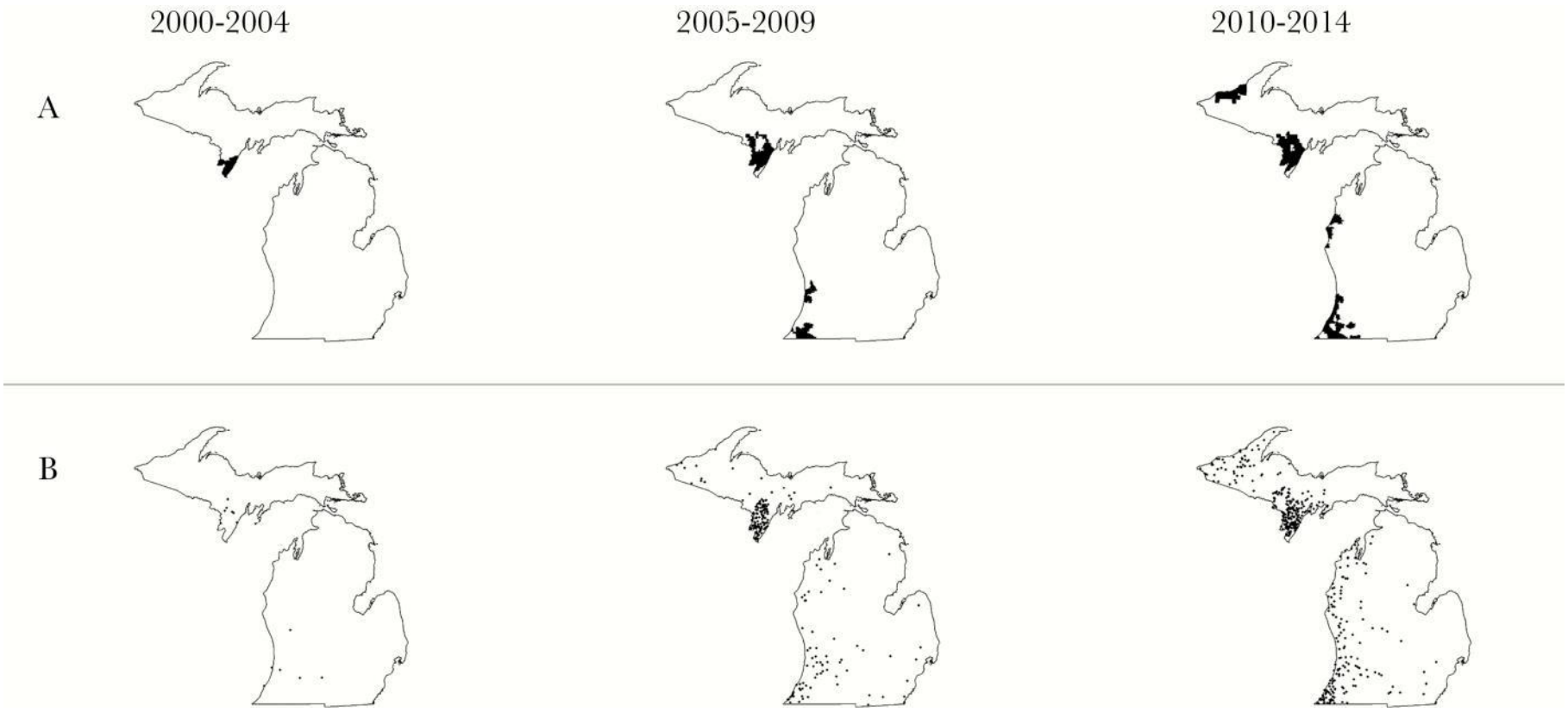


Figure 2. (A) Sequential cluster analysis of Lyme disease cases, grouped by 5-year interval.

Lyme disease clusters

Deer tick population

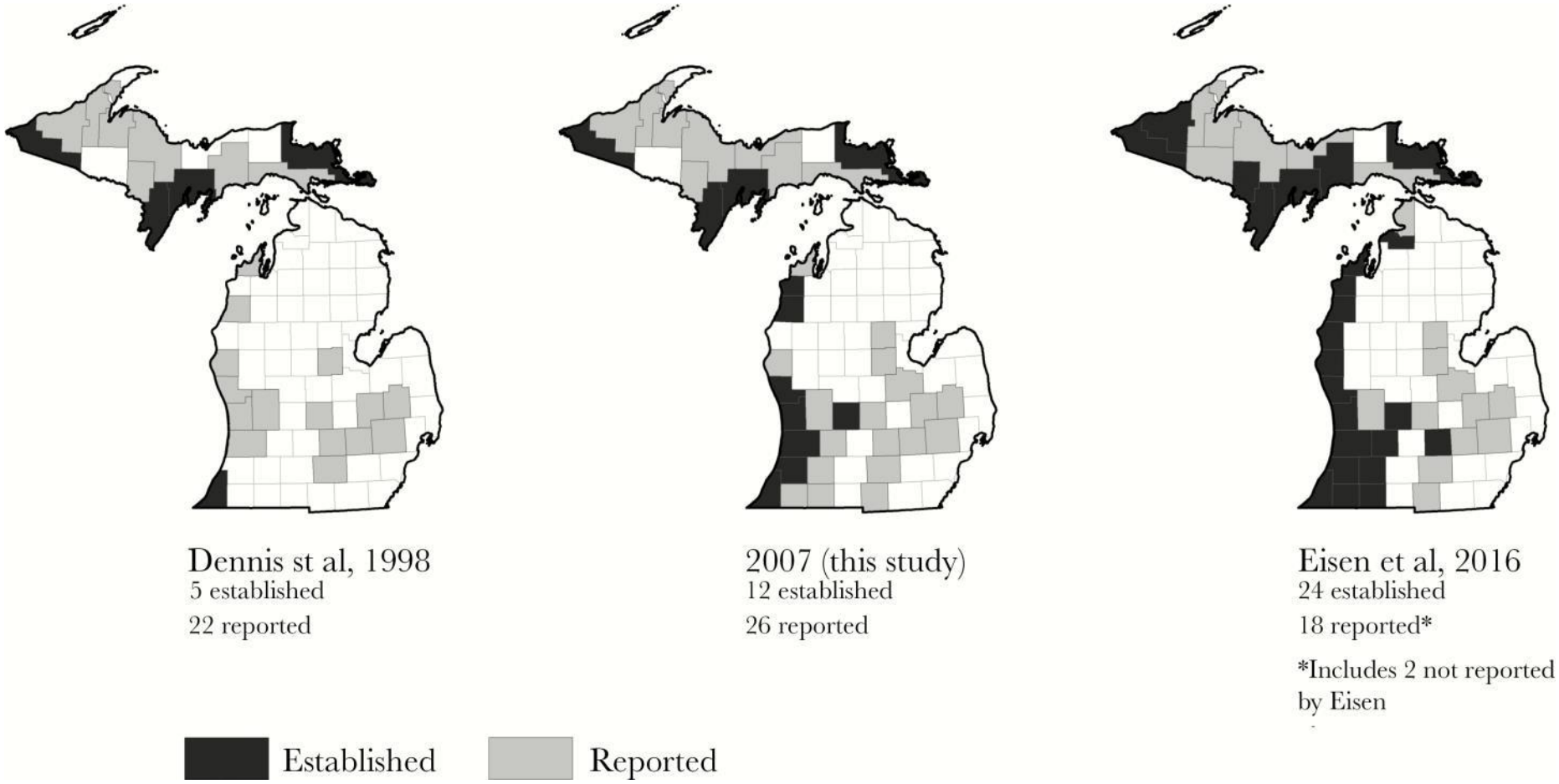


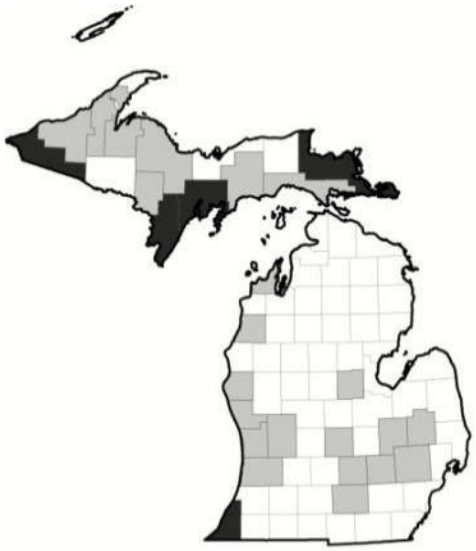
Figure 3. Expanding distribution of established and reported *Ixodes scapularis* populations in Michigan, 1998–2016

A

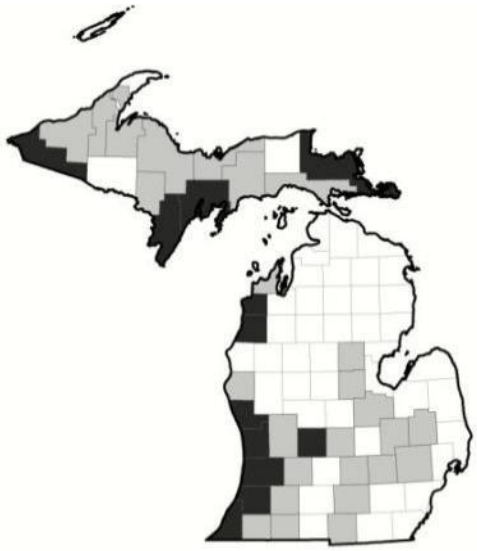
2000-2004

2005-2009

2010-2014



Dennis st al, 1998
5 established
22 reported



2007 (this study)
12 established
26 reported

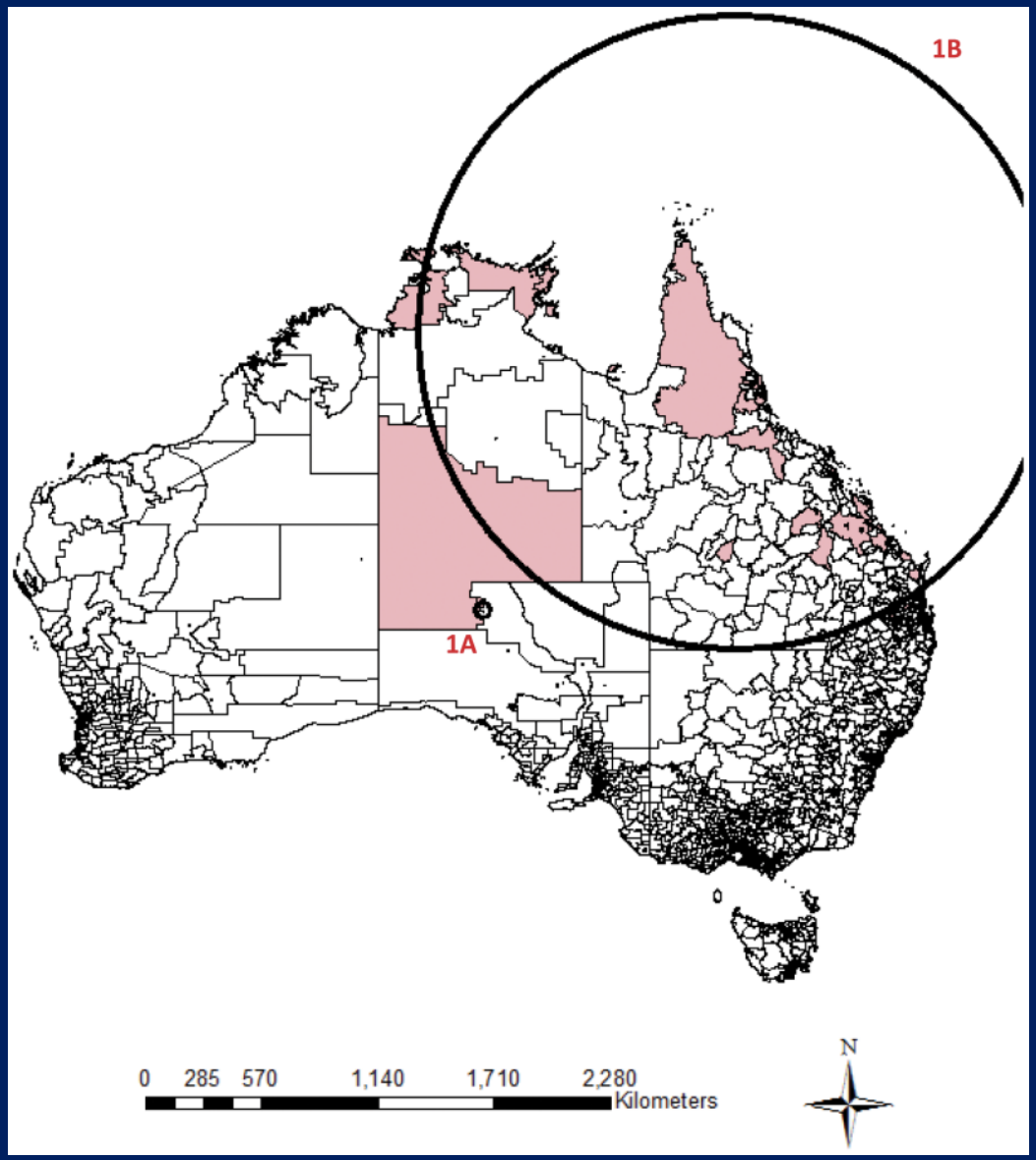
Eisen et al, 2016
24 established
18 reported*

*Includes 2 not reported by Eisen

Established Reported

Suicide cluster analysis

Cheung, Y.T.D., Spittal, M.J., Williamson, M.K., Tung, S.J. and Pirkis, J., 2013. **Application of scan statistics to detect suicide clusters in Australia**. *PLoS One*, *8*(1), p.e54168.



"the majority of spatial-temporal clusters of suicide were located in the inland northern areas, with socio-economic deprivation and higher proportions of indigenous people"

Cheung, Y.T.D., Spittal, M.J., Williamson, M.K., Tung, S.J. and Pirkis, J., 2013. **Application of scan statistics to detect suicide clusters in Australia**. *PLoS One*, *8*(1), p.e54168.

GIS applications in health – part 1

- Geographic distribution and variation of disease (incidence/prevalence)
- Surveillance and monitoring of disease (infectious and chronic)
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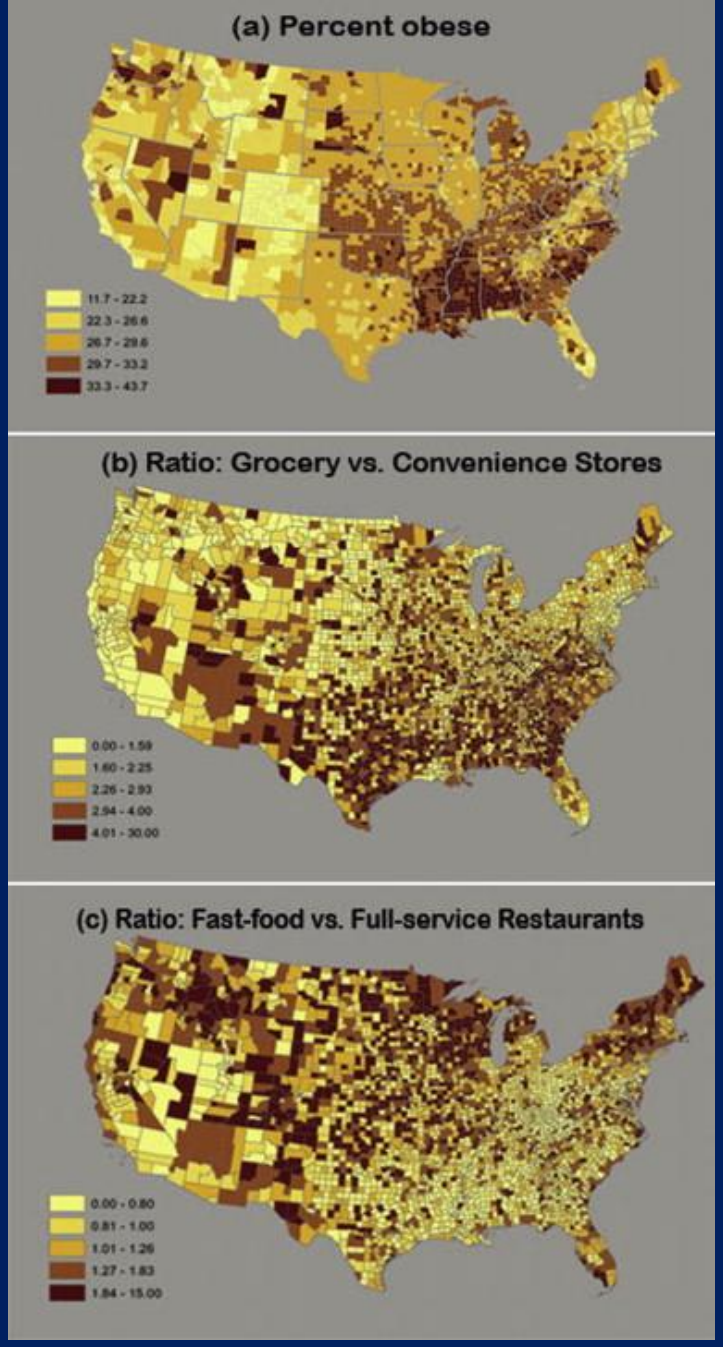
- Identifying spatial patterns, e.g. clusters of disease
- **Spatial statistics, spatial regression, spatial interpolation**

Geographically weighted regression

Chi, S.H., Grigsby-Toussaint, D.S., Bradford, N. and Choi, J., 2013. **Can geographically weighted regression improve our contextual understanding of obesity in the US? Findings from the USDA Food Atlas**. *Applied Geography*, *44*, pp.134-142.



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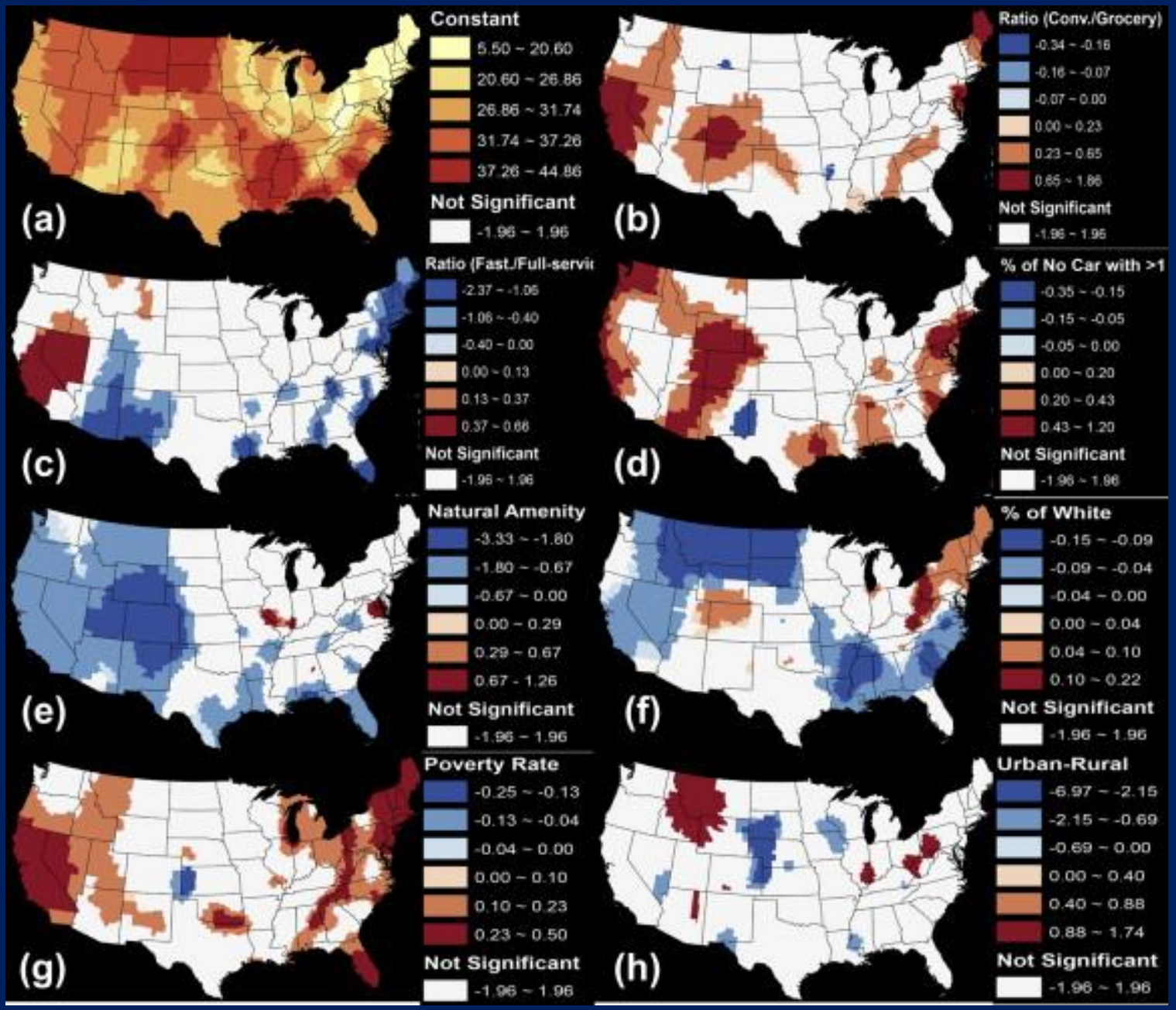

Chi, S.H., Grigsby-Toussaint, D.S., Bradford, N. and Choi, J., 2013. **Can geographically weighted regression improve our contextual understanding of obesity in the US? Findings from the USDA Food Atlas**. *Applied Geography*, *44*, pp.134-142.

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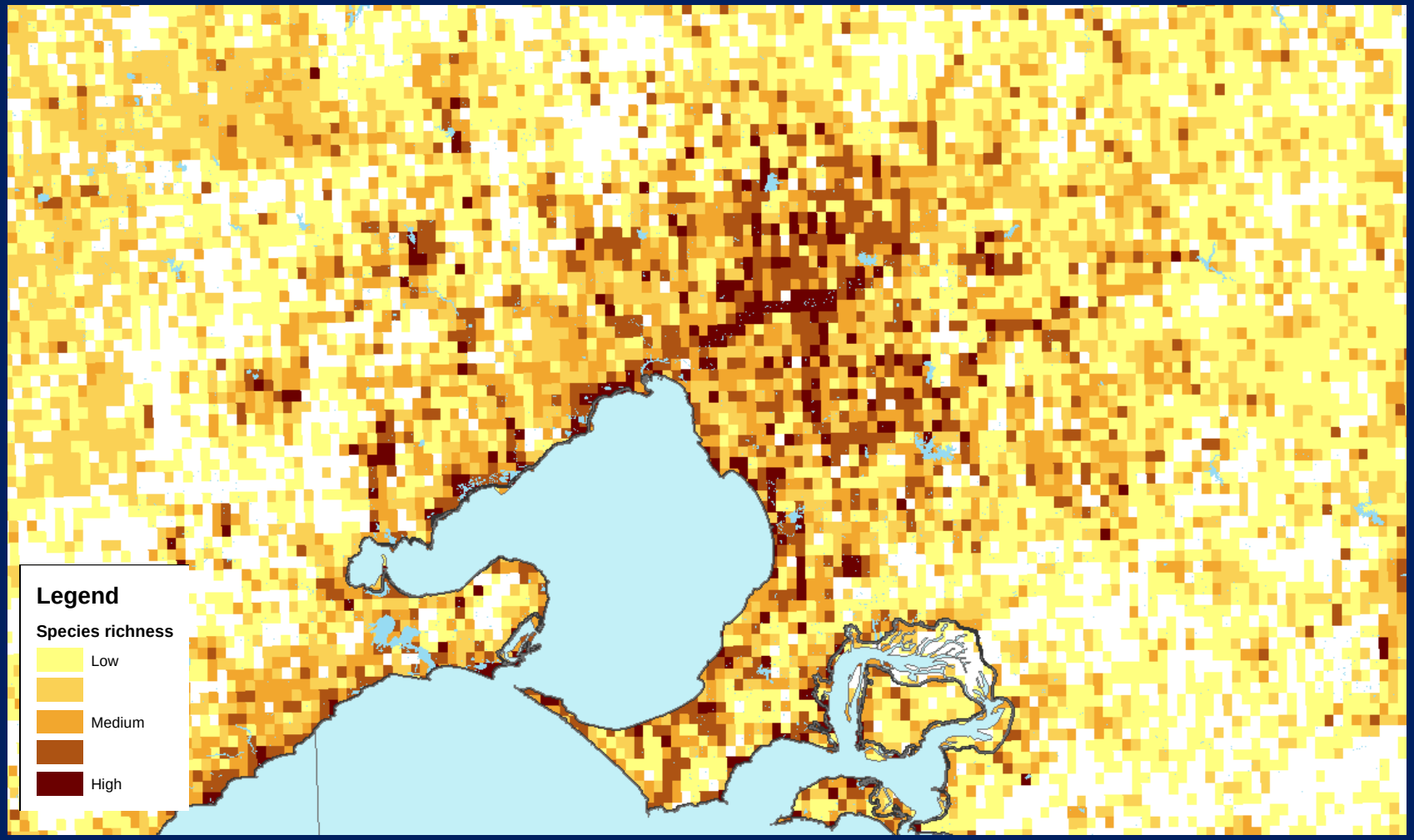
- Spatial statistics, spatial regression, spatial interpolation
- **Measure the environment (generate/test hypotheses)**

Do people who live in environments with more green, water (blue space), and biodiversity have more subjective wellbeing?

Greenness (NDVI) across Metropolitan Melbourne

Source: Mavoa, S. work in progress.

Fauna species richness across Metropolitan Melbourne



Source: Mavoa, S. work in progress.

GIS applications in health – part 1

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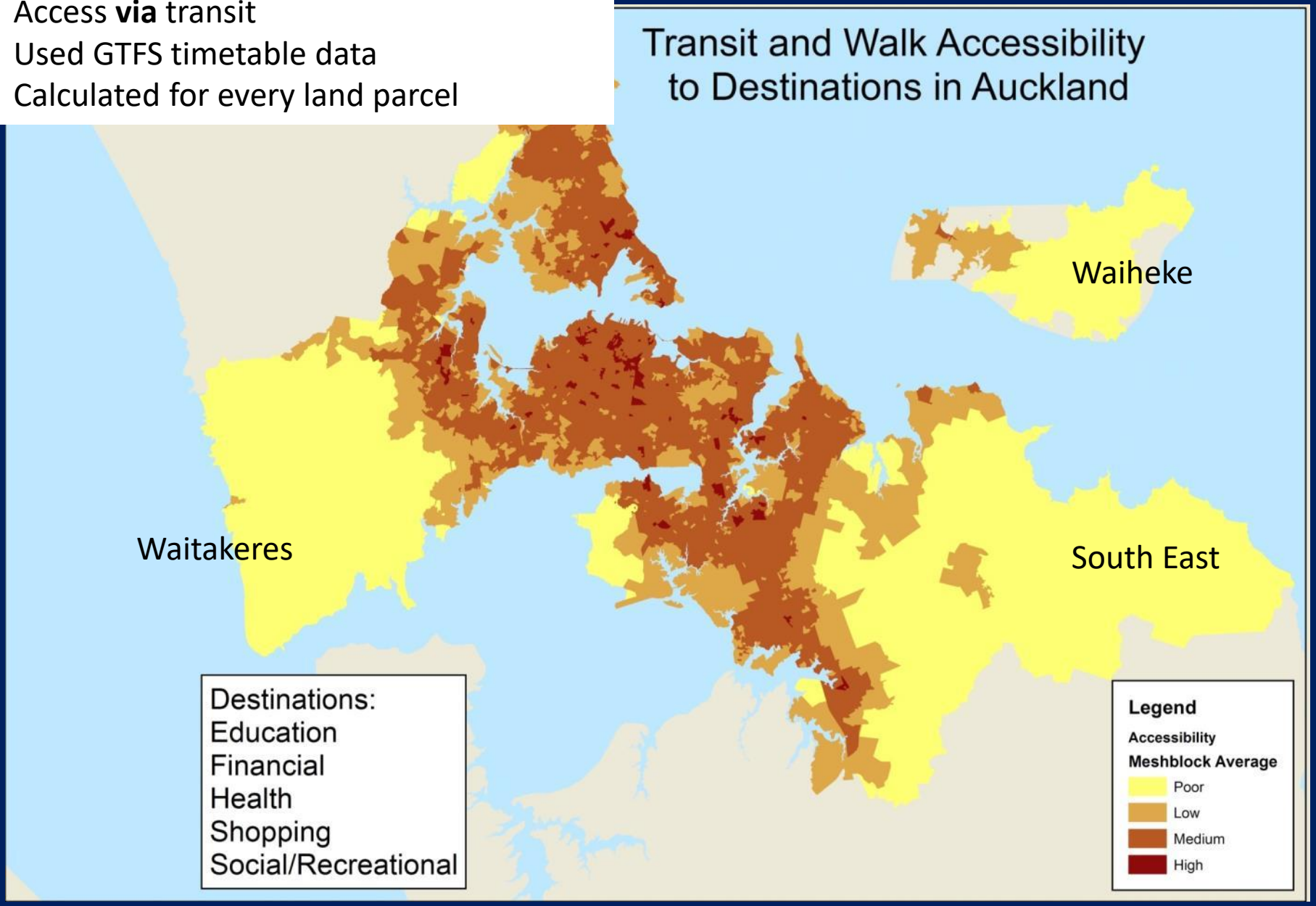
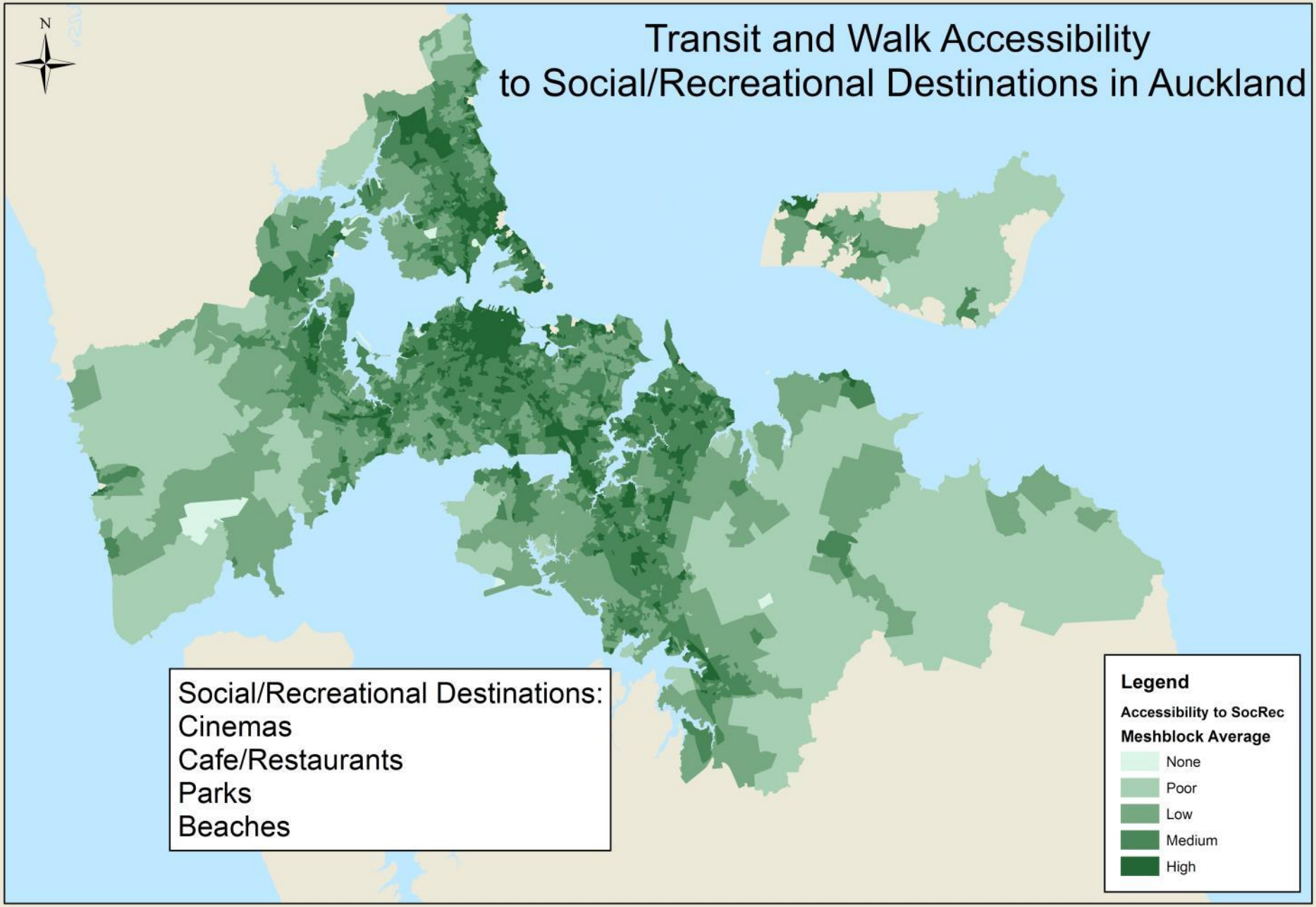
- **Measure the environment (generate/test hypotheses)**
- **Assess resource allocation/accessibility (e.g., health services, schools, water)**

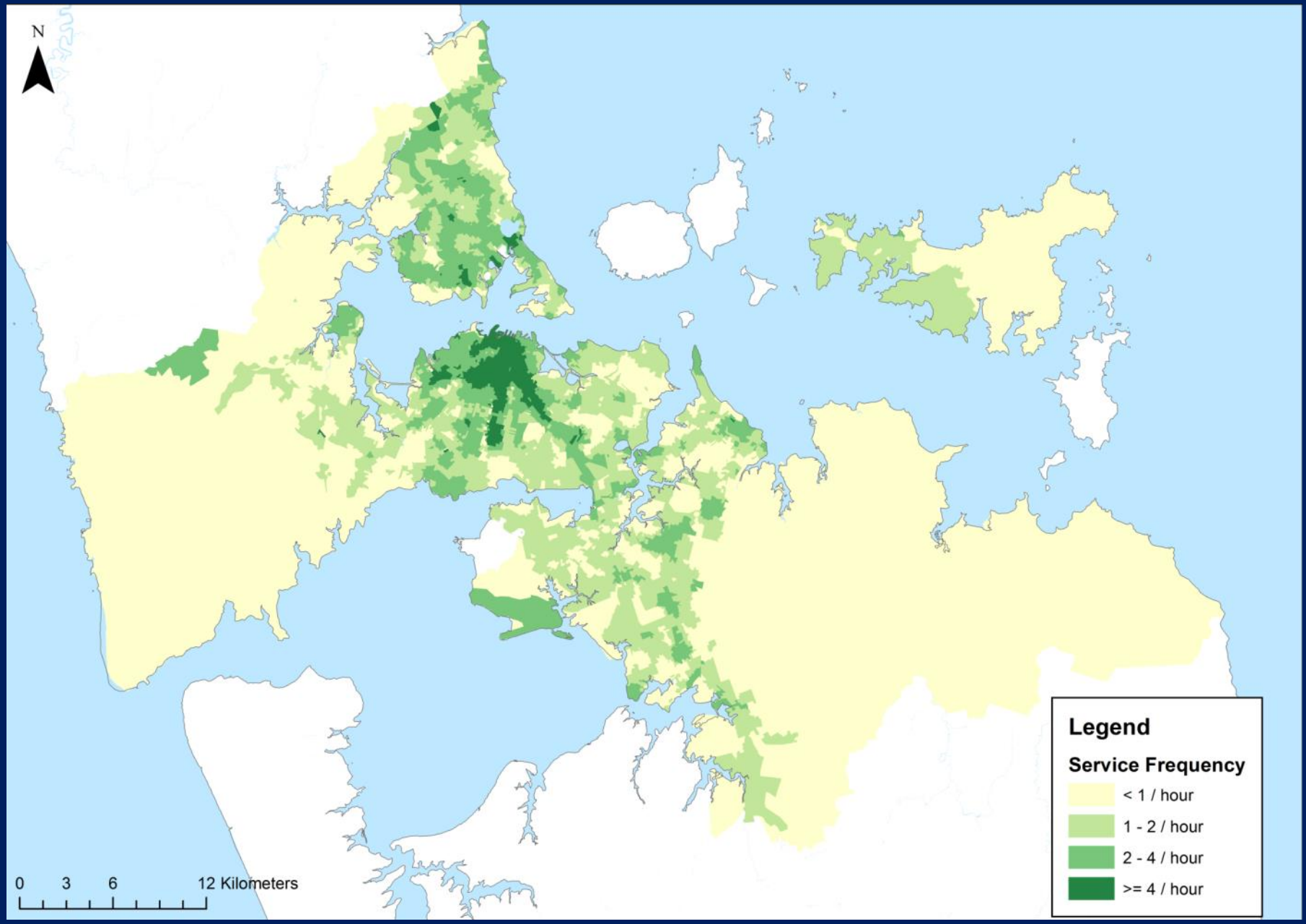
- New public transit & walk access method
- Access **via** transit
- Used GTFS timetable data
- Calculated for every land parcel



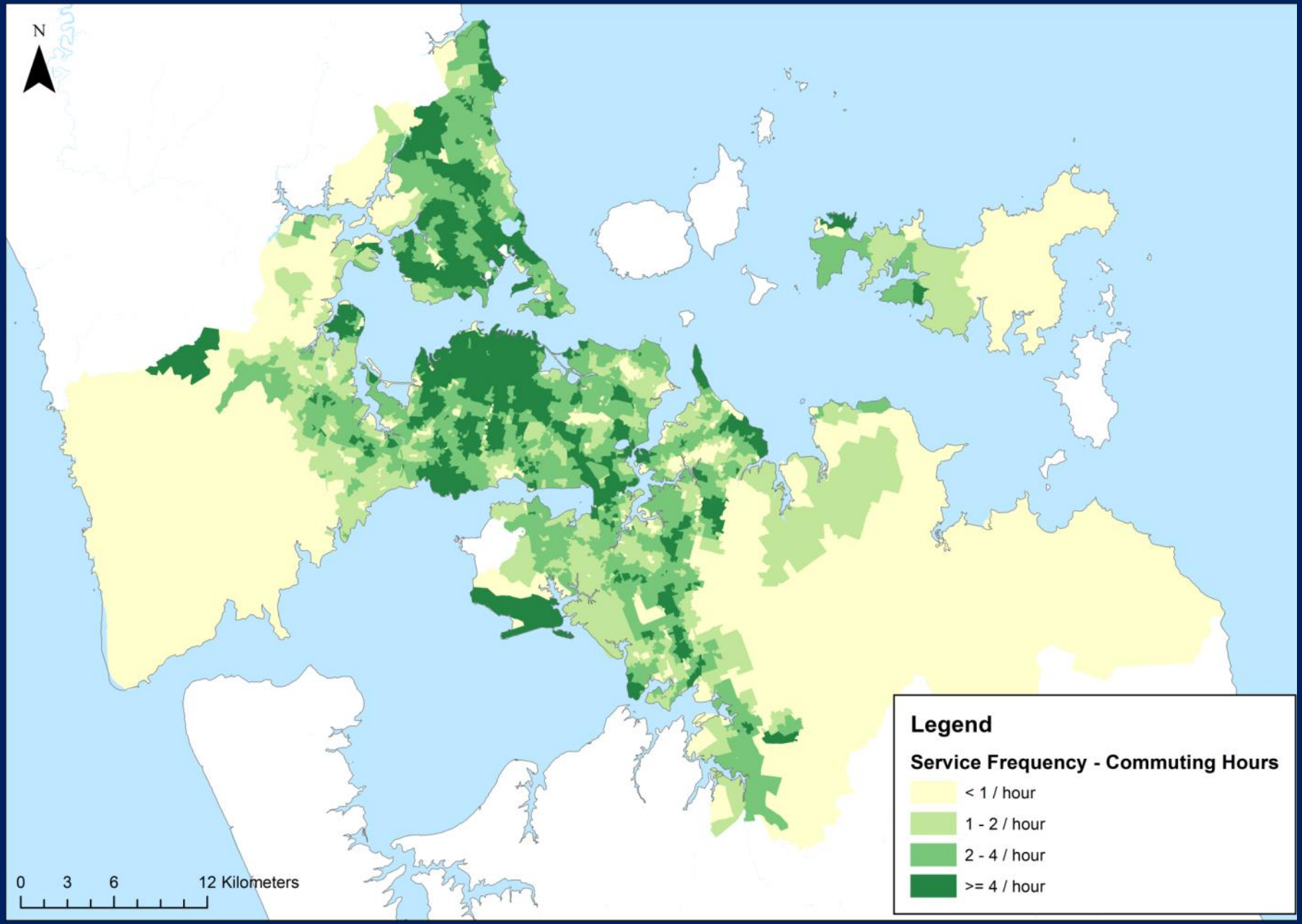
Mavoa, S., Witten, K., McCreanor, T. and O'Sullivan, D., 2012. GIS based destination accessibility via public transit and walking in Auckland, New Zealand. *Journal of Transport Geography*, *20*(1), pp.15-22.


N
Transit and Walk Accessibility
to Social/Recreational Destinations in Auckland
Social/Recreational Destinations:
Cinemas
Cafe/Restaurants
Parks
Beaches
Legend
Accessibility to SocRec
Meshblock Average
None
Poor
Low
Medium
High

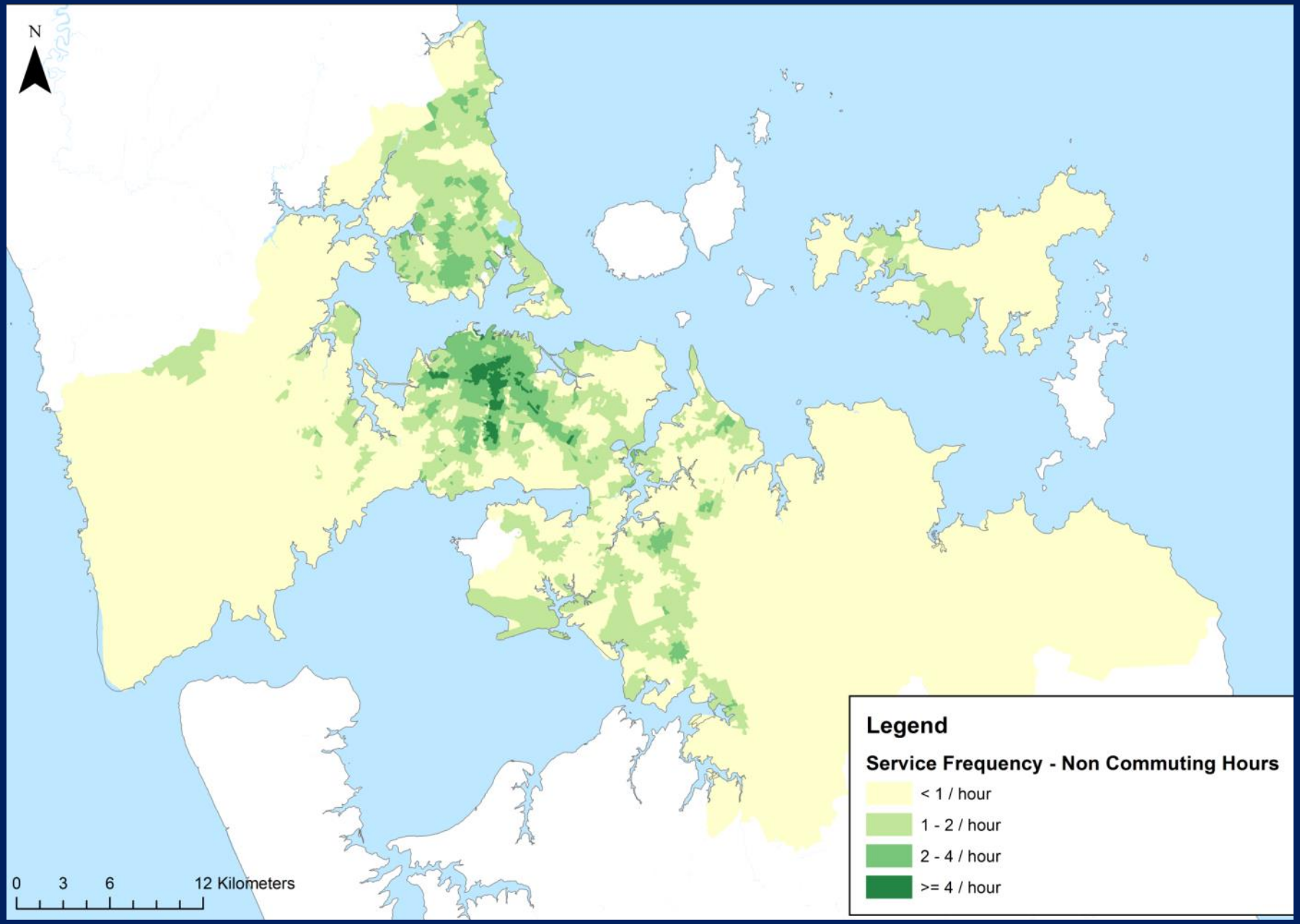
Average public transit service frequency



Average public transit service frequency during commuting hours



Average public transit service frequency during non-commuting hours



GIS applications in health – part 1

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- Measure the environment (generate/test hypotheses)
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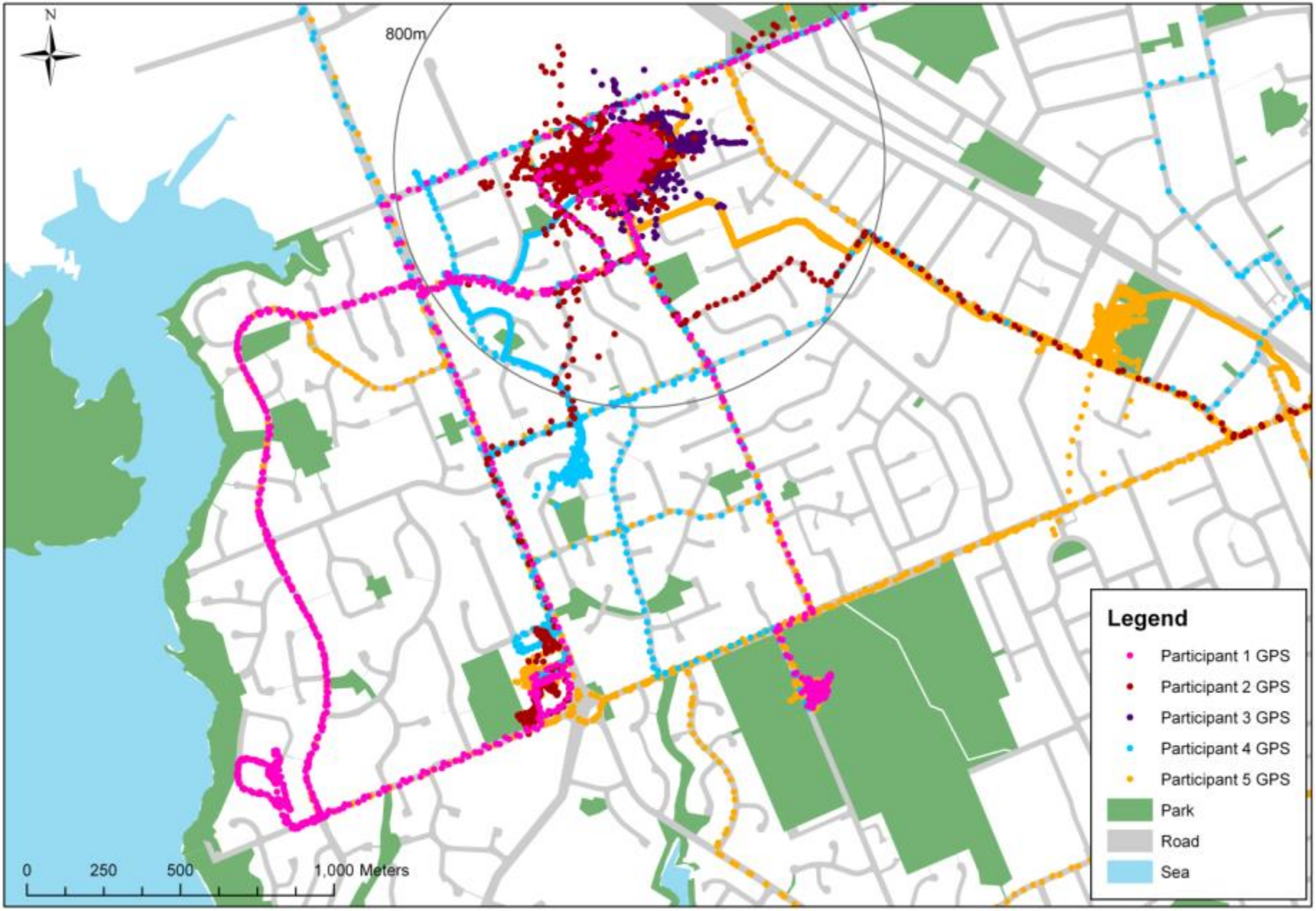
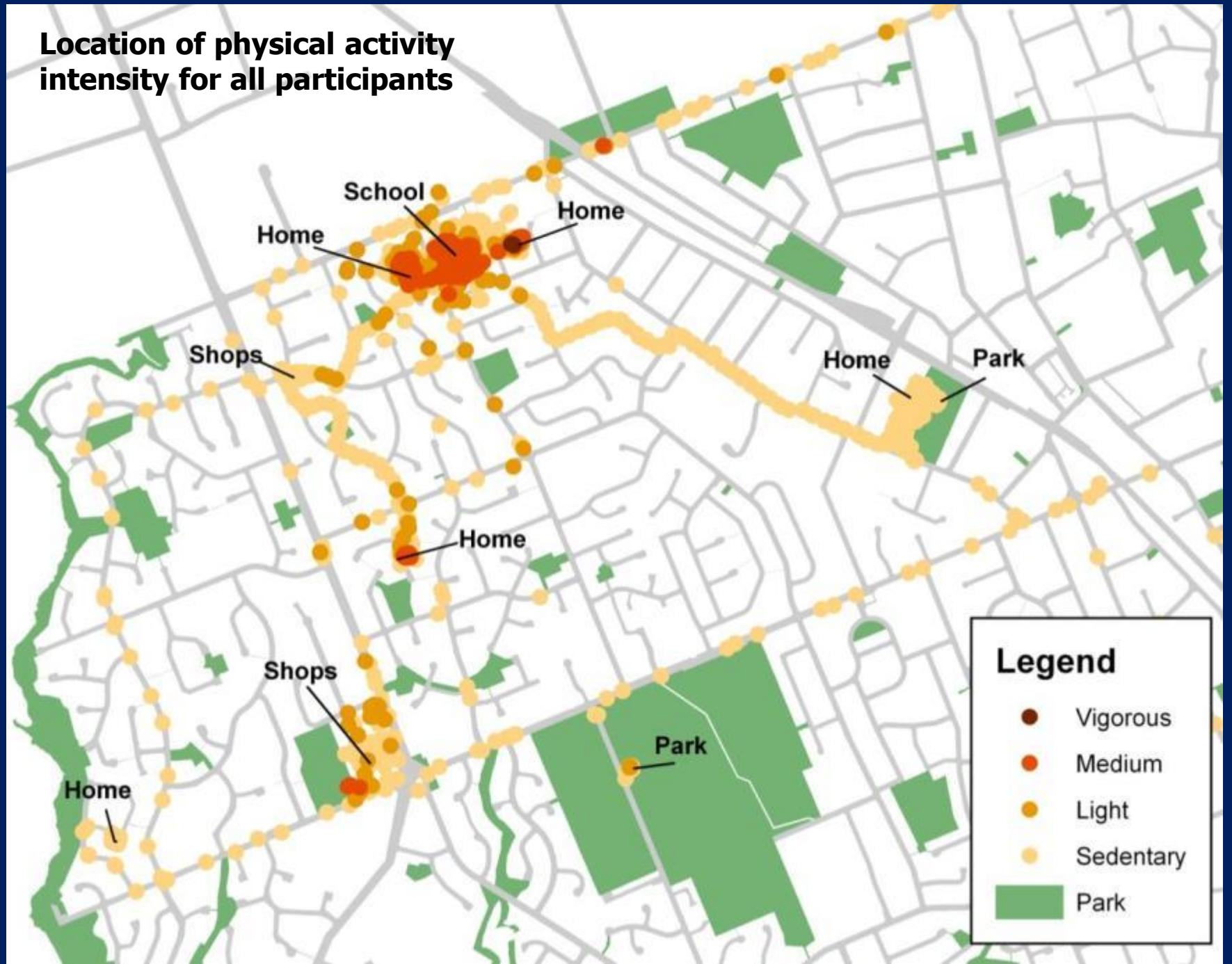
- **Estimate exposure to the environment (e.g, using GPS)**


N
800m
0
250
500
1,000 Meters
Legend
School
Home
Road
Park
Sea


N
800m
Legend
Participant 1 GPS
Participant 2 GPS
Participant 3 GPS
Participant 4 GPS
Participant 5 GPS
Park
Road
Sea
0
250
500
1,000 Meters

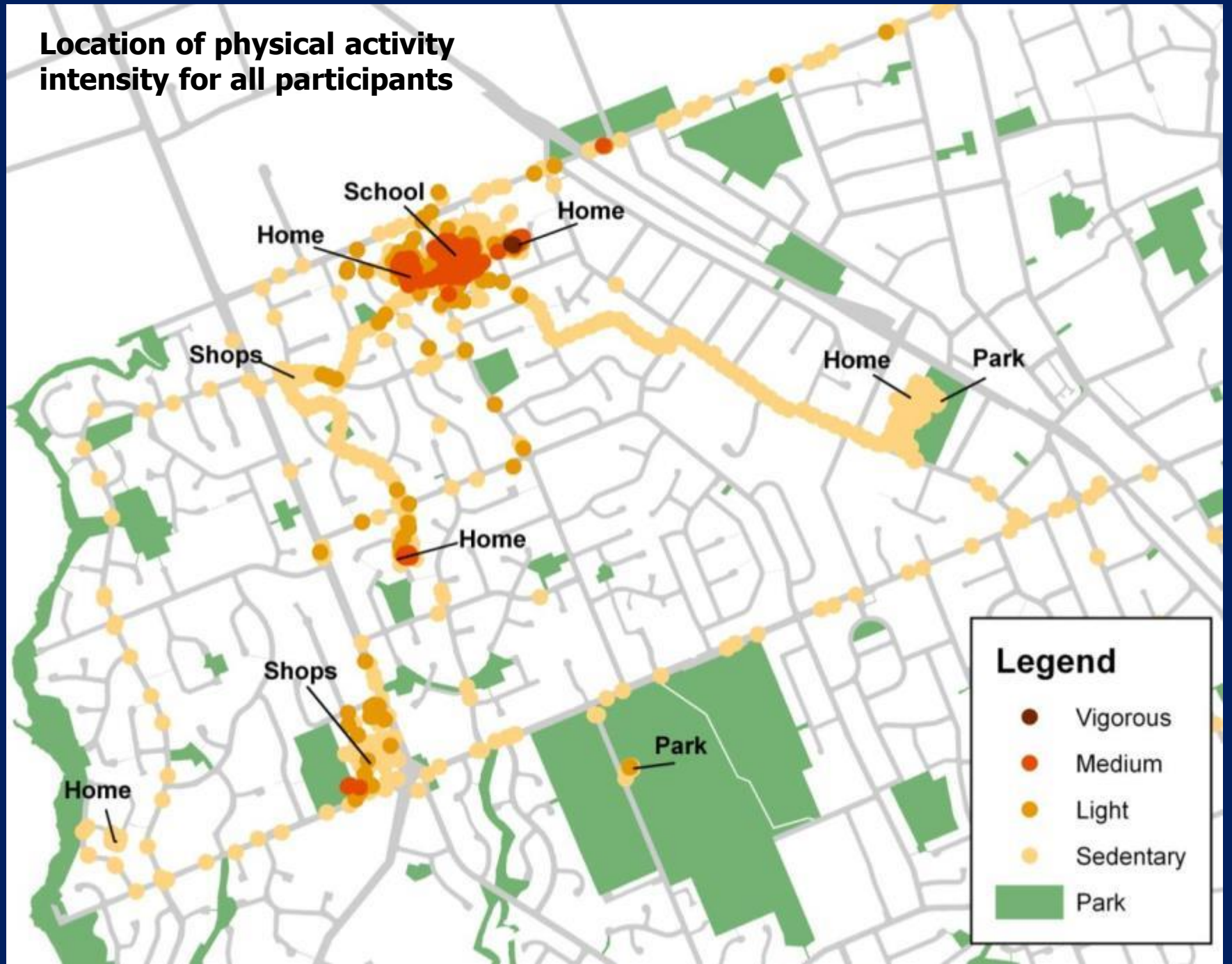
Location of physical activity intensity for all participants



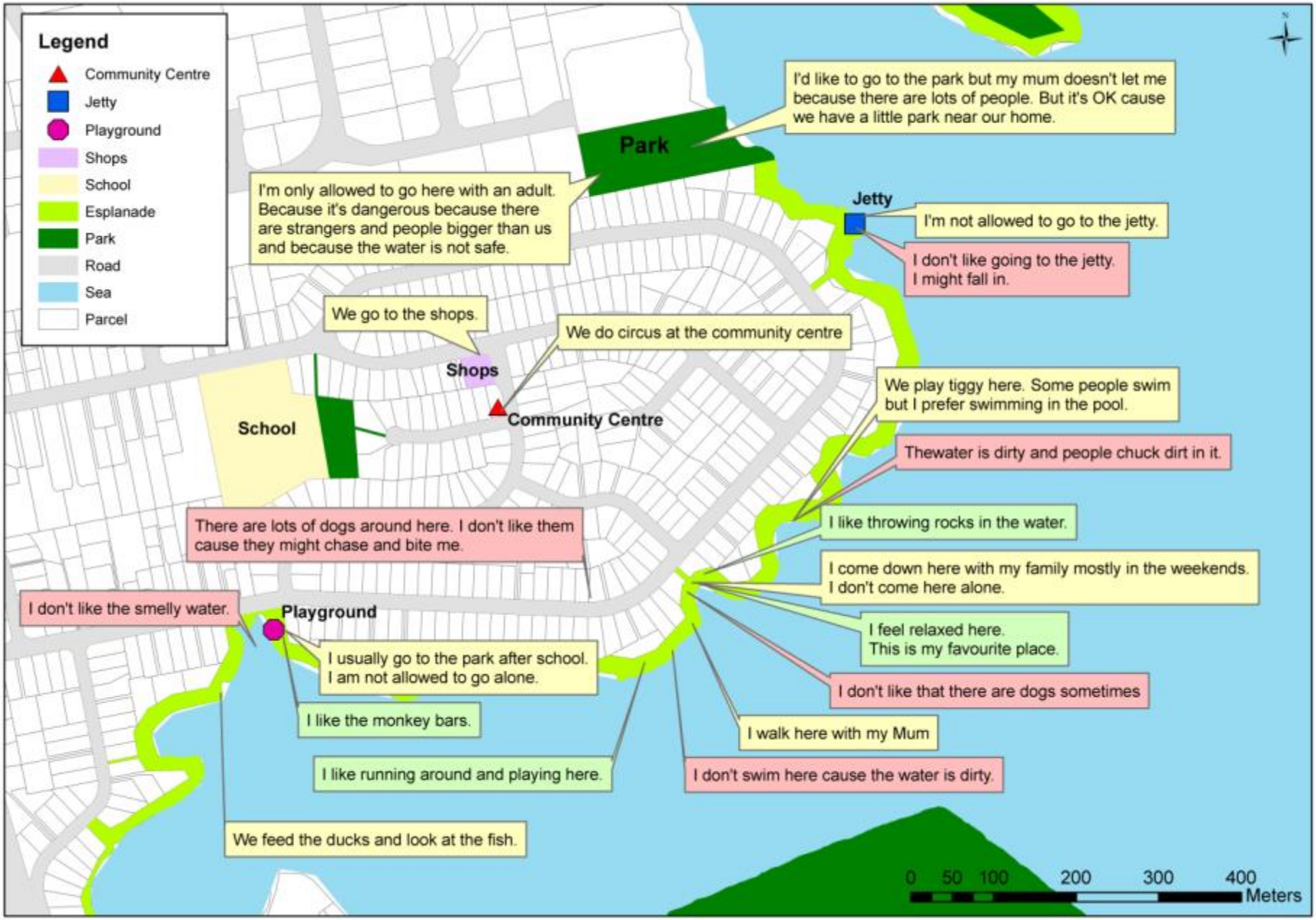
GIS applications in health – part 2

- **Mapping perceptions/qualitative data**

Location of physical activity intensity for all participants

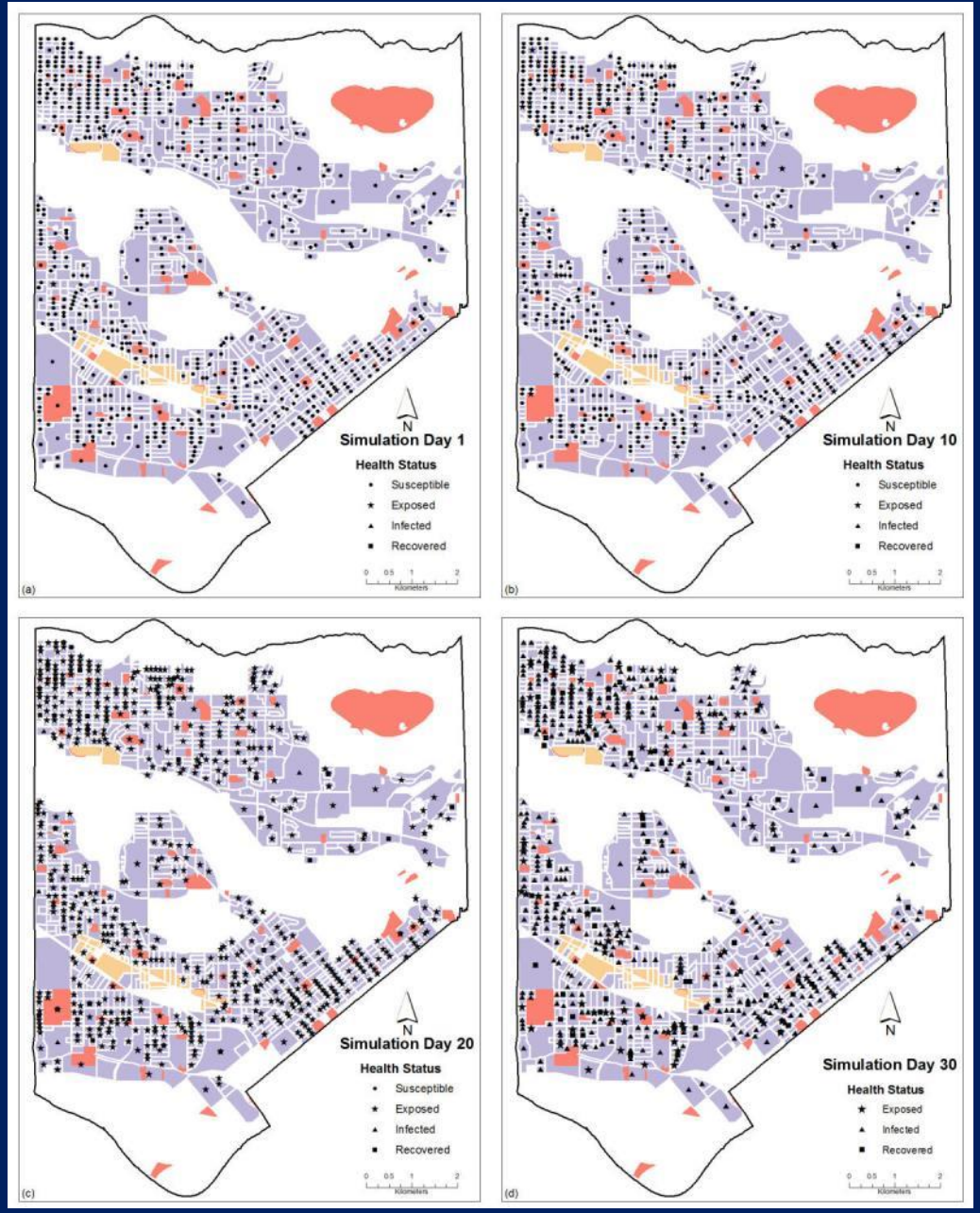



Legend
Community Centre
Jetty
Playground
Shops
School
Esplanade
Park
Road
Sea
Parcel
Park
Jetty
Shops
Community Centre
School
Playground
0 50 100 200 300 400
Meters


Legend
Community Centre
Jetty
Playground
Shops
School
Esplanade
Park
Road
Sea
Parcel
Park
I'd like to go to the park but my mum doesn't let me because there are lots of people. But it's OK cause we have a little park near our home.
I'm only allowed to go here with an adult. Because it's dangerous because there are strangers and people bigger than us and because the water is not safe.
Jetty
I'm not allowed to go to the jetty.
I don't like going to the jetty. I might fall in.
We go to the shops.
We do circus at the community centre
Shops
Community Centre
School
We play tiggy here. Some people swim but I prefer swimming in the pool.
Thewater is dirty and people chuck dirt in it.
There are lots of dogs around here. I don't like them cause they might chase and bite me.
I like throwing rocks in the water.
I come down here with my family mostly in the weekends. I don't come here alone.
I don't like the smelly water.
Playground
I feel relaxed here. This is my favourite place.
I usually go to the park after school. I am not allowed to go alone.
I don't like that there are dogs sometimes
I like the monkey bars.
I walk here with my Mum
I like running around and playing here.
I don't swim here cause the water is dirty.
We feed the ducks and look at the fish.
0 50 100 200 300 400
Meters

GIS applications in health – part 2

- Mapping perceptions/qualitative data
- **Simulating spatial behaviour (e.g, disease transmission, walking)**



Perez, L. and Dragicevic, S., 2009. An agent-based approach for modeling dynamics of contagious disease spread. *International journal of health geographics*, *8*(1), p.50.

GIS applications in health – part 2

- Simulating spatial behaviour (e.g, disease transmission, walking)
- Mapping perceptions/qualitative data
- **Measuring health-related policy implementation/progress**

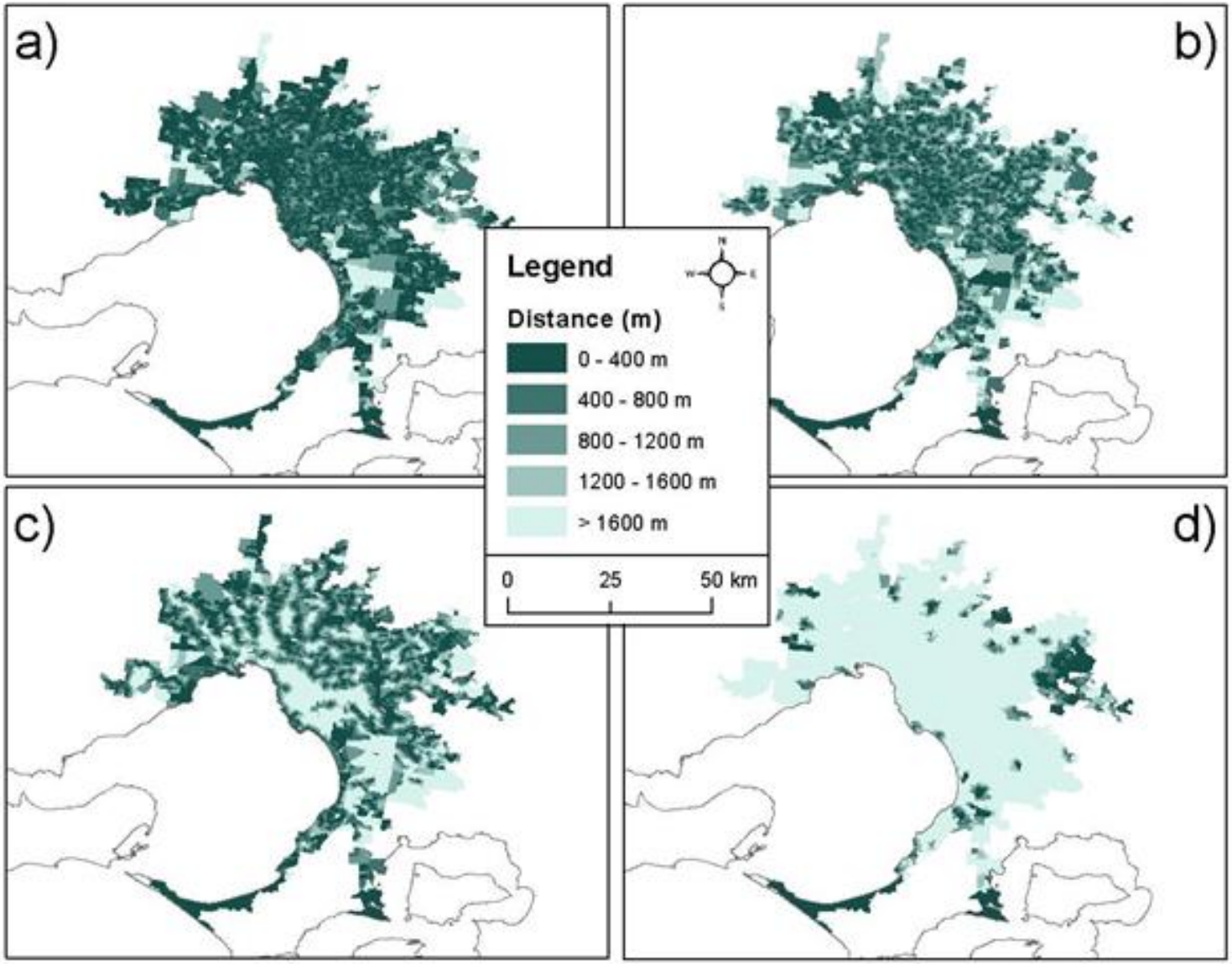
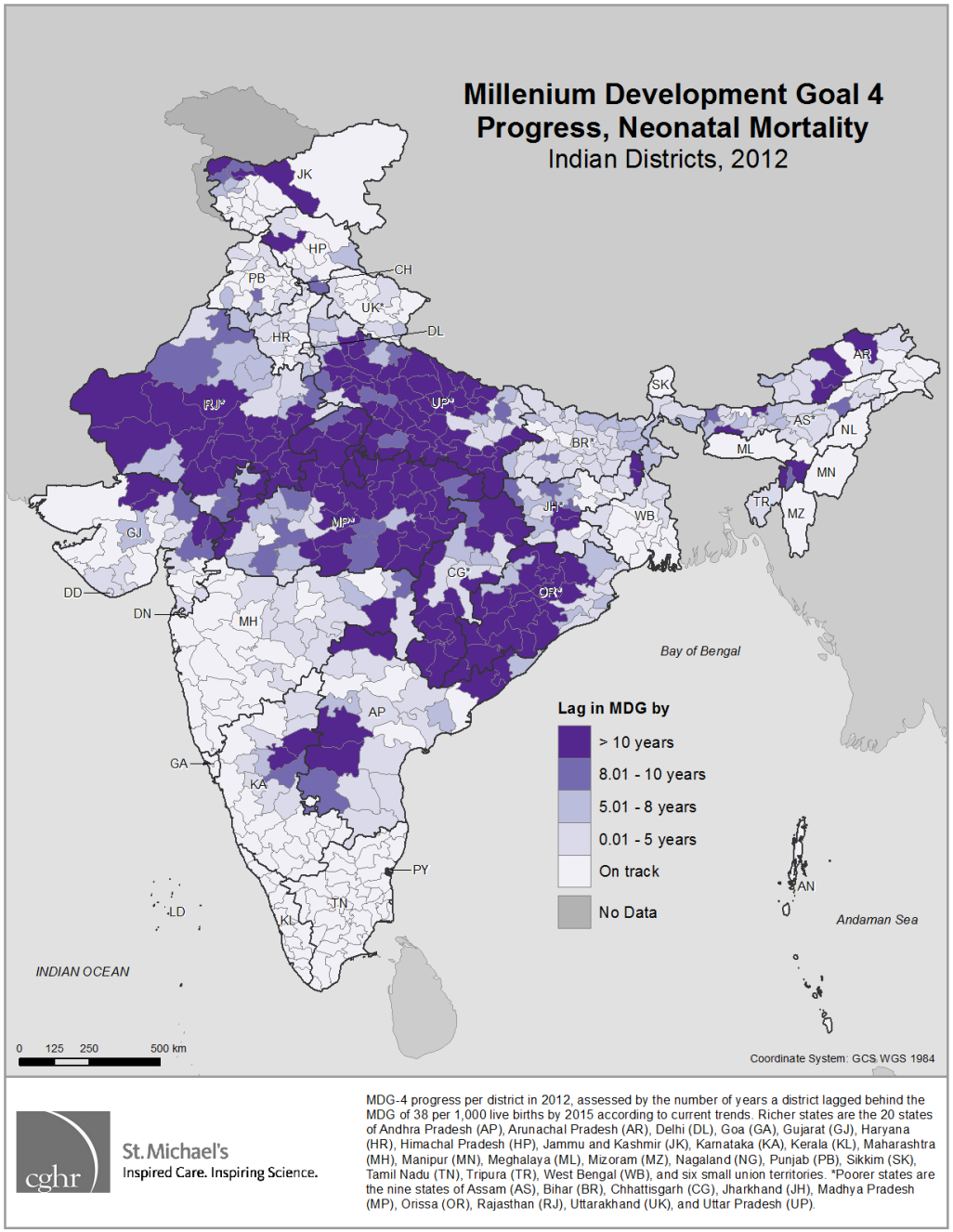


Figure 3. Distance (m) from SA1 population weighted centroid to closest a) park or garden, b) organised recreation area, c) natural or semi-natural area, and d) protected area in metropolitan Melbourne.



India Health Map: http://indiahealthmap.vm-host.net/IndiaHealthMap/

GIS applications in health – part 2

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- **Targeting interventions**
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- **Assisting in research design and data collection (E.g., identifying study area, design of sample frames)**

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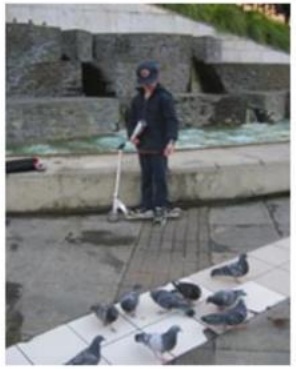
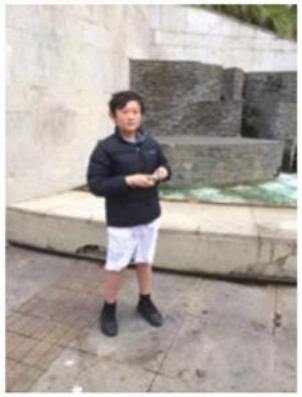
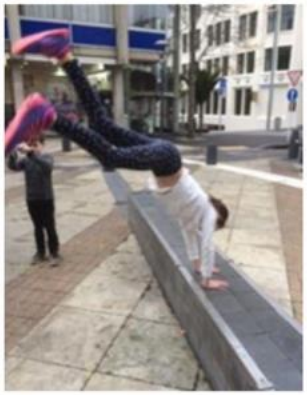
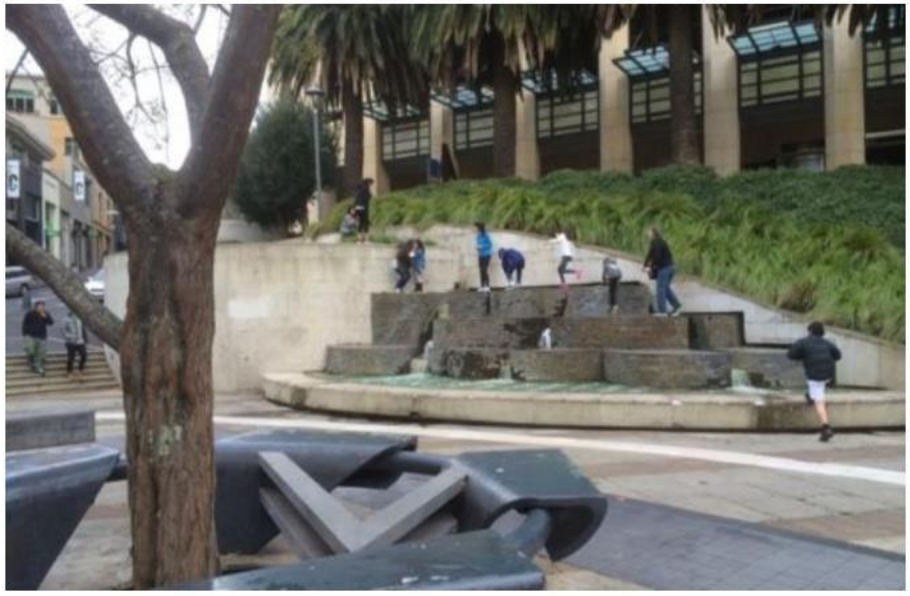
- **Communication/knowledge translation/community engagement**

Kids in the City – child friendly urban design audit





"The water feature was the first thing I saw and the first thing I went to. It was an interactive feature – it wasn't just taking up a chunk of space. It was fun climbing to the top."

"A group of kids could have like a scavenger hunt around the statue and it could be like an adventure."

"I like the water, how it comes down, the noise it makes."

"A drinking fountain."

"I'd come on a warm day with one of my friends, scooter around, go up into the tree, play on a playground – and I'd probably feed the birds."

"No cars should be allowed to drive in."

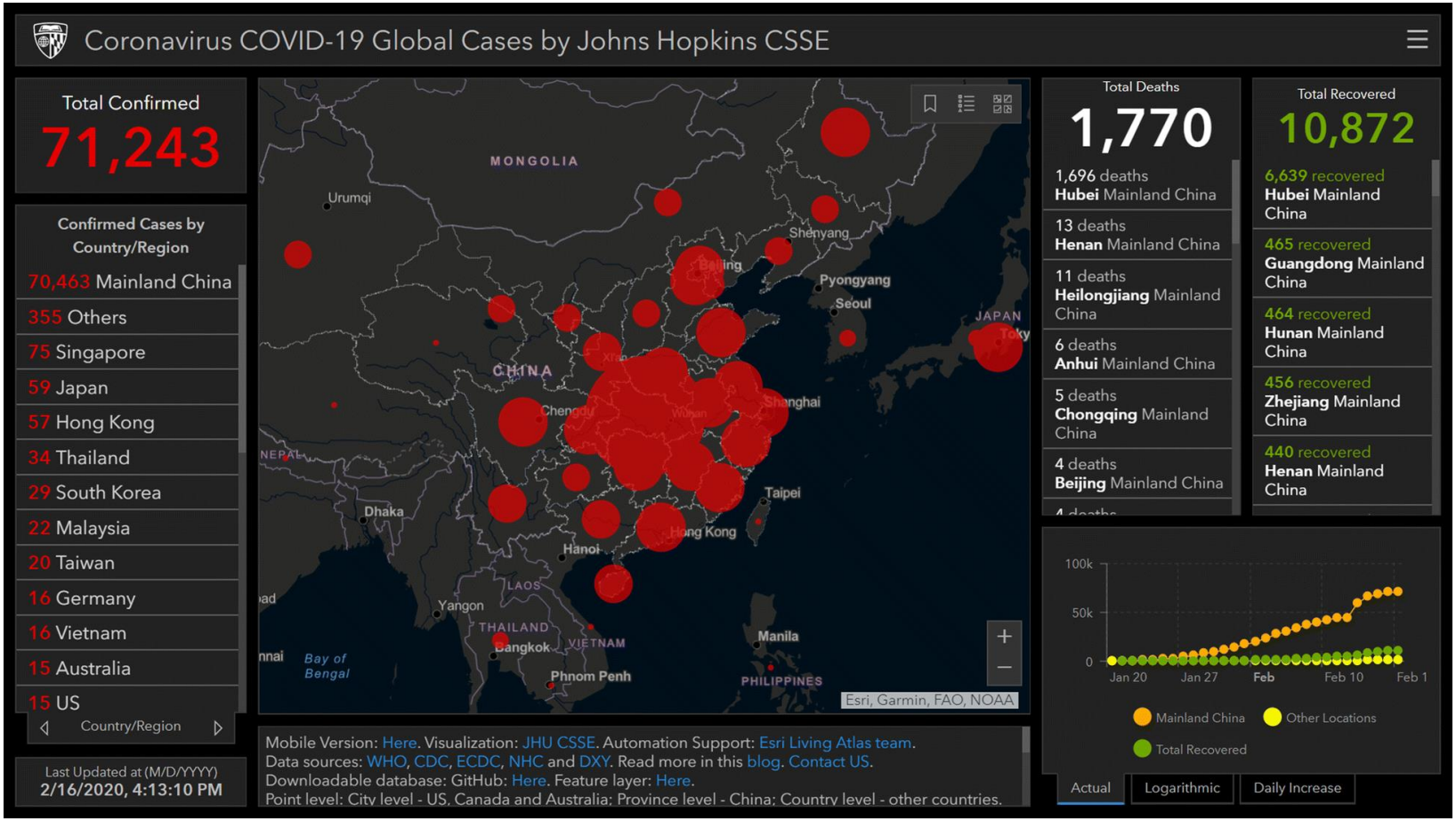
Aerial perspective view of Pioneer Women's & Ellen Melville Hall and Freyberg Square showing the removal of the Freyberg Place roadway to create an integrated public space and community hall. Concrete seating terraces and steps extend up the bank towards the Metropolis, interspersed with native tree and shrub plantings and an interactive water feature, creating a destination public space in the city.

AERIAL PERSPECTIVE

How 21st century GIS technologies are supporting the global fight against outbreaks and epidemics

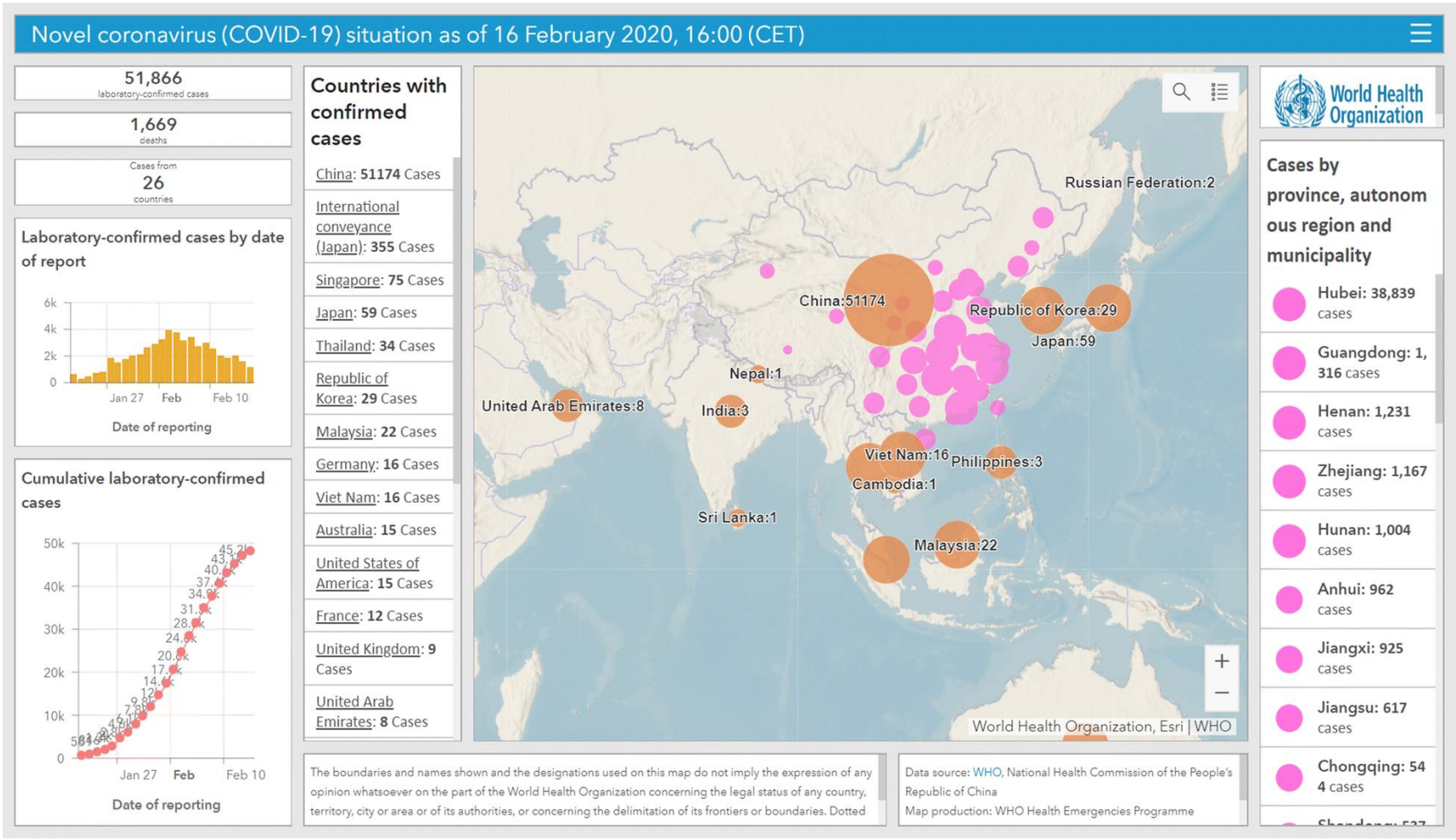
Boulos, M.N.K. and Geraghty, E.M., 2020. Geographical tracking and mapping of coronavirus disease COVID-19/severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) epidemic and associated events around the world: how 21st century GIS technologies are supporting the global fight against outbreaks and epidemics.

Map-based dashboards



integrating disparate information, visualisation/communication

Map-based dashboards



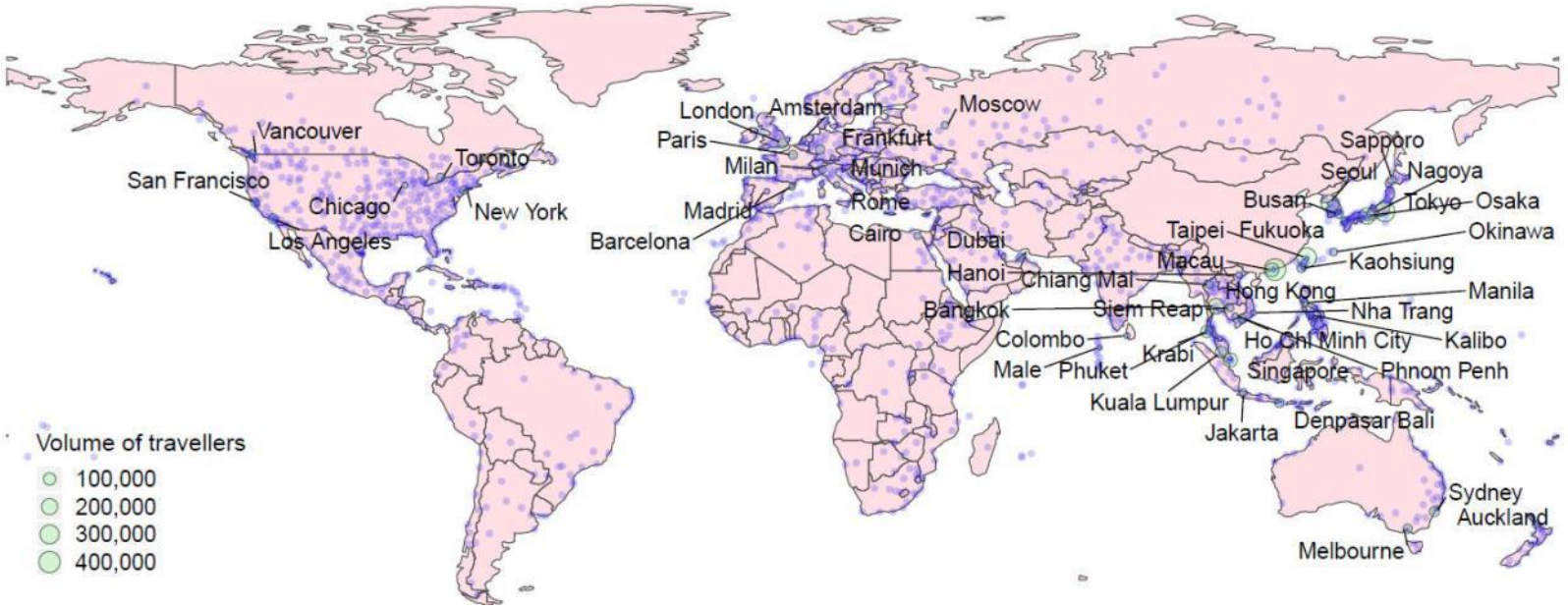
integrating disparate information, visualisation/communication

Geospatial apps ‘close contact detector’

“Functions include: close contact inquiry, including train journey number and plane flight number checking for diagnosed cases, and location information about the activity spaces of nearby confirmed cases (no individual names are ever displayed in returned results)”

integrating disparate information, data collection/creation, spatial analysis, visualisation/communication

WorldPop and EpiRisk predictive global risk analytics and maps for SARS-CoV-2 based on population movements out of Wuhan and travel destinations

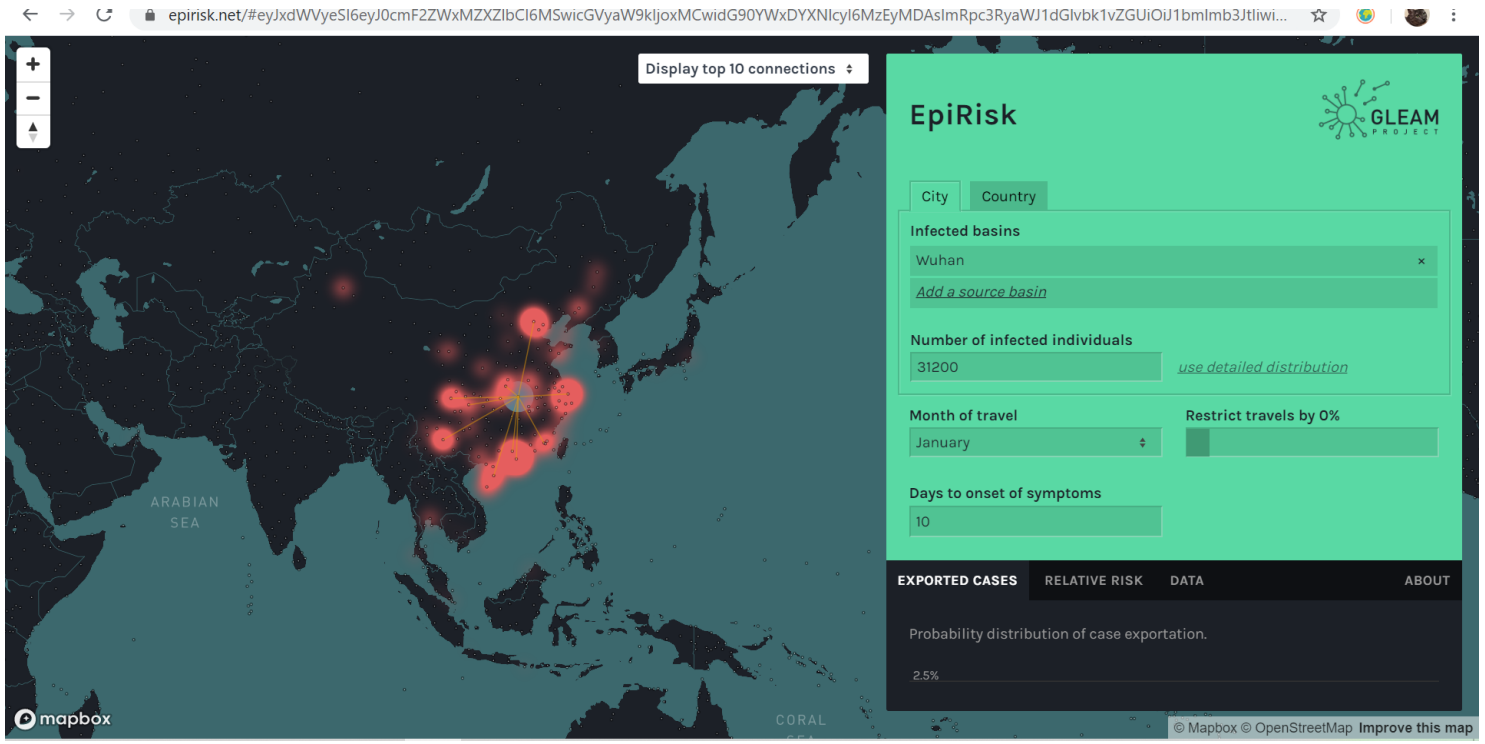


Geographic distribution of cities travellers from high risk cities in China.

Source: Lai et al. 2020: https://www.worldpop.org/events/china

Lai, S., Bogoch, I.I., Ruktanonchai, N., Watts, A.G., Li, Y., Yu, J., Lv, X., Yang, W., Hongjie, Y., Khan, K. and Li, Z., 2020. Assessing spread risk of Wuhan novel coronavirus within and beyond China, January-April 2020: a travel network-based modelling study.

WorldPop and EpiRisk predictive global risk analytics and maps for SARS-CoV-2 based on population movements out of Wuhan and travel destinations



epirisk.net
Interactive risk map

Mapping the worldwide spread of misinformation about coronavirus

Other ways GIS technologies can help in combat infectious disease outbreaks and epidemics

Outbreak source

Spatial analyses integrating phyloepidemiological methods can be used to identify the likely sources of new outbreaks.

Public events

Dashboards and Web maps that bring together location and time-sensitive events to help assess and reduce exposure.

Site selection

Site selection is a common GIS application…relevant to epidemics.

Supply chain

GIS can assist in supply chain planning and management.

Resource locators

Residents of affected areas can use apps and maps to locate aid and resources (including navigation)

Drones

Transporting crucial medical supplies and patient lab sample. Reduce human contact. Used for broad disinfecting. Integrated drone and GIS technologies can help target and speed efforts in places they are needed most.

Key issues applying GIS in public health

- Data
- 2. Delineation of exposures
- 3. Self selection & scale
- 4. Other

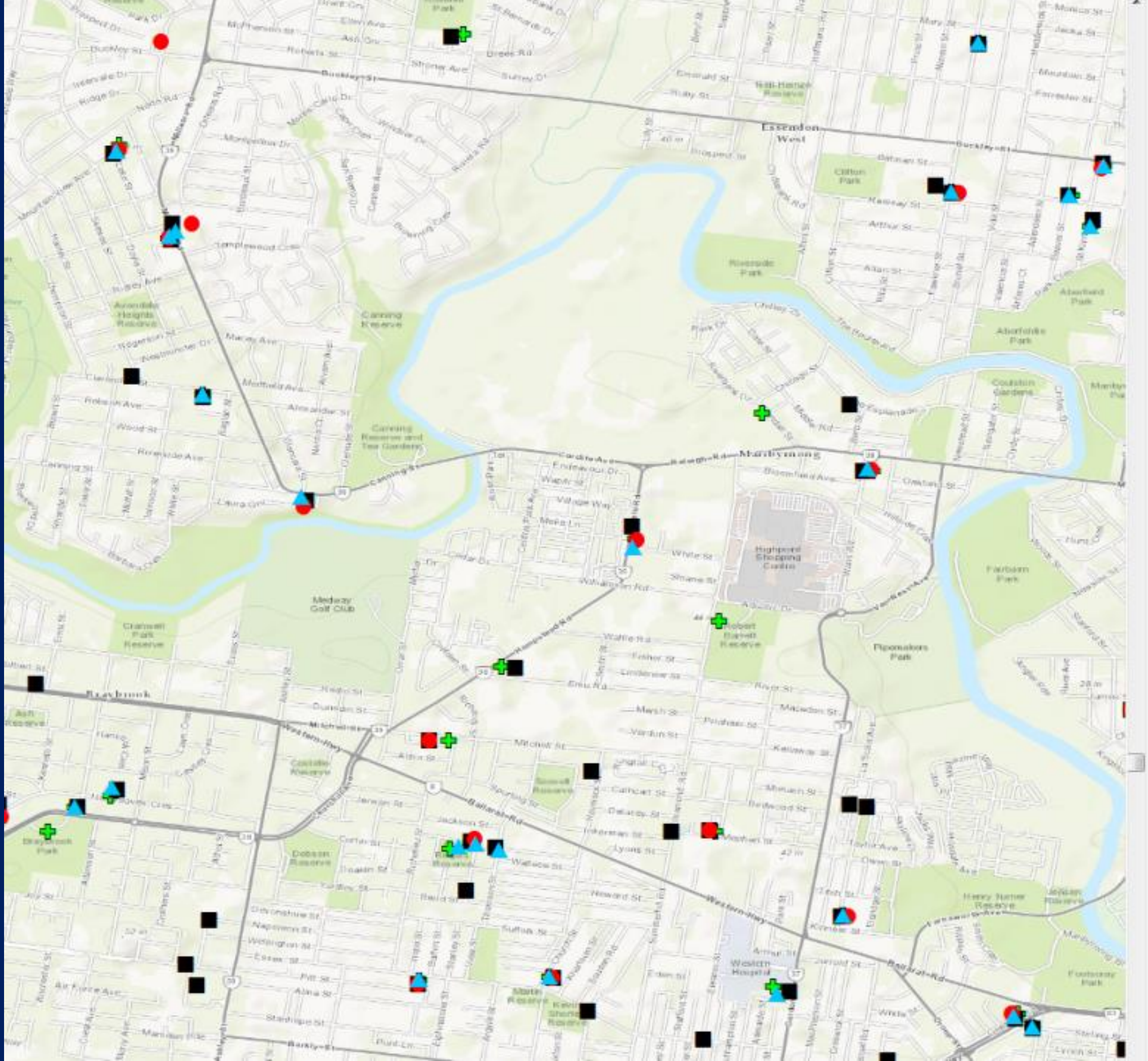
Data challenges

- Sourcing
- Licenses
- Confidentiality/Privacy/Ethics
- Cost
- Error/accuracy
- Resolution/scale/extent
- Temporal matching
- Large datasets -> computationally intensive analysis

Inconsistencies across data sources

Example: Childcare facilities in Victoria

Data source	Count
A	3966
B	4183
C	2799
S	2094



Buckley St
Essendon West
Clifton Park
Riverside Park
Canning Reserve
Canning Reserve and Tea Gardens
Maribyrnong
Highpoint Shopping Centre
Medway Golf Club
Fairbairn Park
Pipemakers Park
Braybrook
Ballarat Rd
Western Hwy
Western Hospital
Henry Turner Reserve

Supermarkets in the ocean

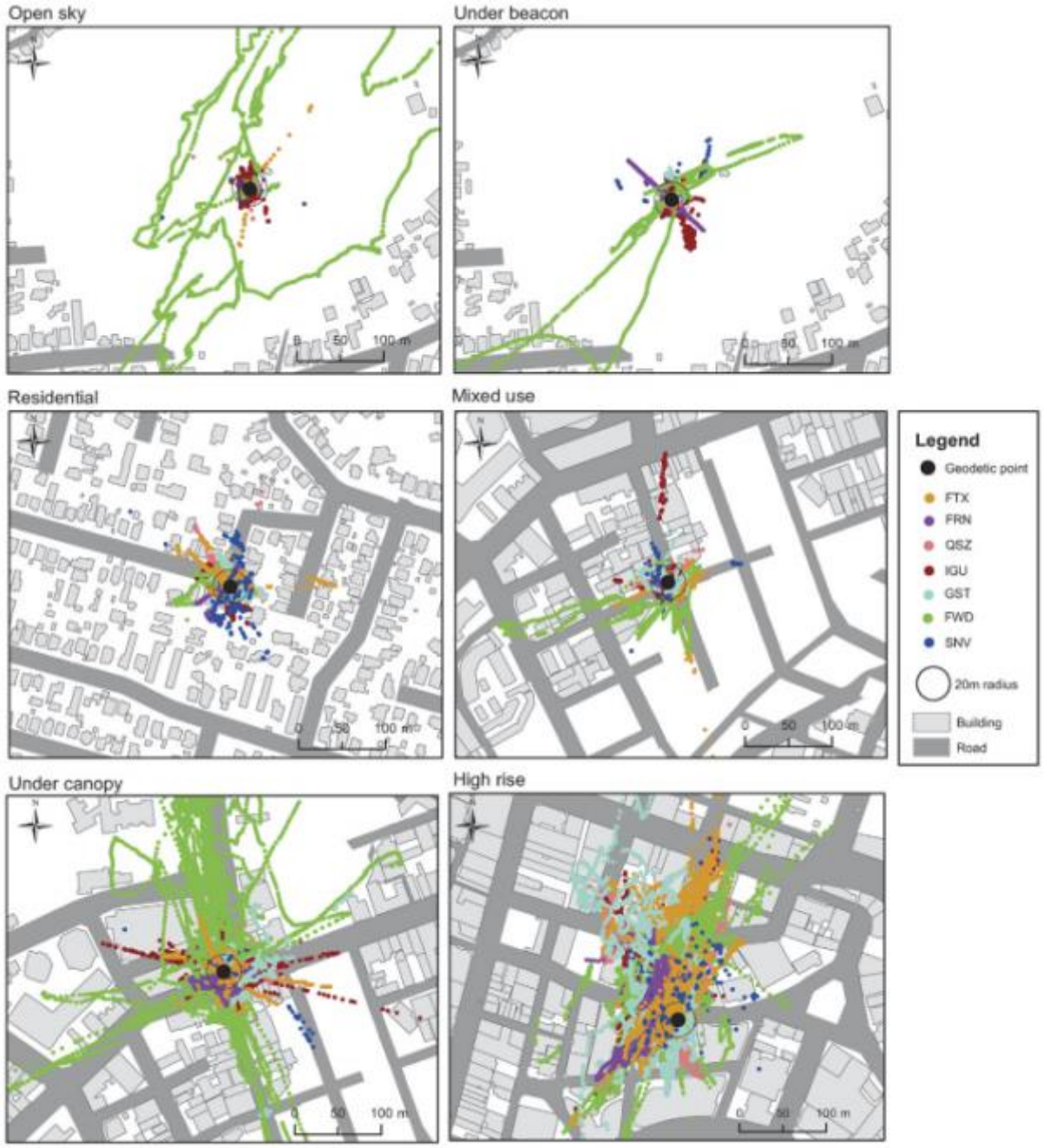


Figure 2. Geospatial distribution of GPS observations for each geodetic site

Note: FRN, Garmin Forerunner 205; FTX, Garmin Foretrex 201; FWD, FRWD B100; GST, GlobalSat TR-203; IGU, i-gotU GT-600 GPS Travel Logger; QSZ, BT-Q1000XT; SNV, StarsNav BTS-110

Duncan S, Stewart TI, Oliver M, Mavoa S, MacRae D, Badland HM, Duncan MJ. Portable global positioning system receivers: static validity and environmental conditions. American journal of preventive medicine. 2013 Feb 28;44(2):e19-29.

Issues: Delineating exposure

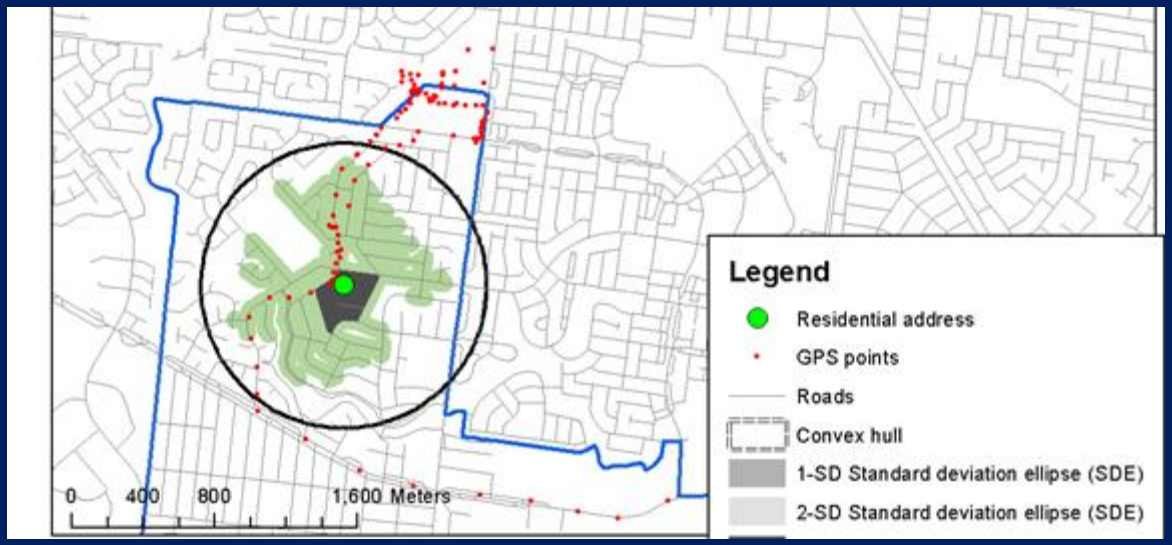
What environment?

How to delineate that environment?

Issues: Delineating exposure

What environment?

How to delineate that environment?



Issues: Self-selection and scale

- Self-selection
  - Studies neglect issue of residential mobility and selection as alternative explanations to causation
  - Need to study movers or adjust for preference
- Scale
  - Scale and extent of spatial analysis needs to match the scale and extent of the actual phenomenon or error will be introduced.

Issues: other

- Secondary data
  - Do they measure what is being examined?
  - Insufficient variation in the variables of interest between areas?
  - Lag time between exposures and disease manifestation?
- Arbitrary administrative boundaries (e.g. ABS)
  - Exposure misclassification of area level variables
  - Readily available data set area boundaries do not represent meaningful geographic communities of interest/ spatial patterning of phenomena
- The modifiable areal unit problem (MAUP)
  - Different results on how data are spatially distributed depending on the size and shape of the areal units.
- Ecological fallacy
  - Inferring individual relationships from relationships observed at a ecological level.

Thank you

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