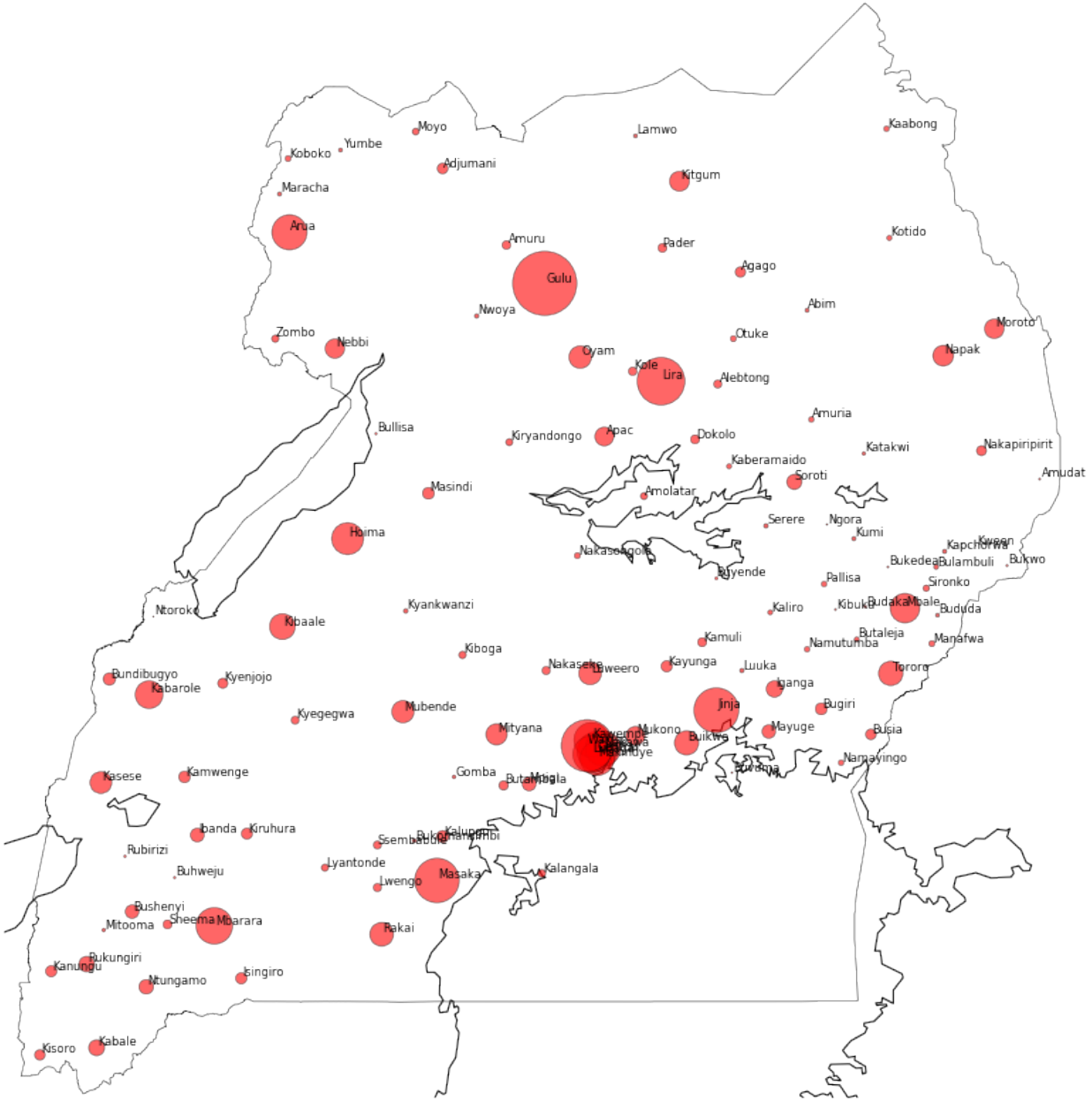
AI RESEARCH

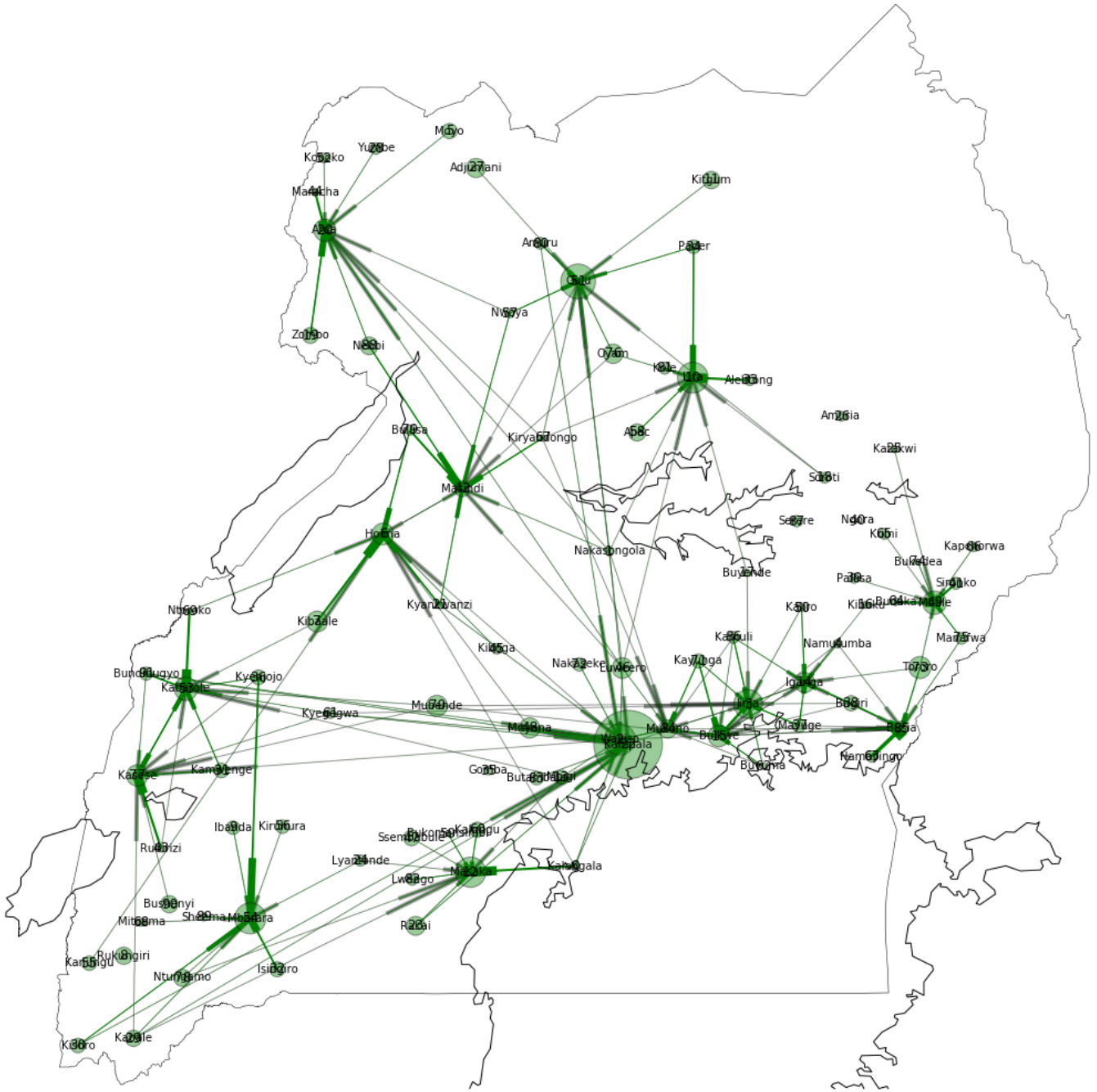
Using spatial features of human settlement to predict epidemic properties

Rahman Sanya

Data Science Africa 2017 Workshop, Jul 20th – 21st, 2017 NM-AIST Arusha Tanzania

the problem


Moyo
Yumbe
Koboko
Adjumani
Maracha
Arua
Lamwo
Kaabong
Kitgum
Amuru
Pader
Kotido
Gulu
Agago
Nwoya
Abim
Zombo
Nebbi
Otuke
Moroto
Napak
Oyam
Kole
Lira
Alebtong
Amuria
Bullisa
Kiryandongo
Apac
Dokolo
Katakwi
Nakapiripirit
Kaberamaido
Soroti
Amudat
Masindi
Amolatar
Serere
Ngora
Kumi
Hoima
Nakasongola
Bukedea
Bulambuli
Bukwo
Kapchorwa
Kwoan
Luyende
Pallisa
Sironko
Ntoroko
Kyankwanzi
Kaliro
Kibuku
Budaka
Mbale
Bududa
Kibaale
Kamuli
Butaleja
Namutumba
Manafwa
Kiboga
Nakaseke
Luweero
Kayunga
Luuka
Iganga
Tororo
Bundibugyo
Kyenjojo
Kabarole
Jinja
Bugiri
Kyegegwa
Mubende
Mityana
Mukono
Mayuge
Busia
Buikwe
Namayingo
Kasese
Kamwenge
Gomba
Kiruhura
Ibanda
Rubirizi
Ssembabule
Lyantonde
Buhweju
Masaka
Kalangala
Lwengo
Bushenyi
Sheema
Mbarara
Mitooma
Rakai
Rukungiri
Kanungu
Ntungamo
Isingiro
Kisoro
Kabale


2-tier hierarchical population mobility in Uganda in 2013

the goal

Understand how settlement characteristics implicate observed spatial epidemic pattern

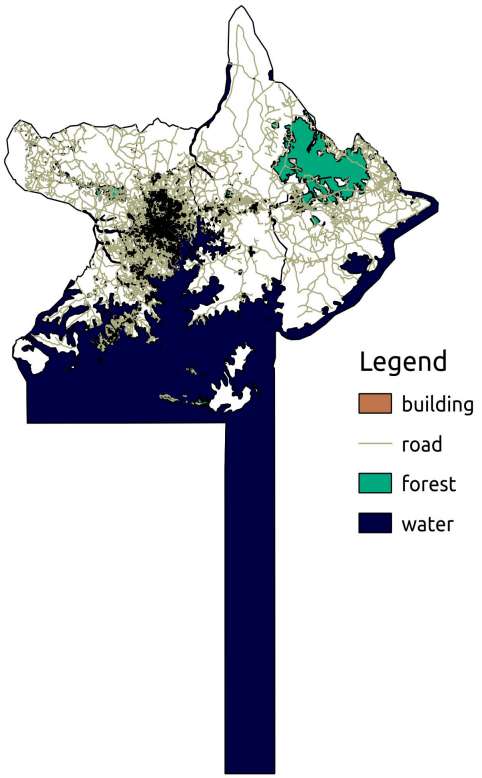
Features we want to explore

- urbanization, accessibility, mobility flux, connectivity, and population density

In this talk: urbanization

- Look for relationship between urban density & spatial epidemic dynamic
- How best to investigate potential relationship

study area



- Four contiguous LAU 4’s
- Pop size 4,524,073
- Area size 5,114.3 km^2
- 58.95 % urban
- Built-up, bare soil, vegetation, water

data sources

Satellite imagery (Landsat 8) from USGS

- 11 bands, cloud < 10%, 30m spatial res

Geospatial dataset (OSM) from Geofabrik

- road network, building blocks

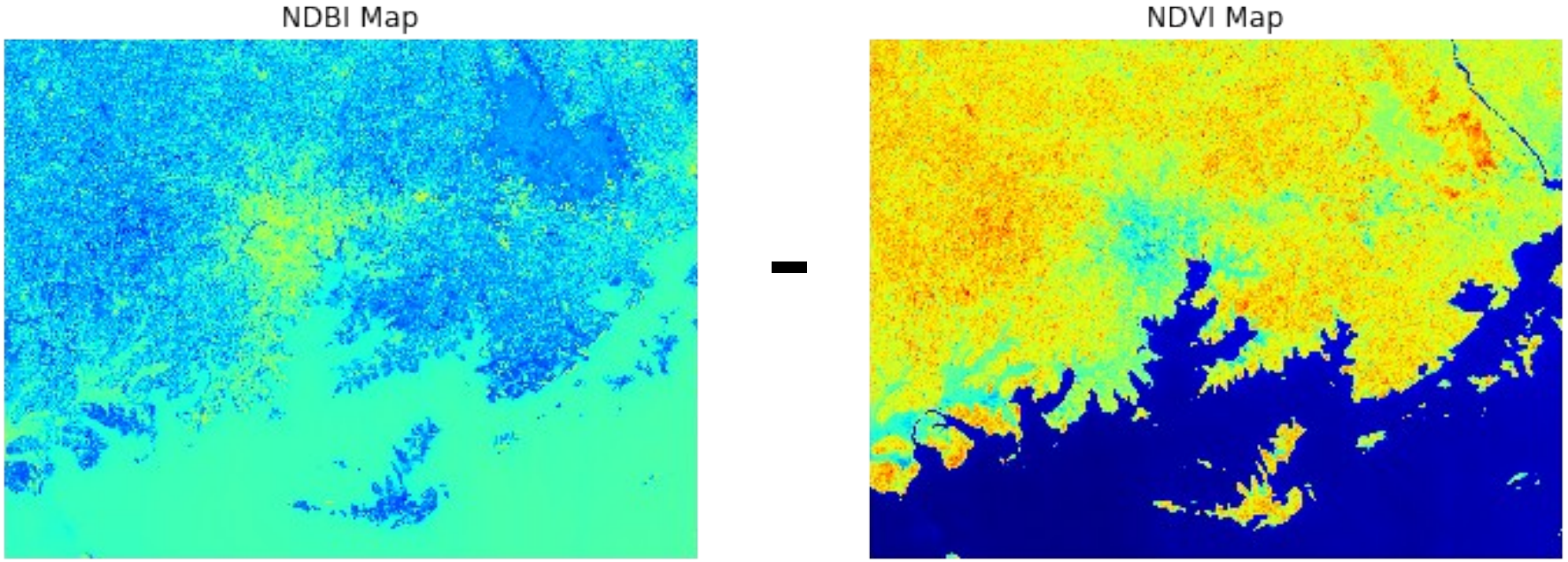
Disease case (DHMIS2)

- TB, HIV/AIDS

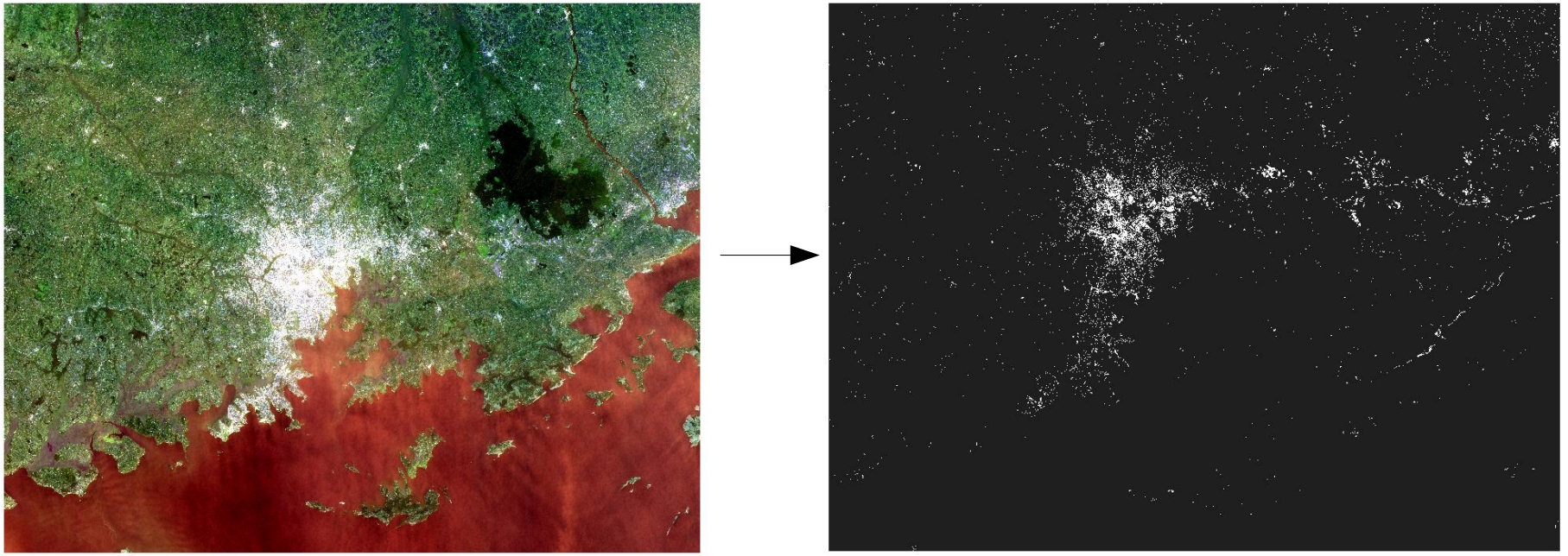
general approach

- Map settlements, quantify urban
- Classify settlements into rural or urban
  - urban is 'a place dominated by built environment'
- Model relationship between urban concentration and disease dynamics

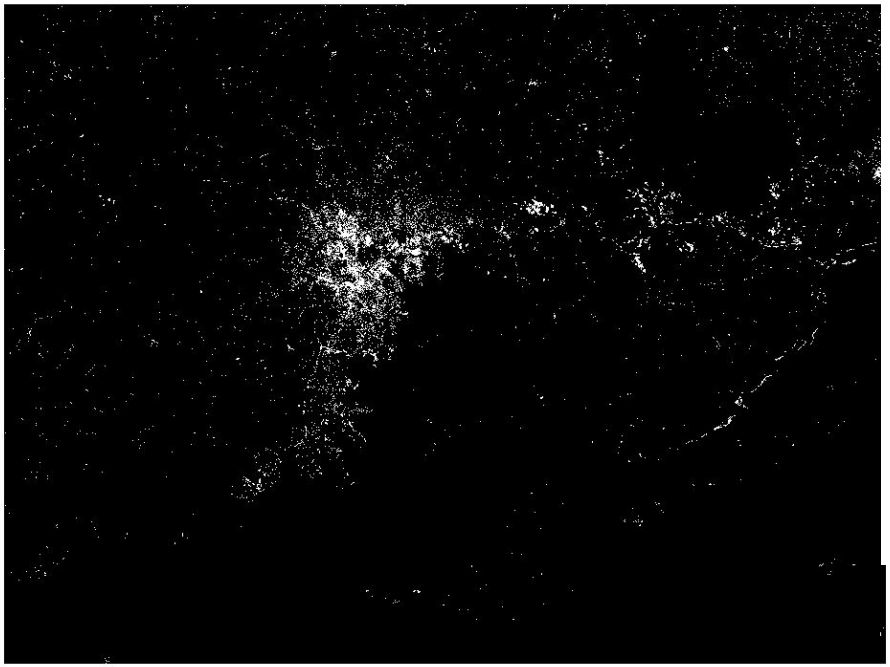
Extract built-up footprint

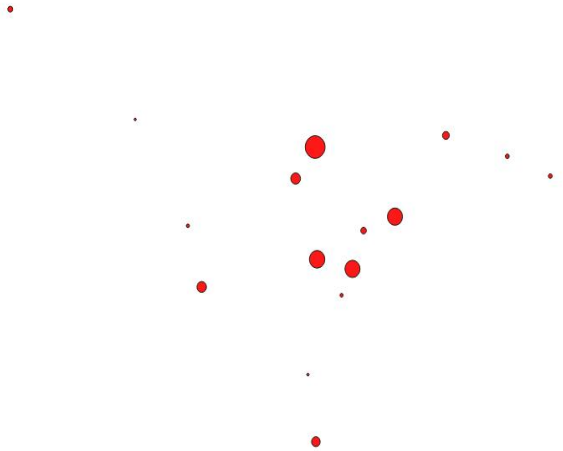


built-up footprint



urban density vs. case distribution





road density

we want to...

relate features to epidemic properties

Using mutual information *I*,

$$I(X;Y)=H(X)+H(Y)-H(X,Y)$$

where

$$H(t)=\frac{-1}{\log V}\sum_j \gamma_j(t)\log\gamma_j(t)$$

extract communities

Using agglomerative hierarchical clustering

$$\chi^{o}_{mn} = \frac{J_{(mn)}}{min(k_m, k_n) + 1 - \theta(A_{mn})}$$

where

X^o is topological overlap matrix
$J_{(mn)}$ is no. of shared neighbors of nodes *m, n*
k is node degree
$\Theta(A_{mn})$ is Heaviside step function

relate pattern across nodes

Node pairs expected to have similar epidemic properties if they

- share neighbors
- have direct link between them
- have comparable spatial features

relate pattern across nodes

Epidemic similarity between nodes *m, n*

$$\phi_{mn} = \frac{\rho_m}{\rho_n} = \frac{\rho_n}{\rho_m} \qquad \rho_m \approx \rho_n ; \vartheta_m \approx \vartheta_n$$

$$\rho = {i_m}/{\sum_n i_n} \qquad \text{and} \qquad i(t) = {I(t)}/{N}$$

$\phi = 1$ if nodes *m, n* have similar epidemic properties

$\phi > 1 ; \phi < 1$ otherwise

conclusion

- Its early days to conclude

- However, our goal is to explore predictive potential of five spatial settlement features for epidemic modeling in coupled human population systems