



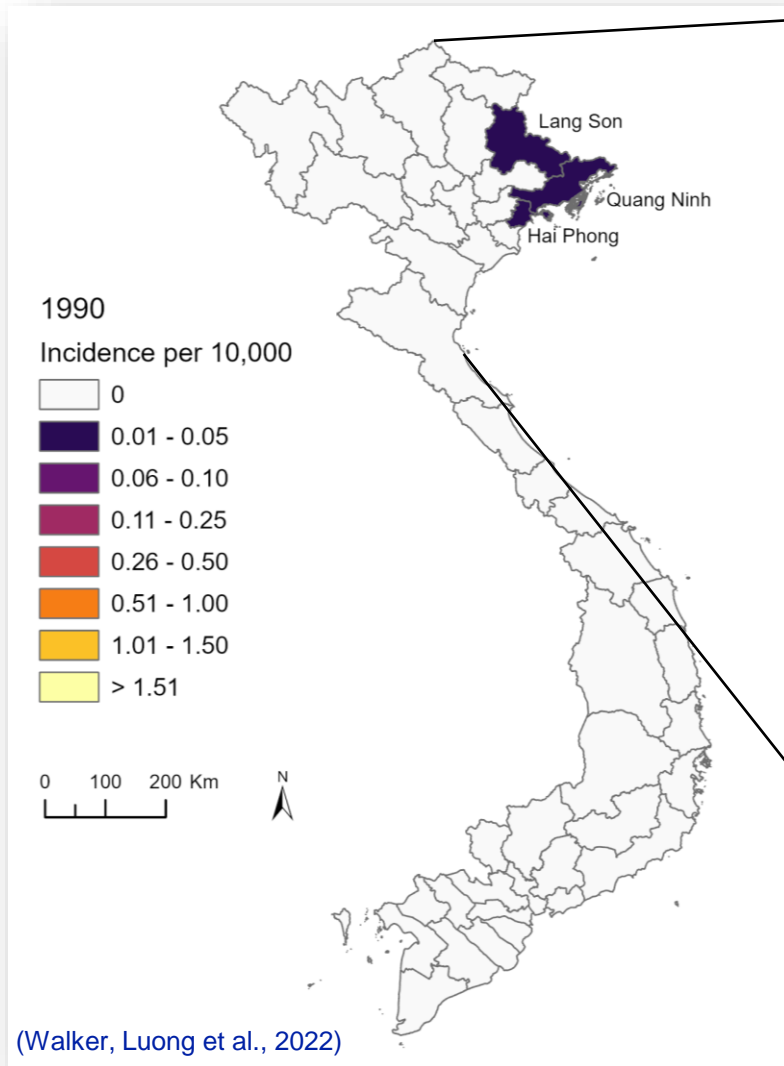
Spatial Epidemiology of Anthrax and the significance of livestock anthrax vaccination in Dien Bien province, Vietnam (2010-2019)

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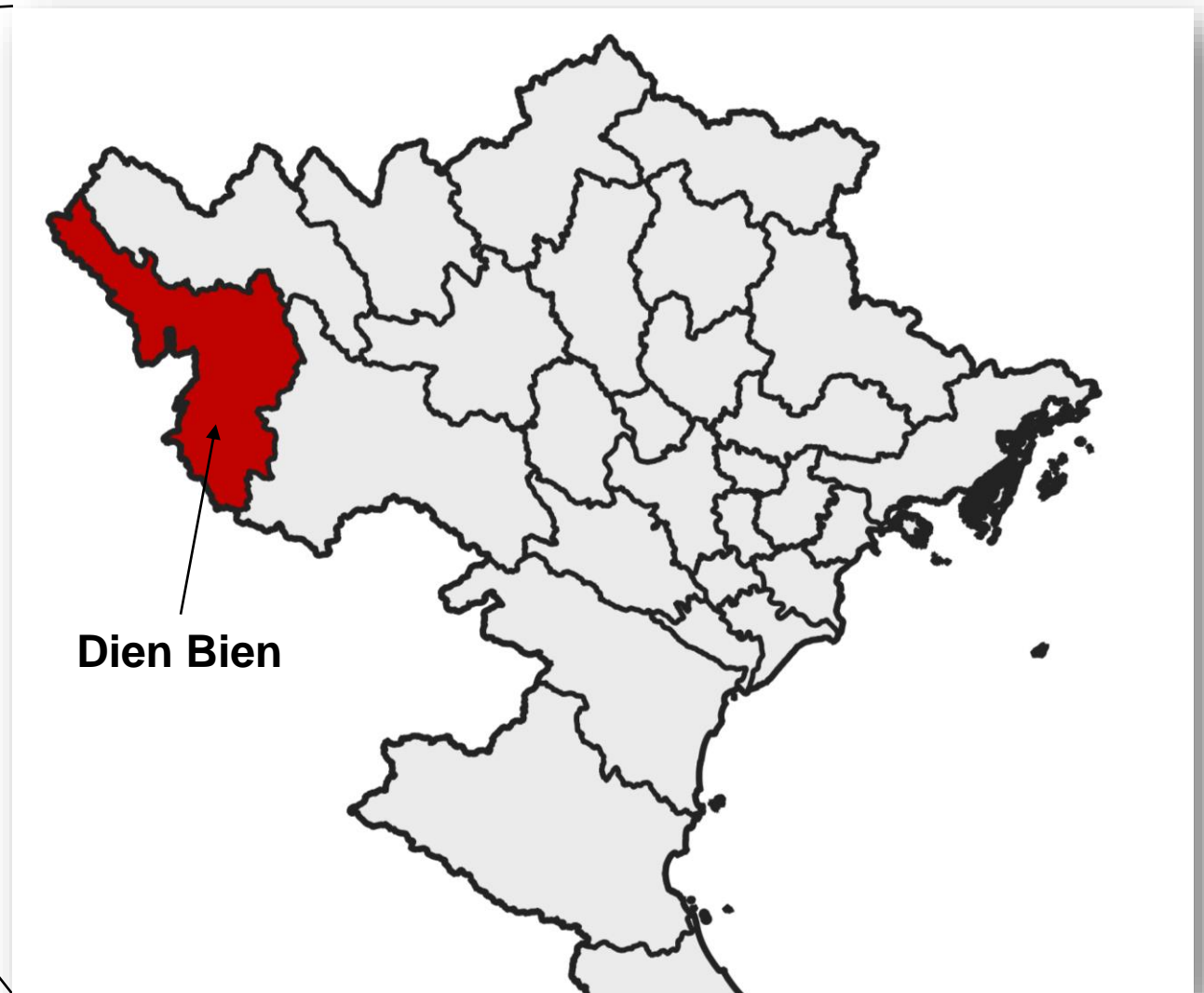
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**Annual AAG Meeting
Denver, March 2023**

Anthrax in Vietnam and a focus in Dien Bien province



Human anthrax in Vietnam, 1990-2015



Dien Bien province: 388 human cases, 32 animal cases (2010-2019)

Background & Study Objectives



Background:

- Anthrax is an underreported, high consequence disease caused by *Bacillus anthracis*, a spore-forming bacteria that persists in the environment, making it difficult to eradicate.
- Anthrax was **prioritized** as a zoonosis for One Health surveillance and response in Vietnam in 2013.
- Human anthrax was made **nationally reportable** in 2015 with clearer procedures and guidelines.

Objectives:

- 1) Describe **epidemiological characteristics** of human anthrax in Dien Bien province (2012-2018)
- 2) Identify **space-time clusters** of human anthrax in Dien Bien province (2010-2018)
- 3) Compare **livestock anthrax vaccine coverage** to anthrax incidence rates in humans and livestock (2010-2019)

Challenges in disease surveillance and livestock vaccination program



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Where and when do we need to prioritize control efforts?



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Methods



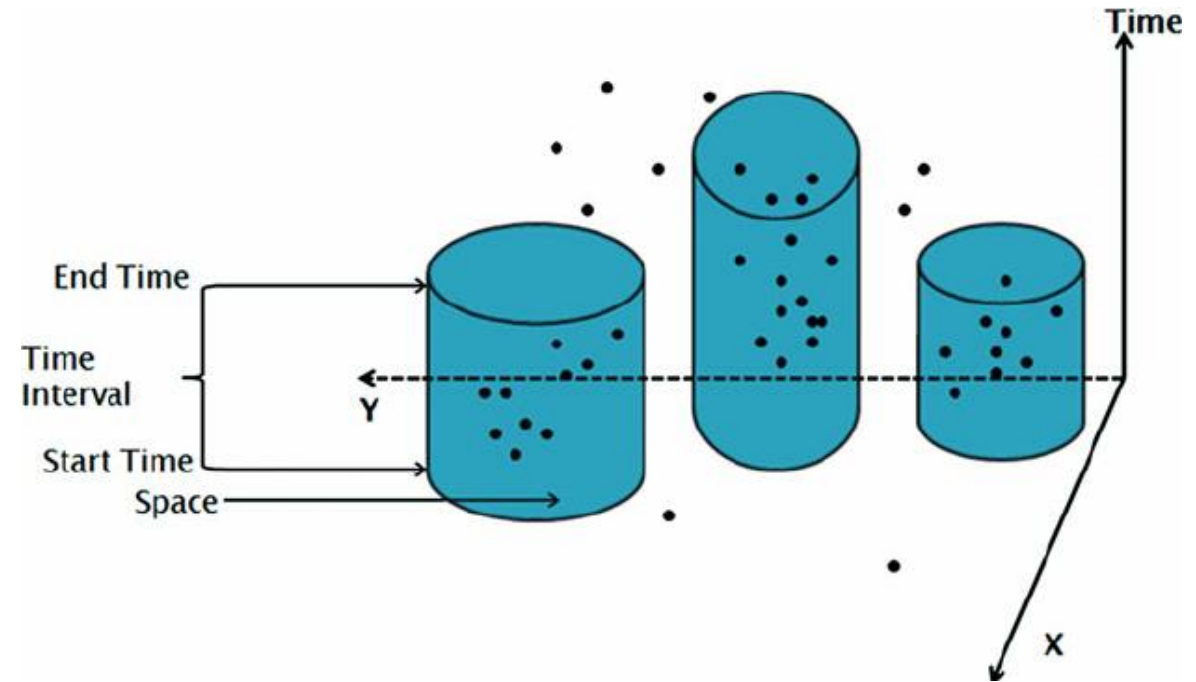
- Anthrax case data were provided by Dien Bien provincial human health and animal health sectors.
- Total anthrax vaccine doses administered in buffalo and cattle.
- Population estimation using Zonal statistic and datasets in *Worldpop.org* (humans) and Havard Dataverse (livestock).

→ We computed:

- Commune level:
 - Annual disease incidence for human or livestock anthrax (per 10,000)
 - Cumulative disease incidence for 3-year intervals (per 10,000)
- Provincial level:
 - Biannual disease incidence change (% increase or decrease).
 - Annual livestock vaccine coverage (% of total livestock population)

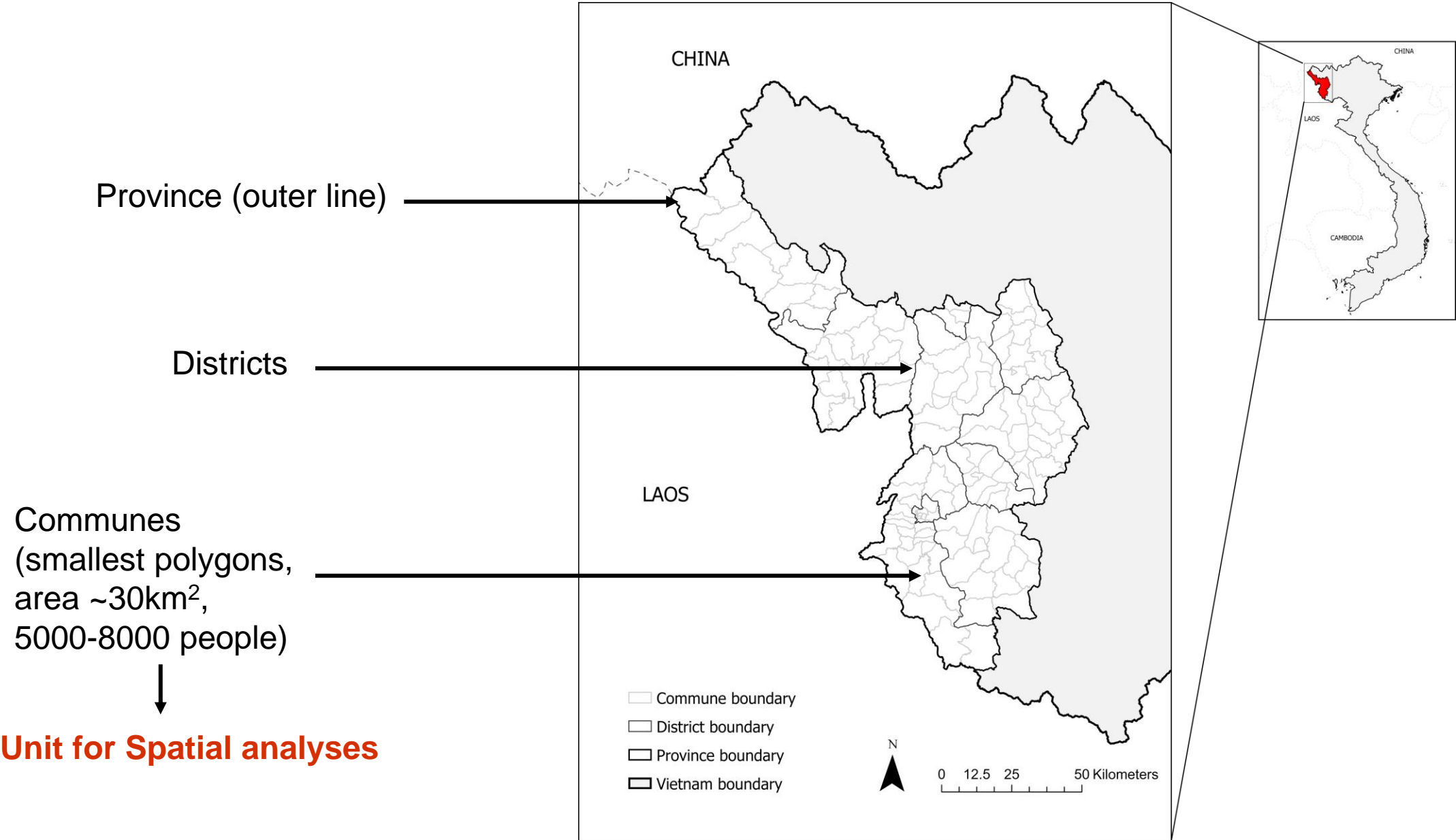
Space-time cluster analysis by SaTScan (Kulldorf, 1997)

- Search circles of varying diameters defined by 15%, 25%, 50% population at risk to detect **spatial clusters**
- Series of cylinders varying heights to detect **temporal clusters**
- Poisson model, 999 permutations
- Likelihood Ratio Test: significant with $p < 0.05$ (H_0 : risk inside = outside search area, proportional to population)
- Relative risk.



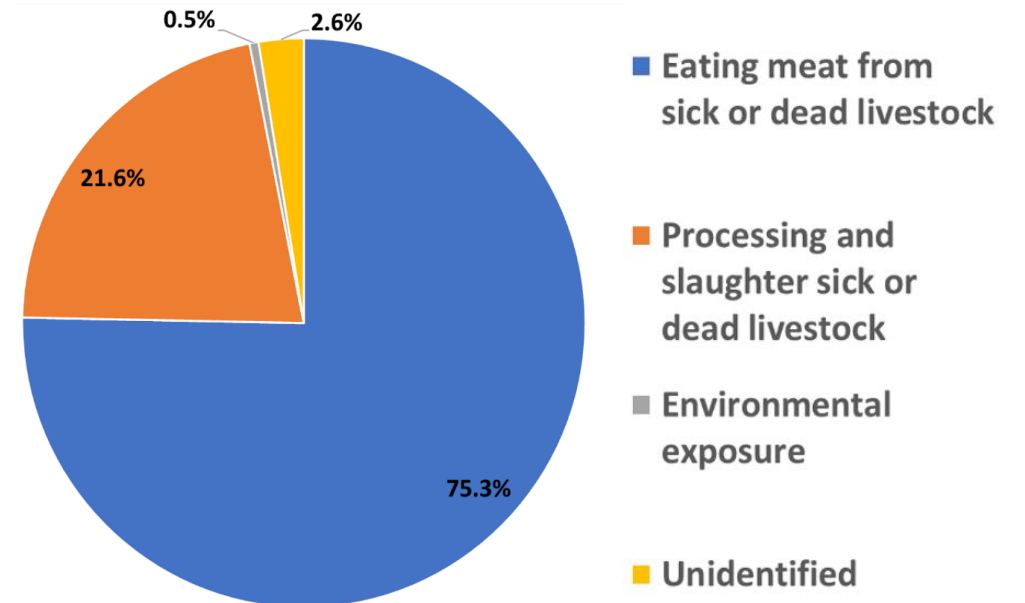
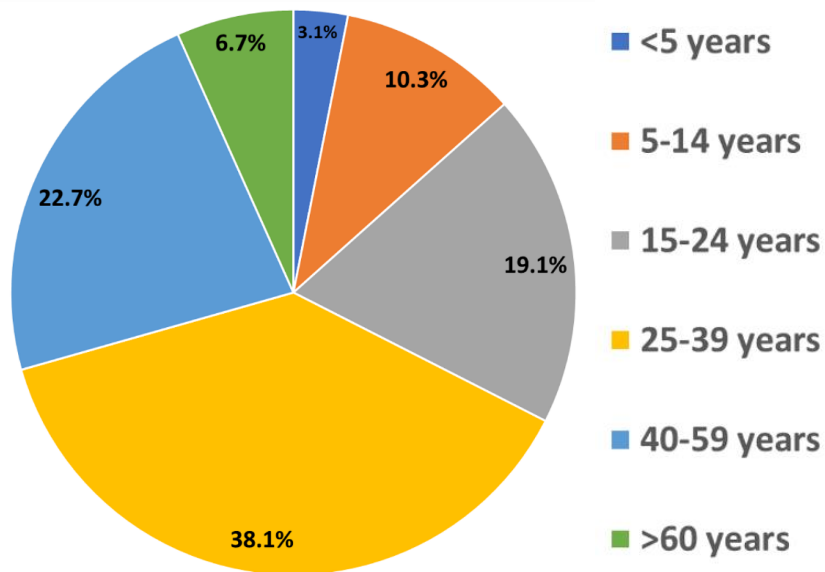
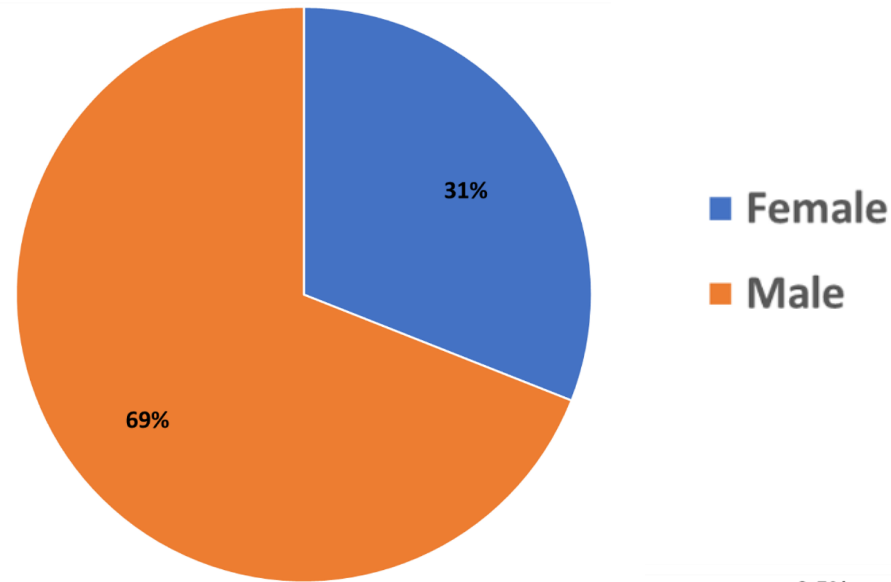
SaTScan results and cumulative disease incidence were mapped in ArcGIS Pro.

Dien Bien Province and 3 levels of governmental administration



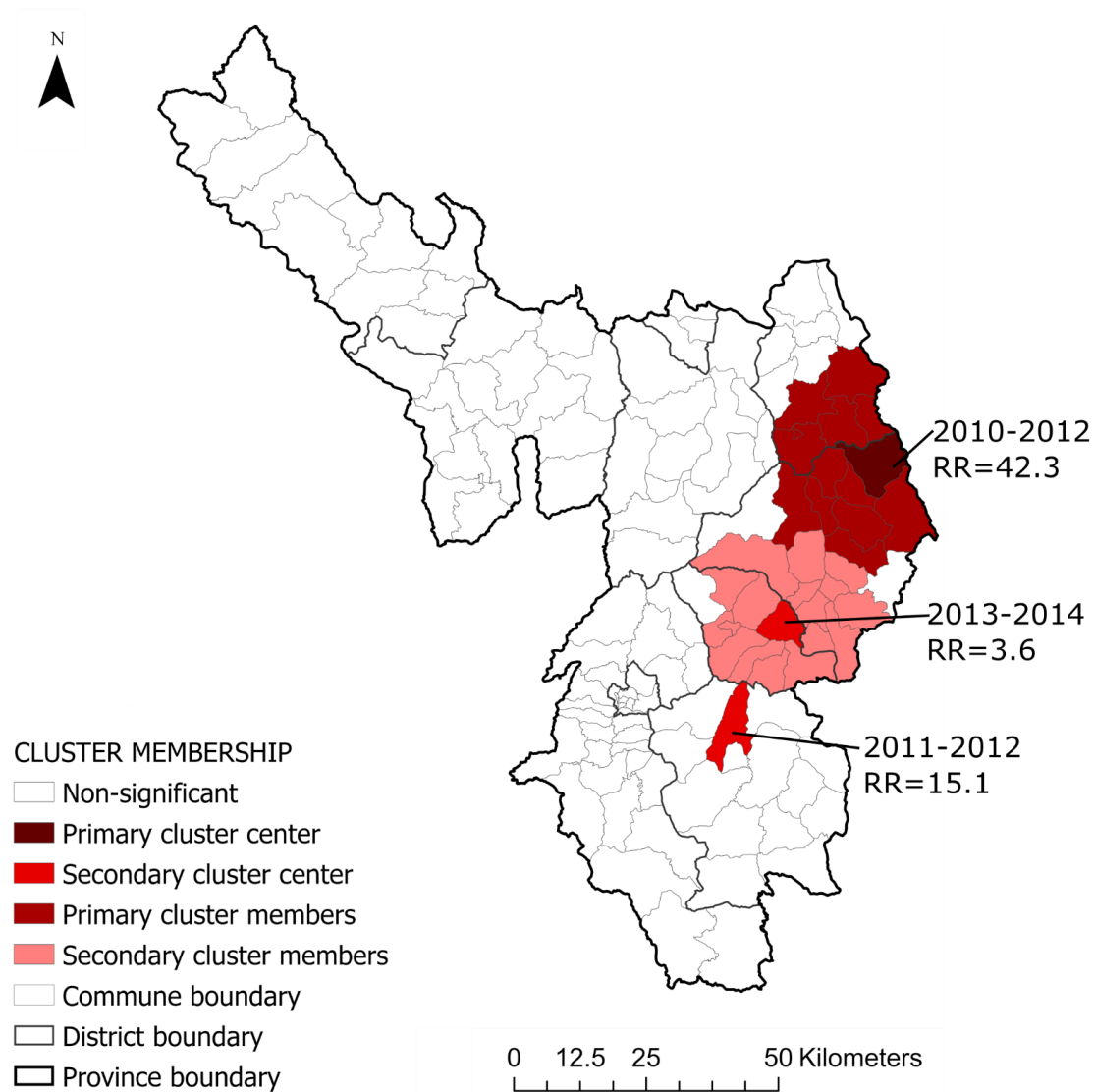
RESULTS: Epidemiological characteristics of human anthrax

187 human cases (2012-2018)

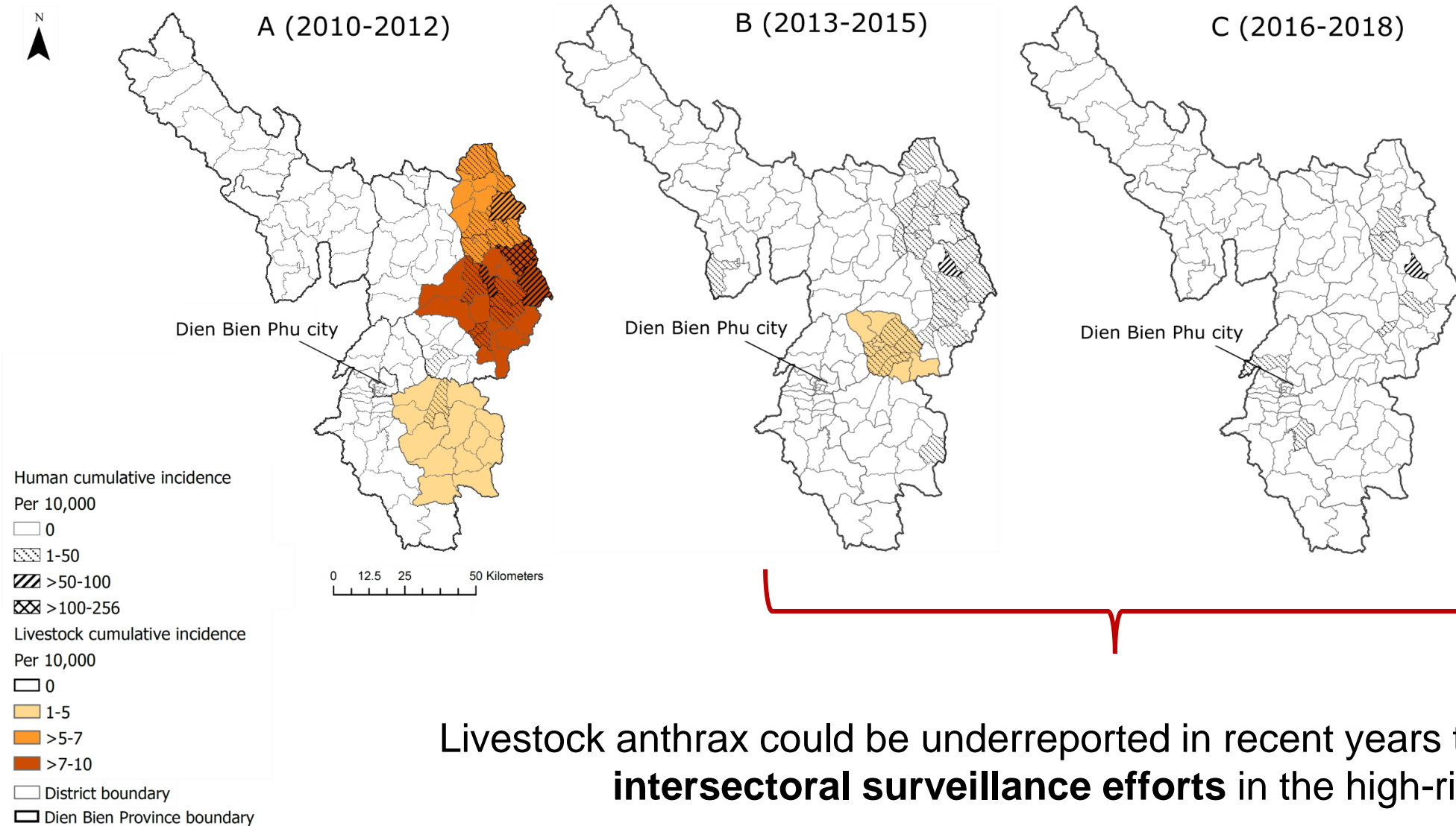


RESULTS: Space-time clusters of human anthrax in Dien Bien province (2010-2018)

High-risk areas for intensive public health interventions and vaccination campaign



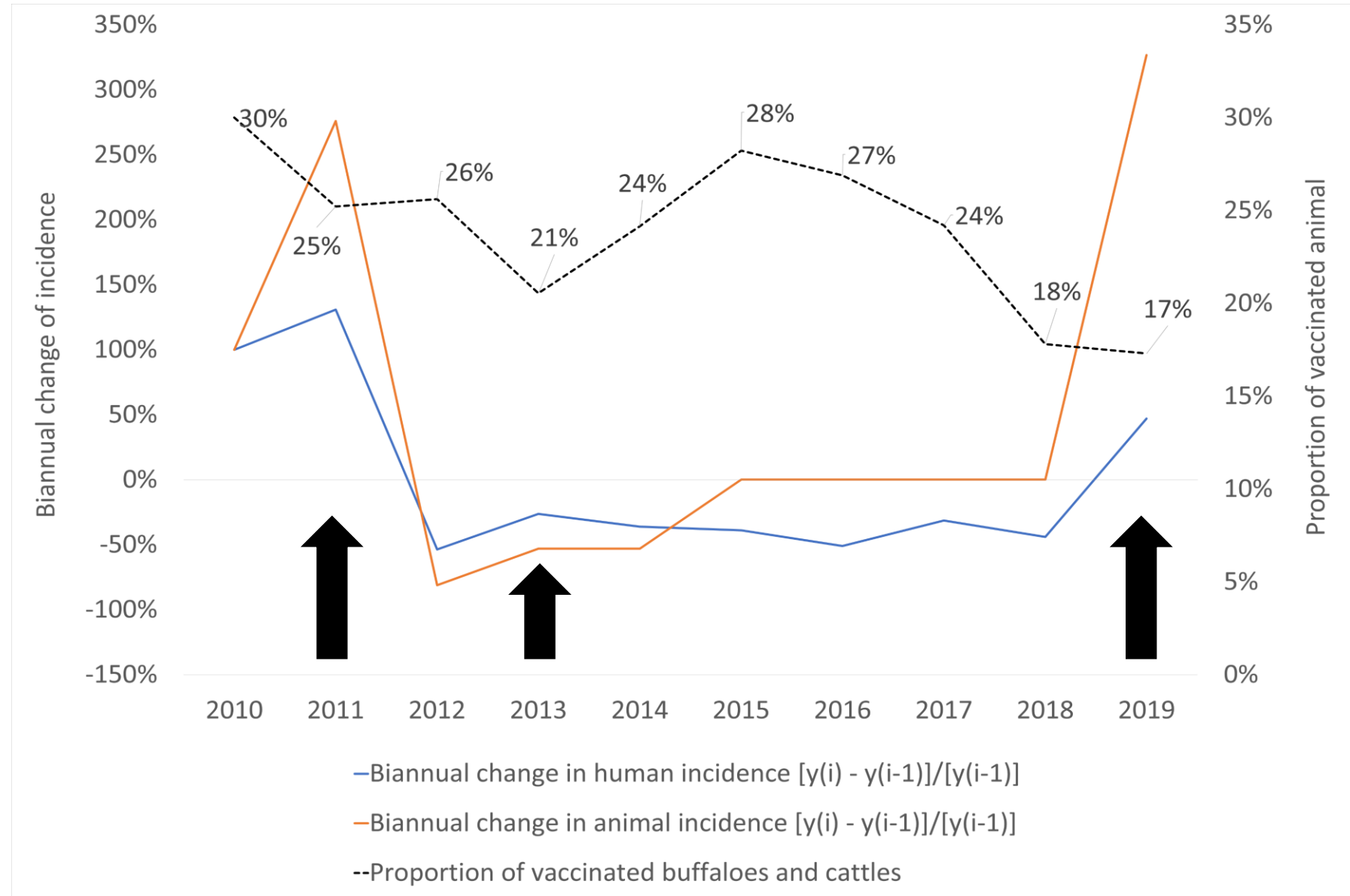
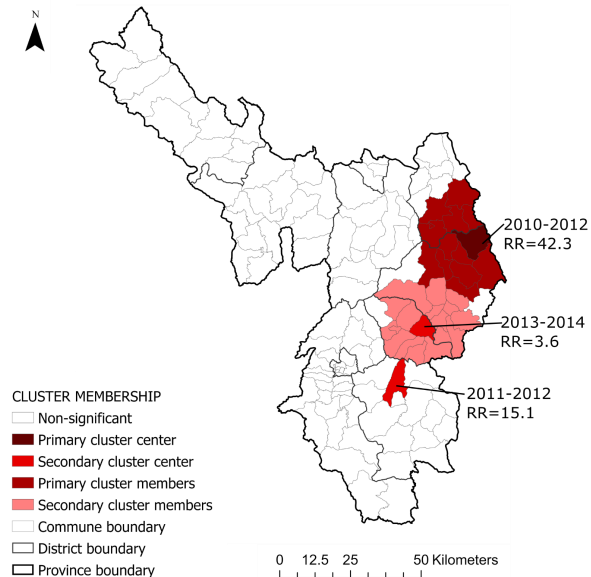
RESULTS: Spatial overlaps of human and livestock anthrax in every 3-year interval using cumulative incidence



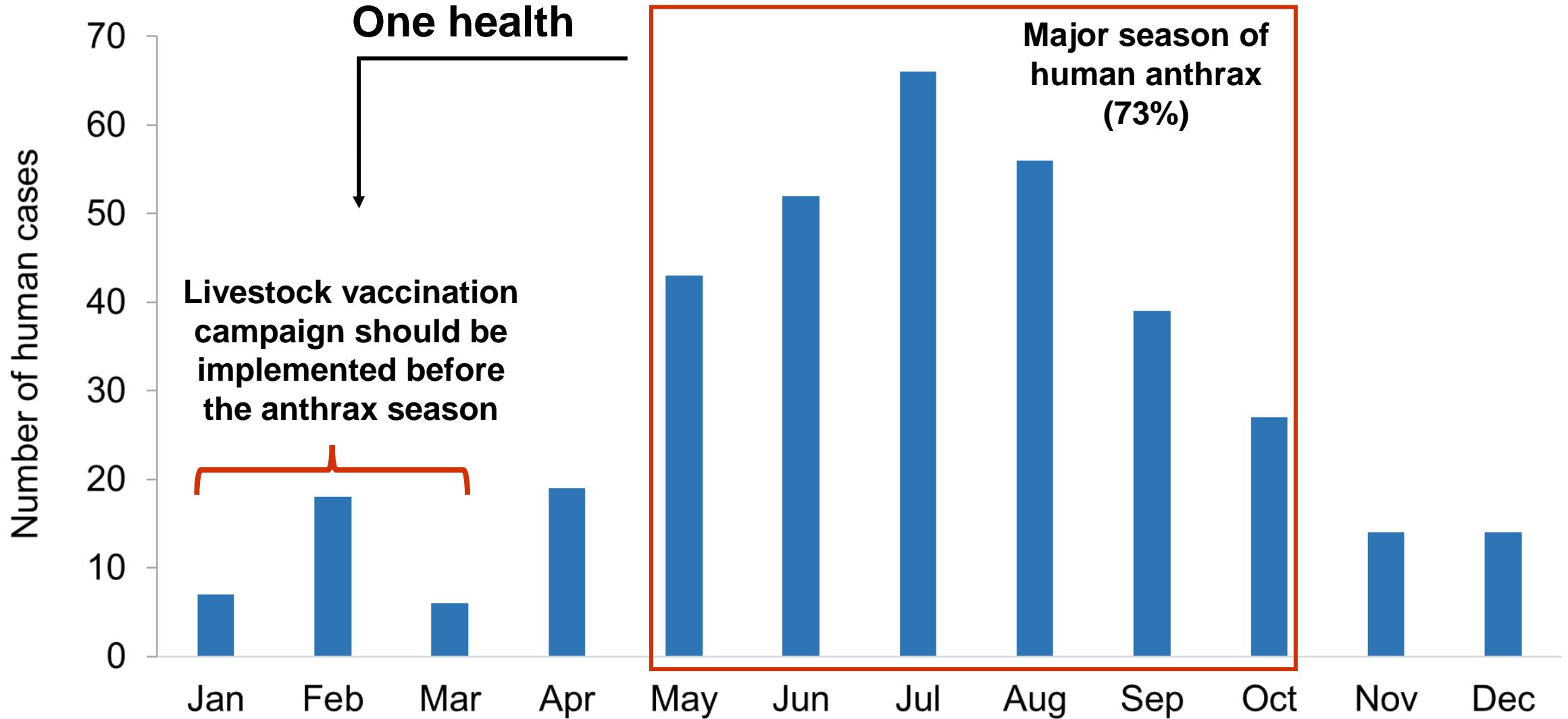
RESULTS: Livestock anthrax vaccine coverage and biannual disease incidence change

Biannual disease incidence change compares the disease incidence in a year to its prior year.

**Vaccine decrease →
Incidence increase**



RESULTS: Seasonal pattern of human anthrax in Dien Bien province, Vietnam (2010-2019)



Main implications for One health efforts

- **Determine high-risk areas:**
 - Intensive intersectoral surveillance
 - Public health interventions
 - Livestock vaccination program
- **Maintain livestock anthrax vaccination to protect livestock and humans**
 - In high-risk areas
 - Before the anthrax season

This work was supported by the US Defense Threat Reduction Agency's Biological Threat Reduction Program through DTRA grant #HDTRA1-20-1-0003 to JKB

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Department of Animal Health
Dien Bien Provincial Center for Disease Control
Dien Bien Provincial Sub-Department of Animal Health
District and commune health centers



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Supplement

Project: Estimating the burden of anthrax and brucellosis in northern Vietnam

SEER Lab, NIHE, DAH

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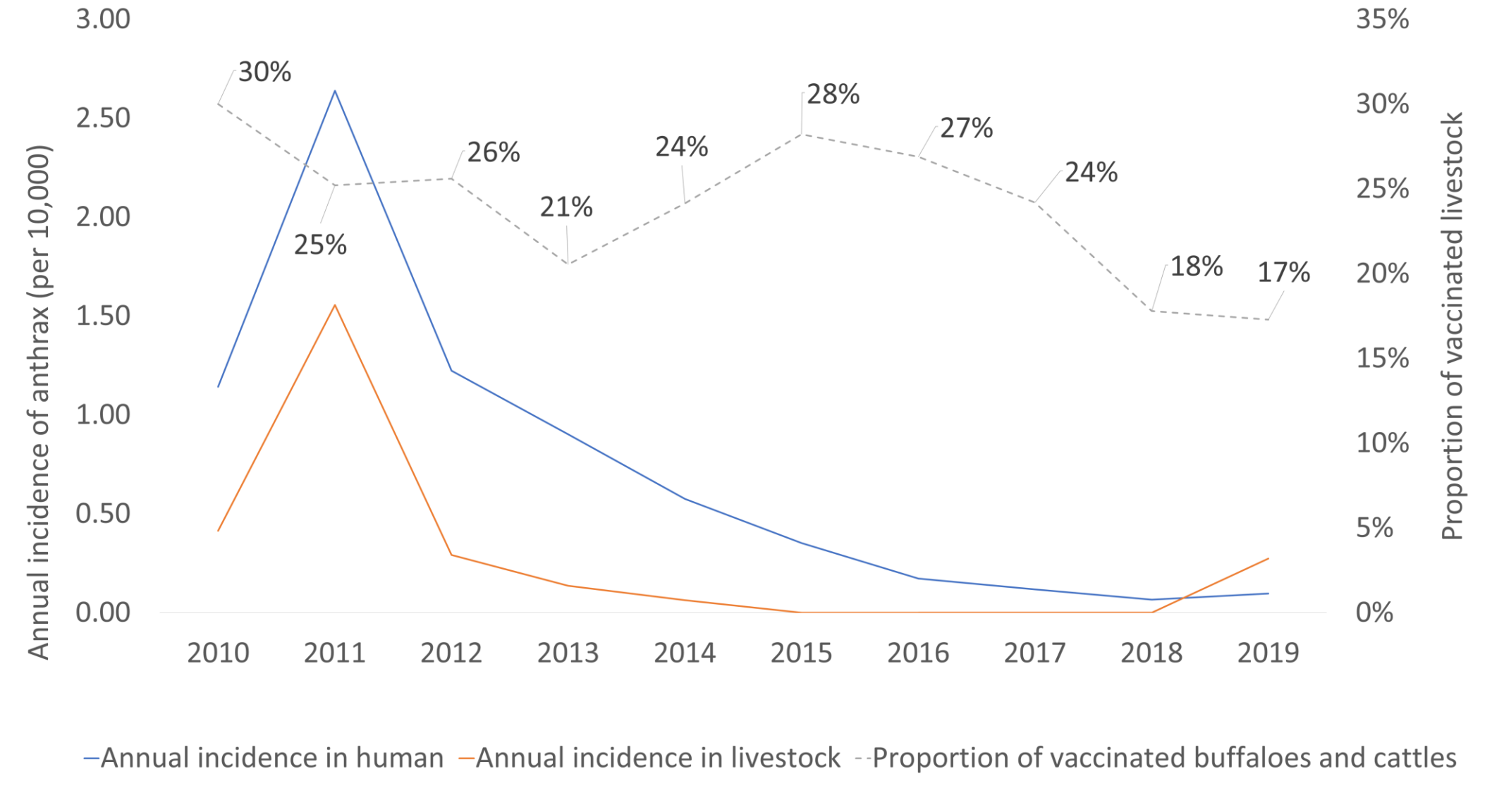


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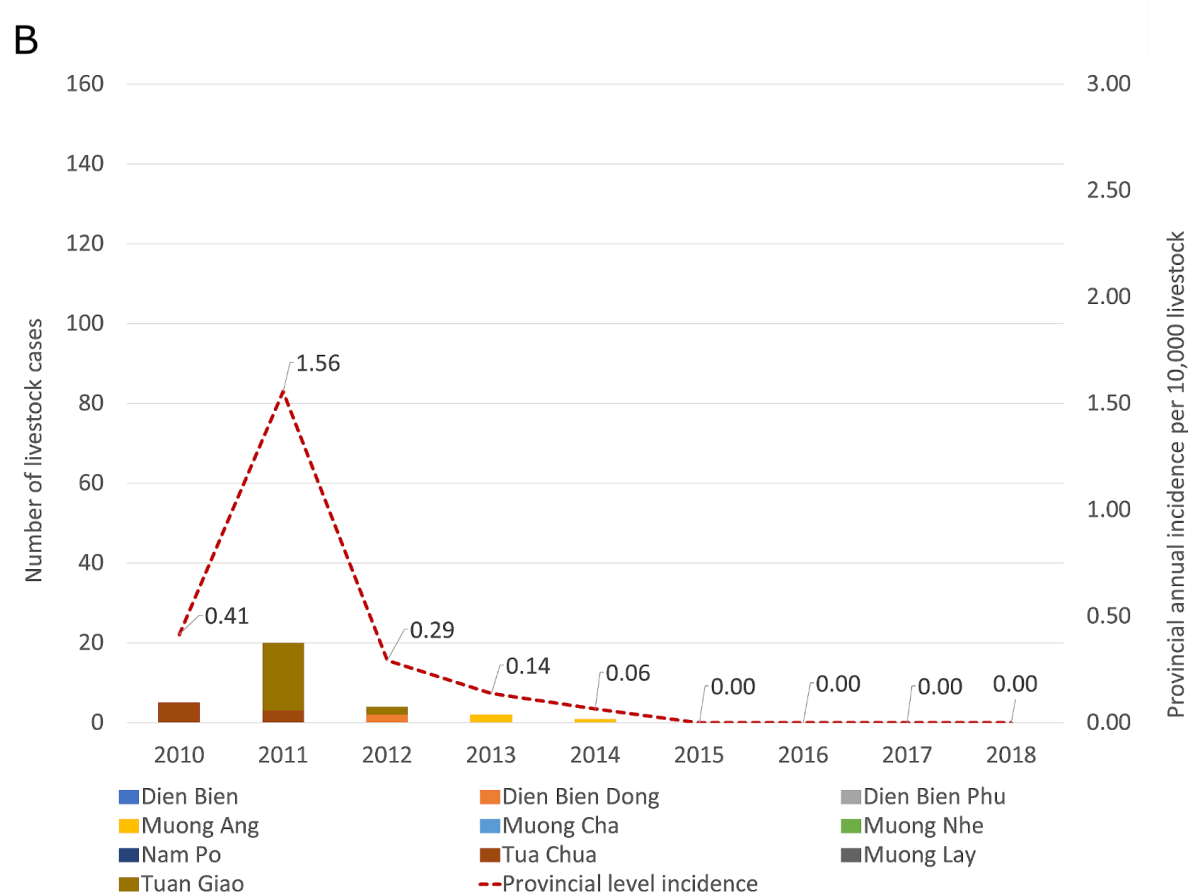
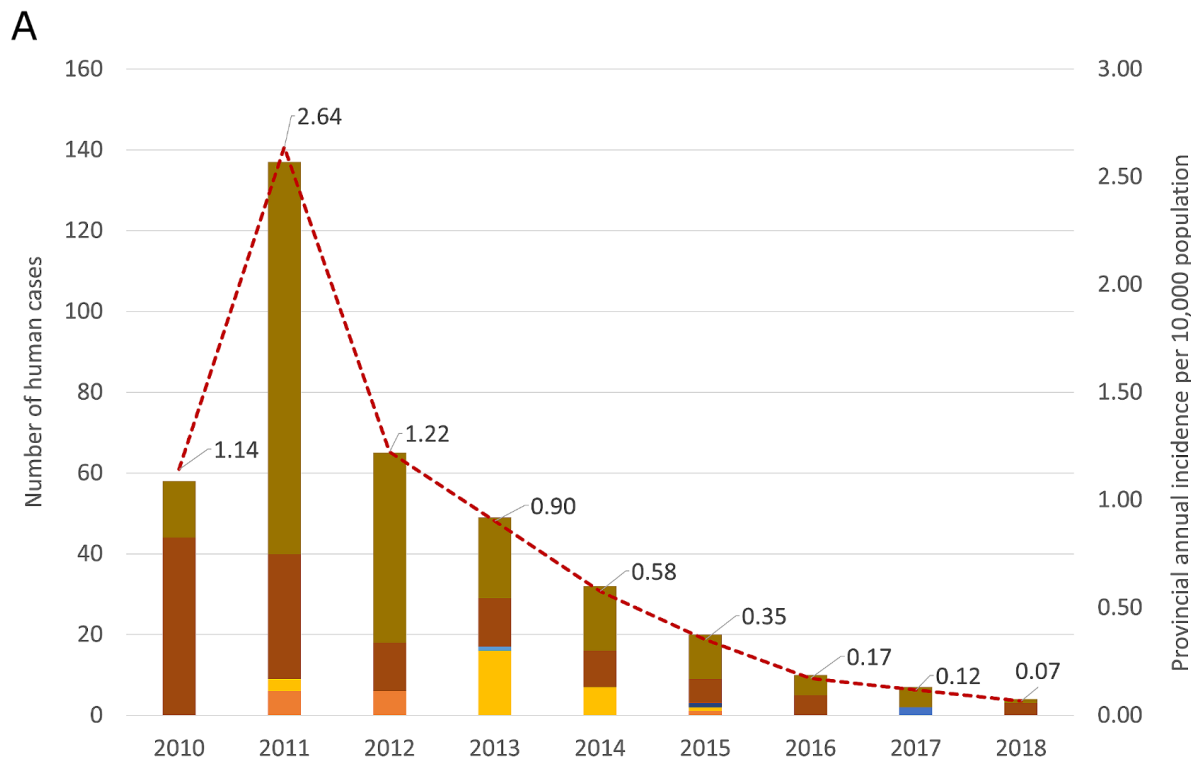


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Significance of livestock anthrax vaccine coverage and the disease incidence in human and livestock



Annual trend of anthrax in human (A) and livestock (B) at provincial level and contribution of each district to the trends (2010-2018)



- Dien Bien
- Dien Bien Dong
- Dien Bien Phu
- Muong Ang
- Muong Cha
- Muong Nhe
- Nam Po
- Tua Chua
- Muong Lay
- - Provincial level incidence
- Tuan Giao

Space-time cluster analysis by SaTScan (Kulldorf, 1997)

- Search circles of varying diameter defined by max 15%, 25%, 50% population at risk to detect spatial clusters
- Series of cylinders varying heights to detect temporal clusters
- Centroid of the communes
- Poisson model, 999 permutations
- Likelihood Ratio Test: $p < 0.05$ level of significance (H_0 : risk inside = outside search area, proportional to population)
- Relative risk

$$RR = \frac{c / E[c]}{(C - c) / (E[C] - E[c])} = \frac{c / E[c]}{(C - c) / (C - E[c])}$$

$$\left\{ \frac{c}{E[c]} \right\}^c \left\{ \frac{C - c}{C - E[c]} \right\}^{C - c} I(\)$$

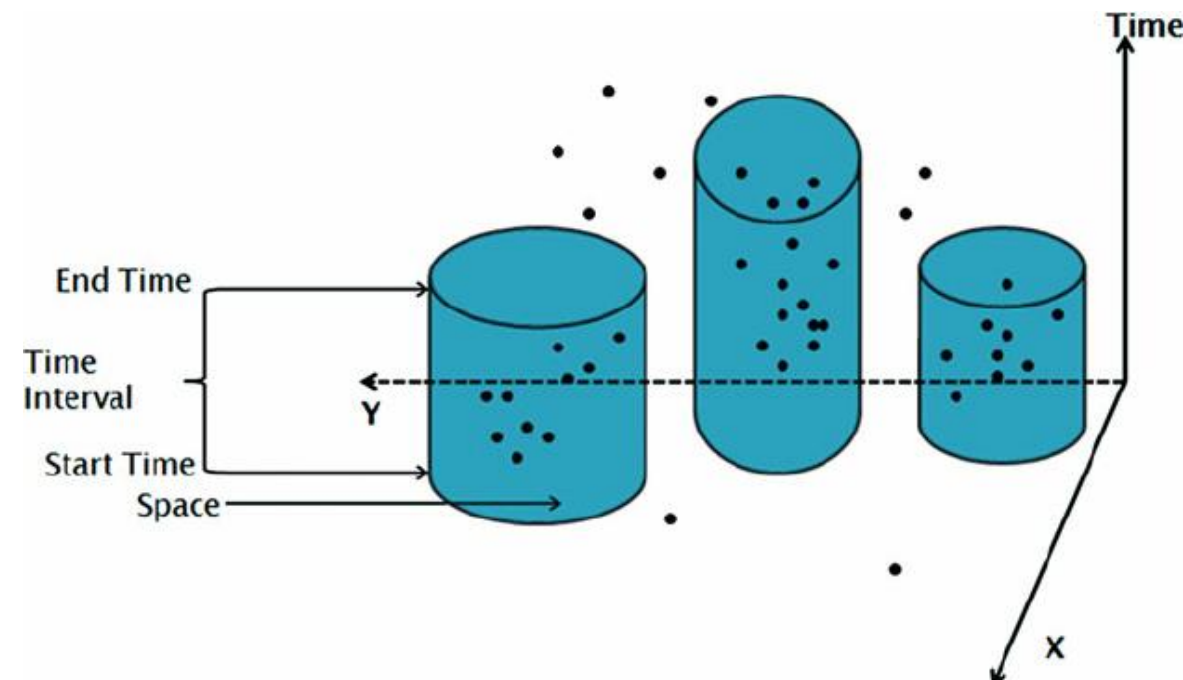
C is the total number of cases

c is the observed number of cases within the window

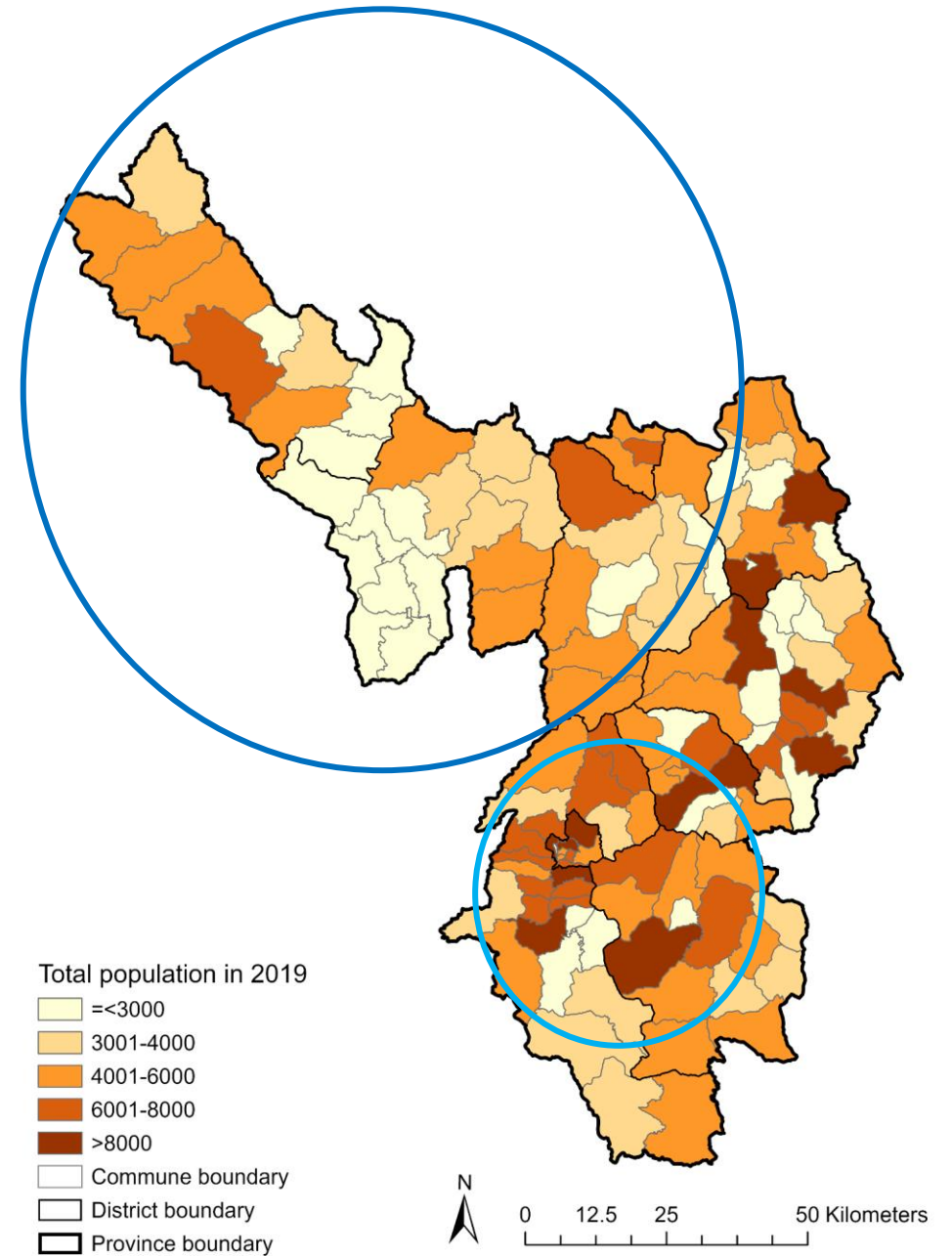
$E[c]$ is the expected number of cases within the window

$C - E[c]$ is the expected number of cases outside the window.

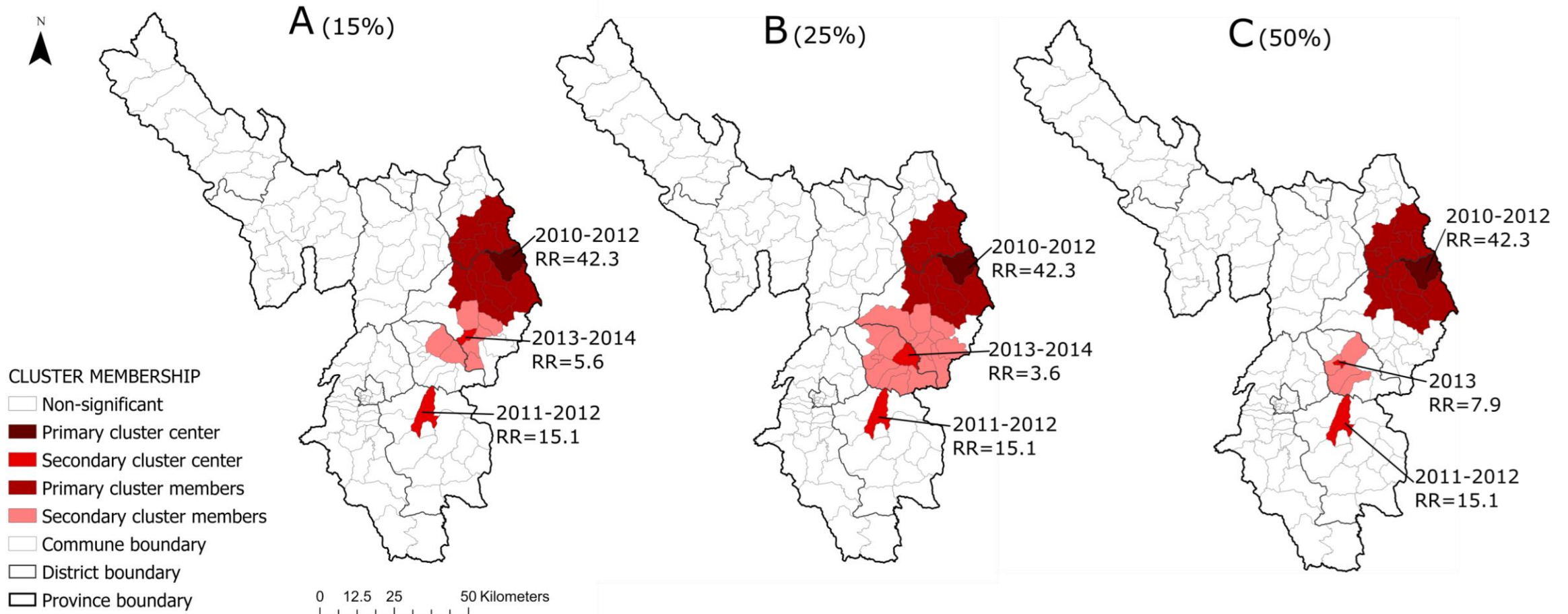
$I()$ is an indicator function. $I()$ is equal to 1 when the window has more cases than expected, and 0 otherwise (high rates only)



Population at risk and maximum diameter of search circles



SATScan statistics defined Space-time clusters and relative risk of communes inside over outside of clusters (Poisson model, 999 permutations, 15%, 25% and 50% population at risk)



METHODS

- Spatial Data analysis:

Local Moran's I for identifying Spatial clusters in GeoDa version 3.18: like value surrounded by like values

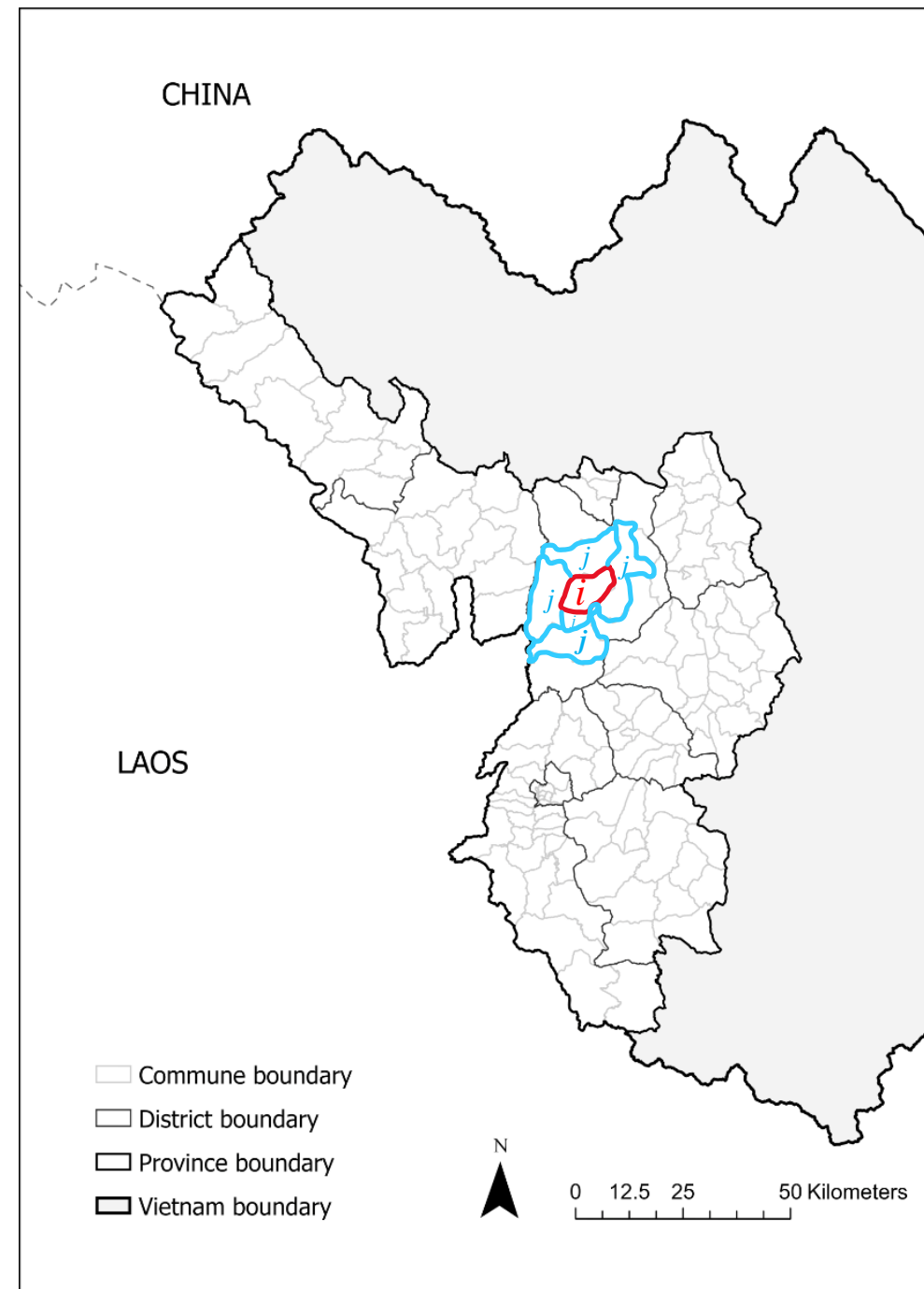
$$I_i = Z_i \sum W_{ij} Z_j$$

I_i is the statistic for a commune i

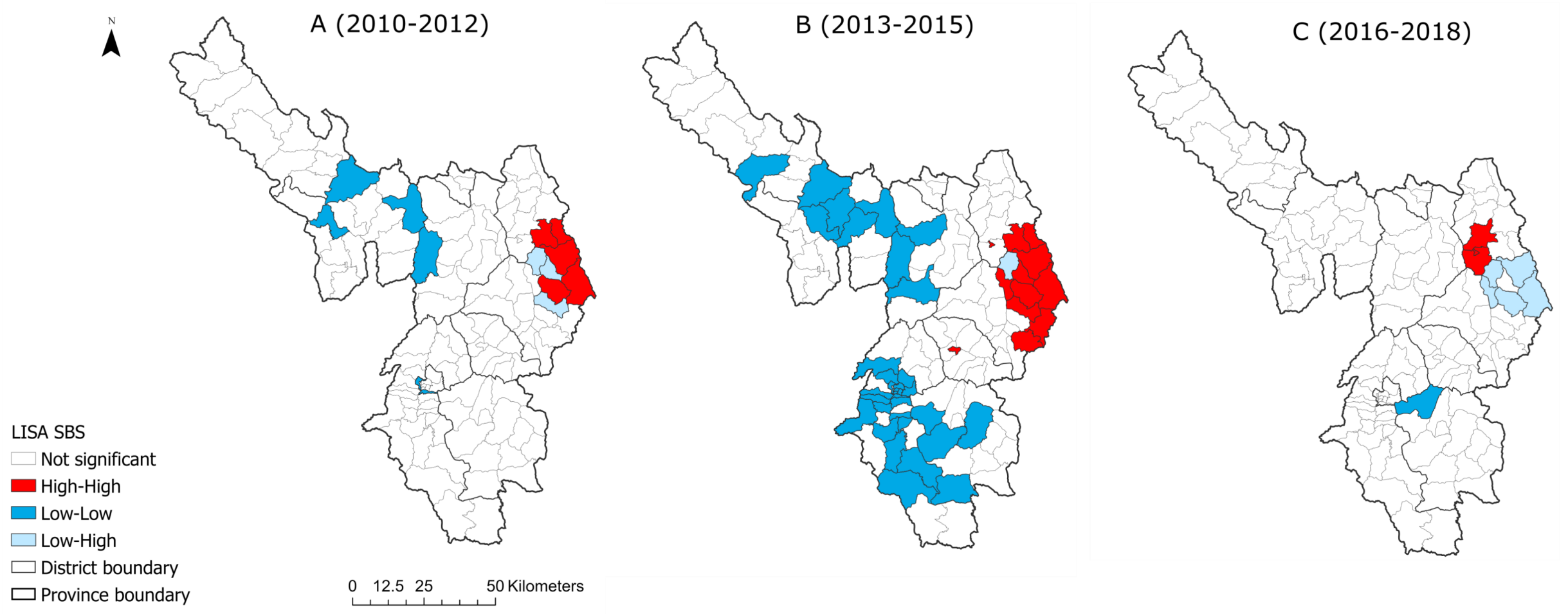
Z_i is the difference between the anthrax rate at commune i and the mean anthrax rate of the whole province for the 10-year interval

Z_j is the difference between anthrax rate at commune j and the mean anthrax rate of the whole province for the 10-year interval

W_{ij} is the weights matrix using 1st order queen contiguity. W_{ij} equals $1/n$ if a commune shares a boundary or vertex and 0 if not.

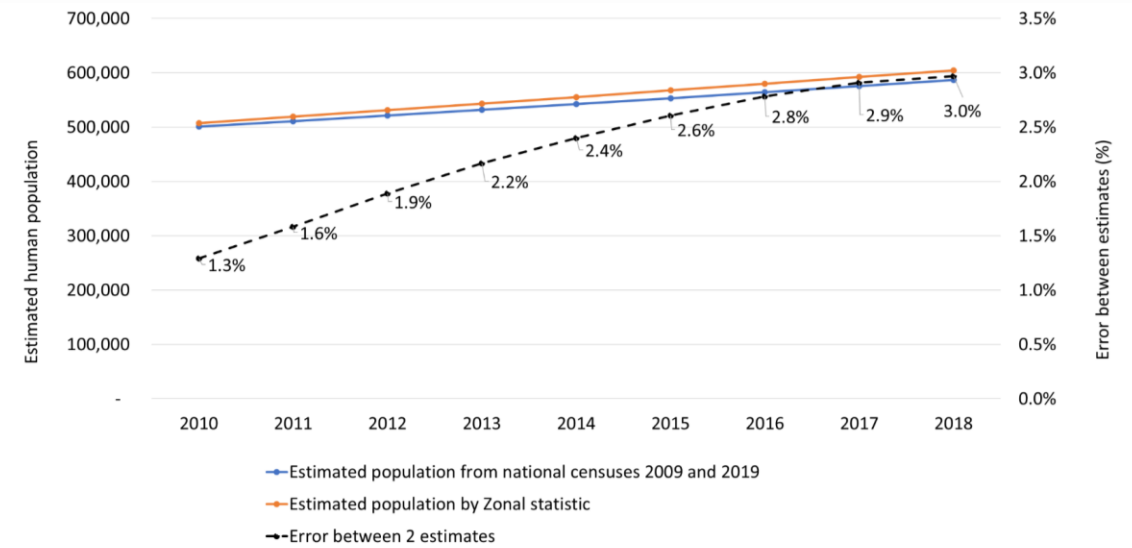


Local Moran's I defined spatial clusters of human anthrax incidence (per 10,000) per commune for 3-year intervals.

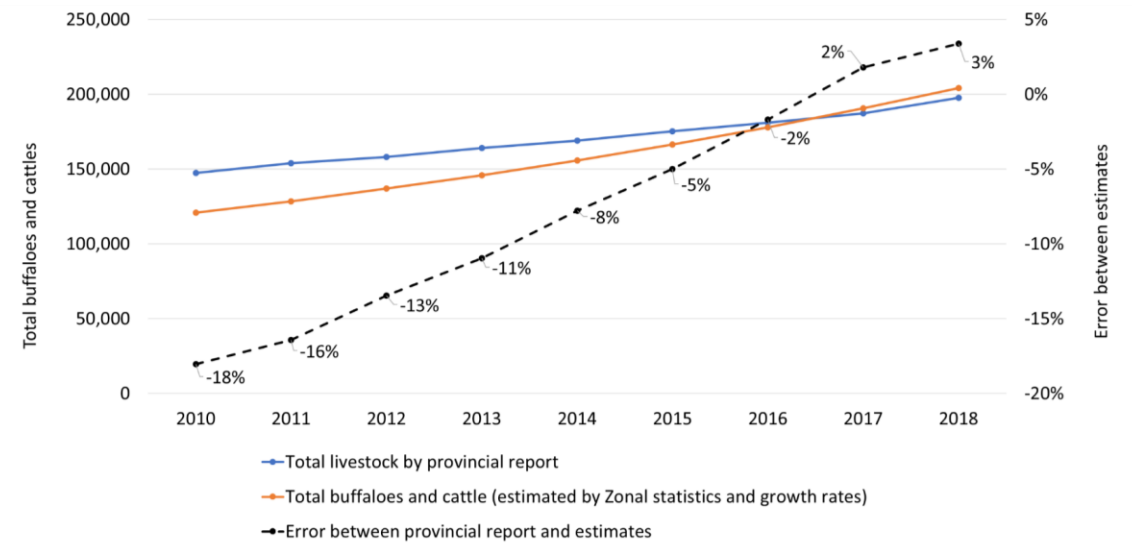


Comparison of population estimated by Zonal statistics based on population censuses (A) and livestock herd provided by Dien Bien Sub-DAH (B)

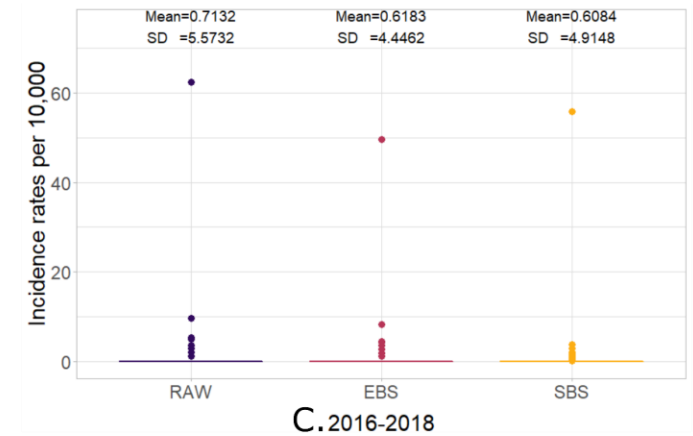
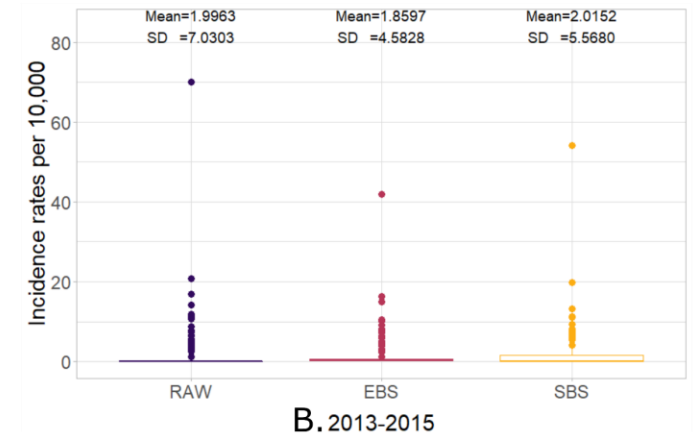
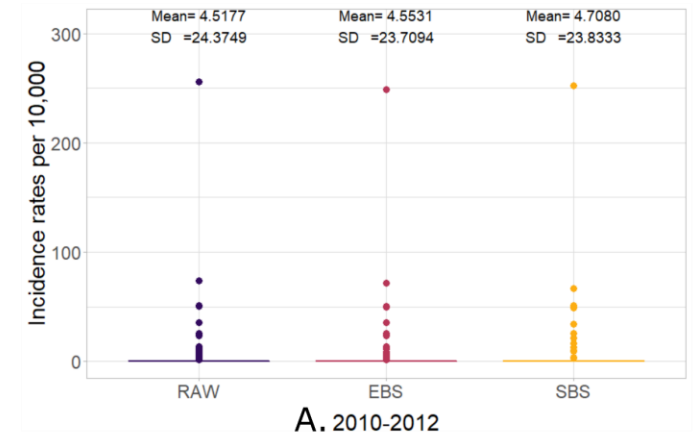
A



B

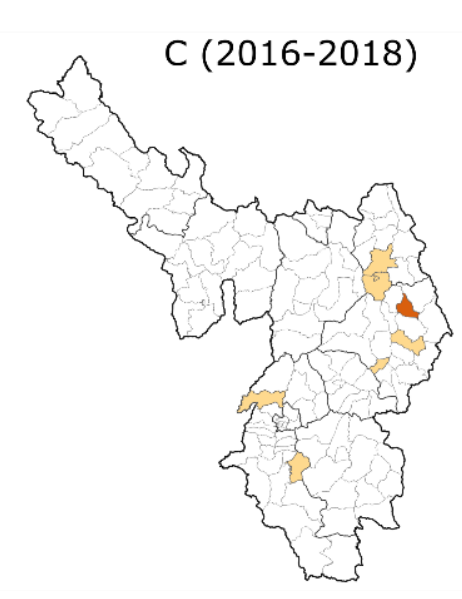
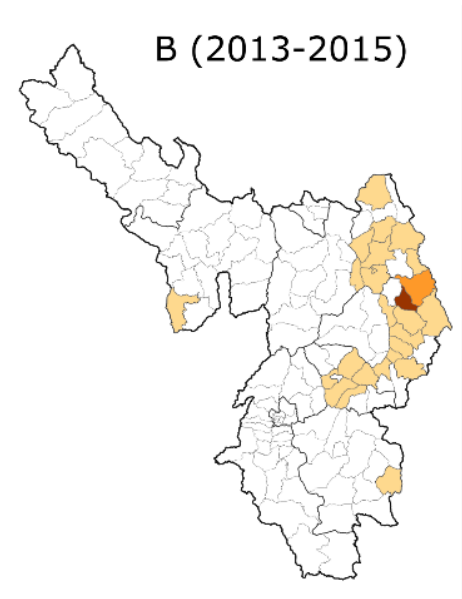
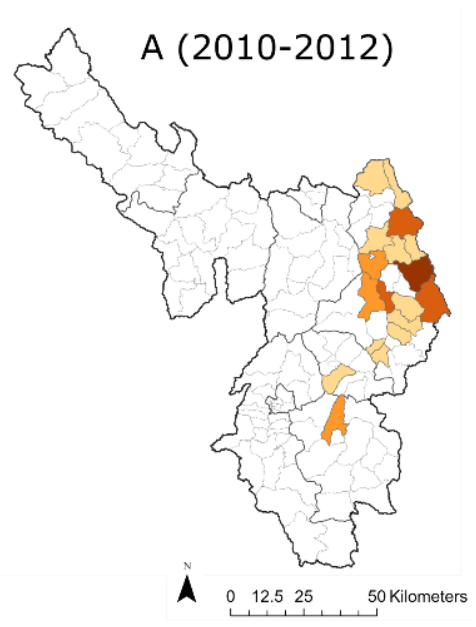


Comparison between crude, Empirical Bayes Smoothed, and Spatial Bayes Smoothed cumulative incidence of human anthrax in 3-year intervals (A: 2010-2012; B: 2013-2015; C: 2016-2018)

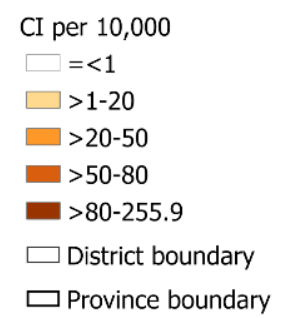
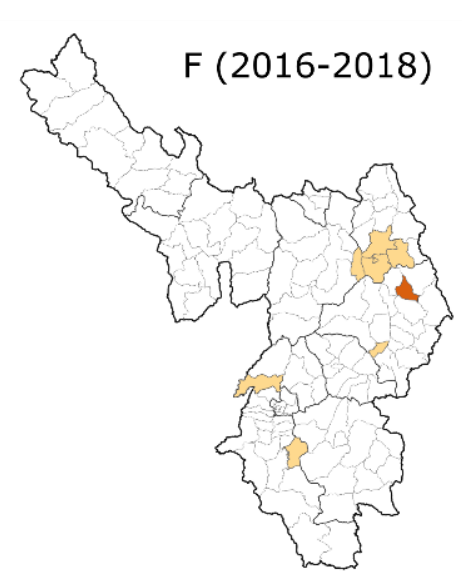
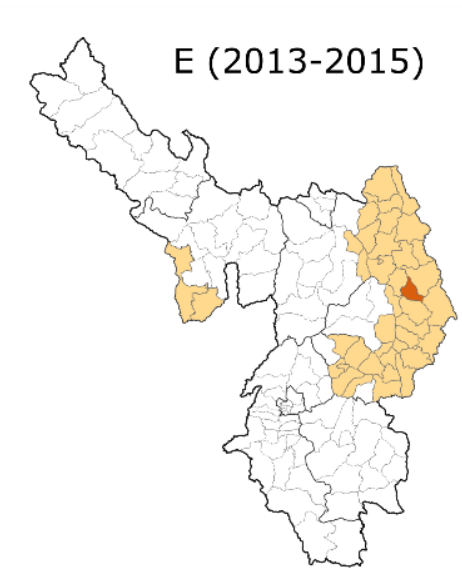
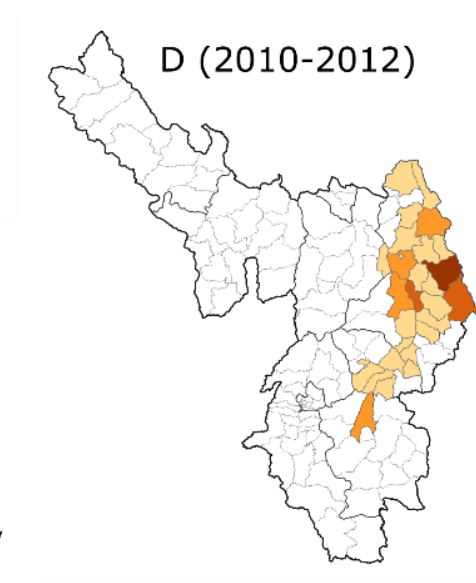


Comparing distribution of human anthrax by crude and Spatial Bayes Smoothed cumulative incidence (per 10,000) at commune level in Dien Bien province in every 3-year intervals (A, B, C for crude CI, and D, E, F for SBS CI)

CRUDE CI



SBS CI



Global distribution of anthrax



(Carlson et al. 2019)

