Vector-borne diseases in a changing world

Case studies of Japanese encephalitis virus and East African arboviruses

Kansas State University

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CGIAR

SLU

ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

NATURAL ENVIRONMENT RESEARCH COUNCIL

espa ecosystem services for poverty alleviation

How to squeeze as much as possible into a presentation:

1. International Livestock Research Institute
   i. What does ILRI do?
   ii. What do I do for ILRI?
2. Introduction: EIDs, vectors and why we have a problem
3. Japanese Encephalitis Virus in Viet Nam
   i. Background JEV
   ii. Studies and results
4. Rift Valley fever virus in Kenya
   i. Background RVF
   ii. Studies and results (so far)
5. Dynamic drivers of disease in Africa

International Livestock Research Institute
Consultative Group for International Agricultural Research

2 Departments:

Integrated sciences

- Food safety and zoonoses

Biosciences

Main campus Nairobi

Second campus Addis Ababa

ILRI
CGIAR

CGIAR Research Program

Agriculture for Nutrition and Health (A4NH)

Agriculture for Improved Nutrition & Health

12 CGIAR centers

- IFPRI
- ILRI
- BIOVERSITY
- CIAT
- CIMMYT
- CIP
- ICARDA
- ICRAF
- ICRISAT
- IITA
- IWMI
- WORLD FISH

4 Themes

1. *Leveraging value chains for nutrition*
2. Biofortification of staple crops: Harvest +
3. **Agricultural associated diseases**
4. Evaluating nutrition outcomes in programs

Agriculture associated disease

1. Food Safety
2. Emerging infectious disease
3. Neglected zoonoses

CGIAR Research Program

Livestock and fish-
More meat, milk and fish for and by the poor

My main projects

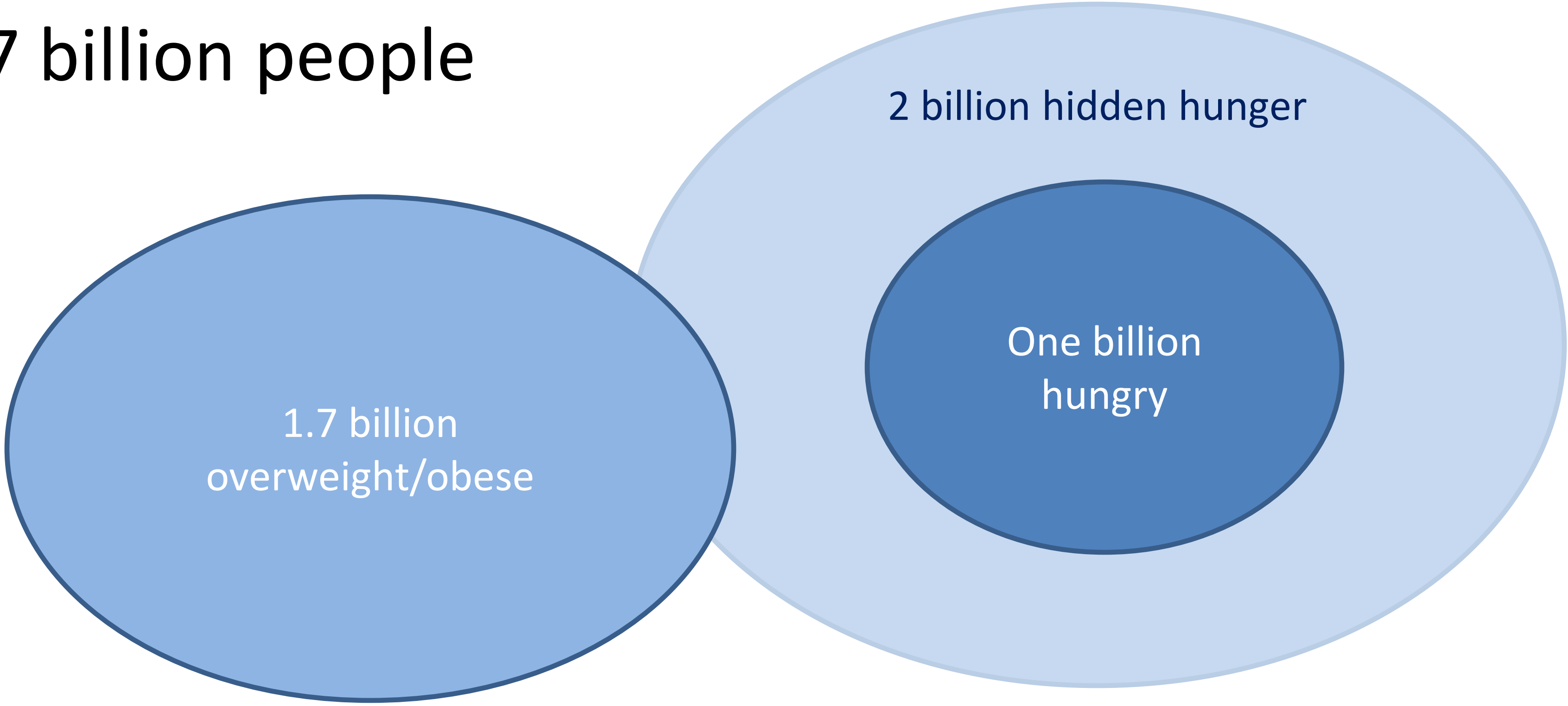
1. DDDAC
   i. **RVF**
   ii. Cross-sectional socio-economic
2. Aflatoxins
   i. Aflatoxin risk assessment Kenya
   ii. More aflatoxin stuff (Uganda, Vietnam, India, Senegal, etc)
3. Dairy in India
   i. Hygiene project
   ii. Tuberculosis, brucellosis and antibiotic resistance
4. Upcoming
   i. Vector and water associated diseases in SEA

An introduction to disease emergence and anthropogenic influences

- Humans are affecting every part of this planet
  - Directly or indirectly

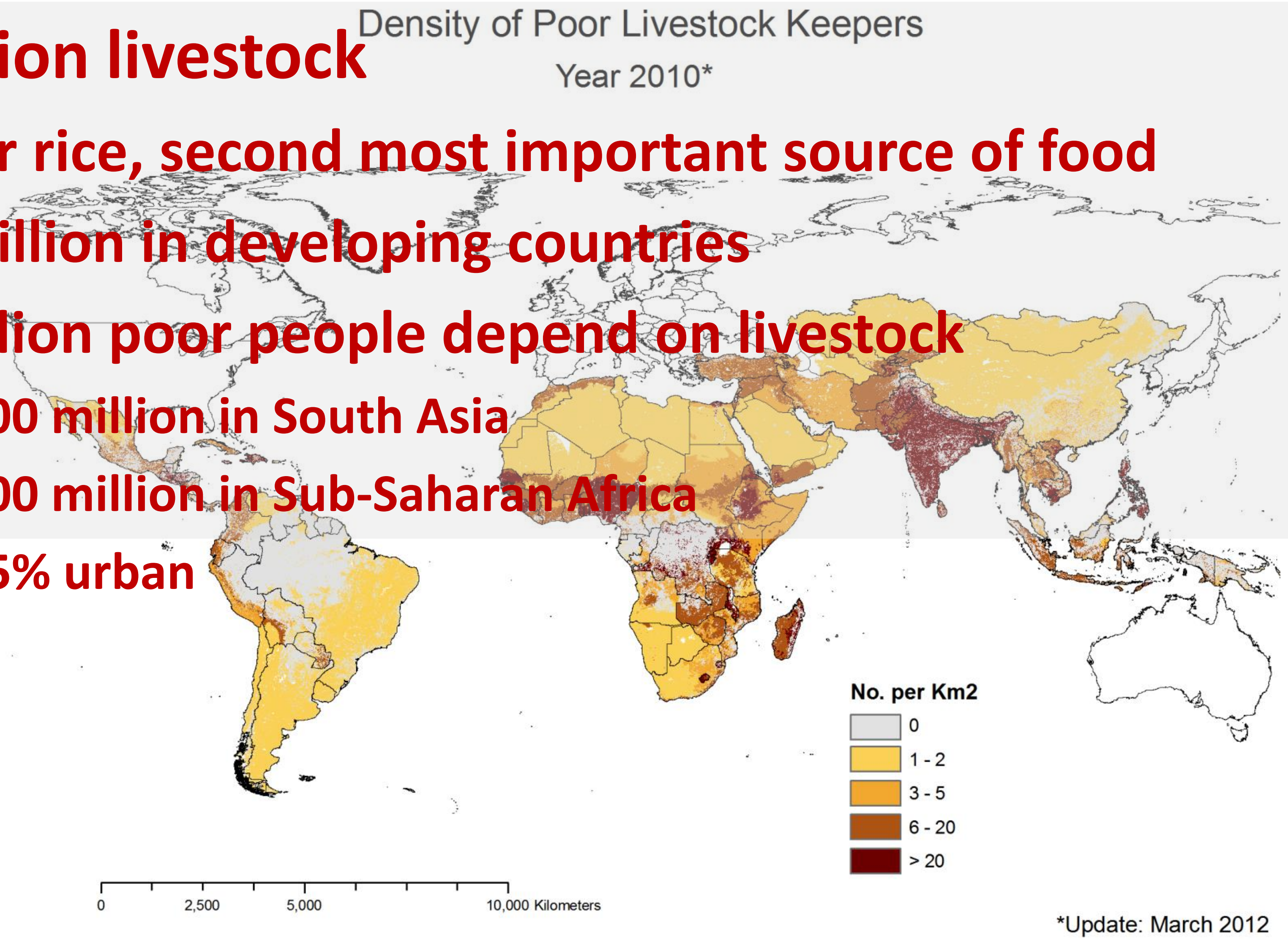
The world today

7 billion people



Livestock is important

- **24 billion livestock**
  - **After rice, second most important source of food**
  - **19 billion in developing countries**
  - **1 billion poor people depend on livestock**
    - ✓ **600 million in South Asia**
    - ✓ **300 million in Sub-Saharan Africa**
    - ✓ **25% urban**



There is a business case for one health

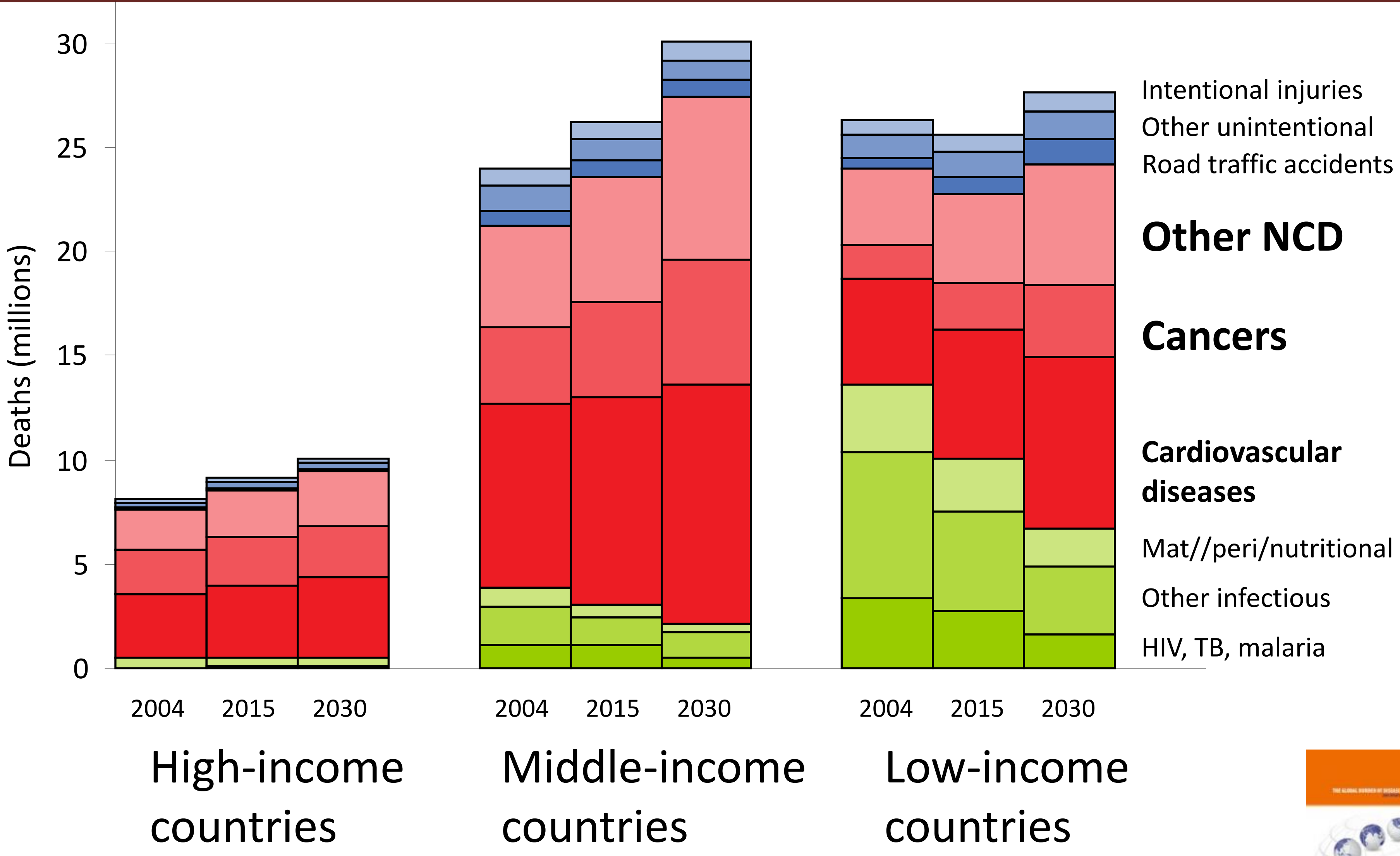
- **Zoonoses sicken 2.4 billion people, kill 2.2 million people and affect more than 1 in 7 livestock each year**
- **Cost $9 billion in lost productivity; $25 billion in animal mortality; and$50 billion in human health**

Infectious diseases- historically important

- In 1918-1920 Spanish flu:
  - 50- 100 million humans
- Late 19th century Rinderpest:
  - Death of 2/3 of Maasai population in Tanzania and Kenya
- Early 19th century Potato blight:
  - 25% of Irish population starved or migrated

- 1967: "…war against infectious diseases has been won“
  - US Surgeon General William H. Steward

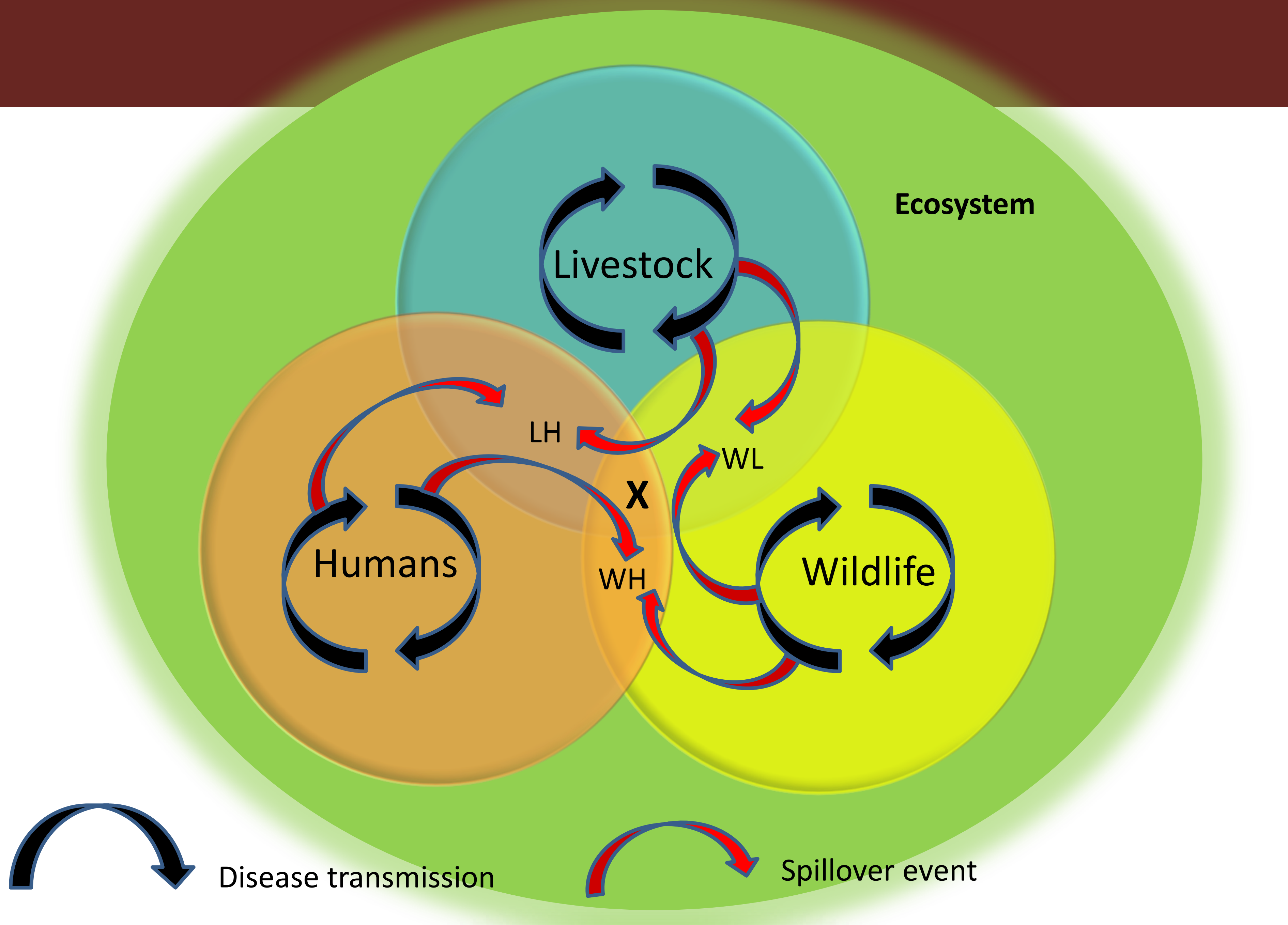
US Surgeon General William H. Steward was wrong



Mortality: global projection, 2004-2030

Disease emergence?

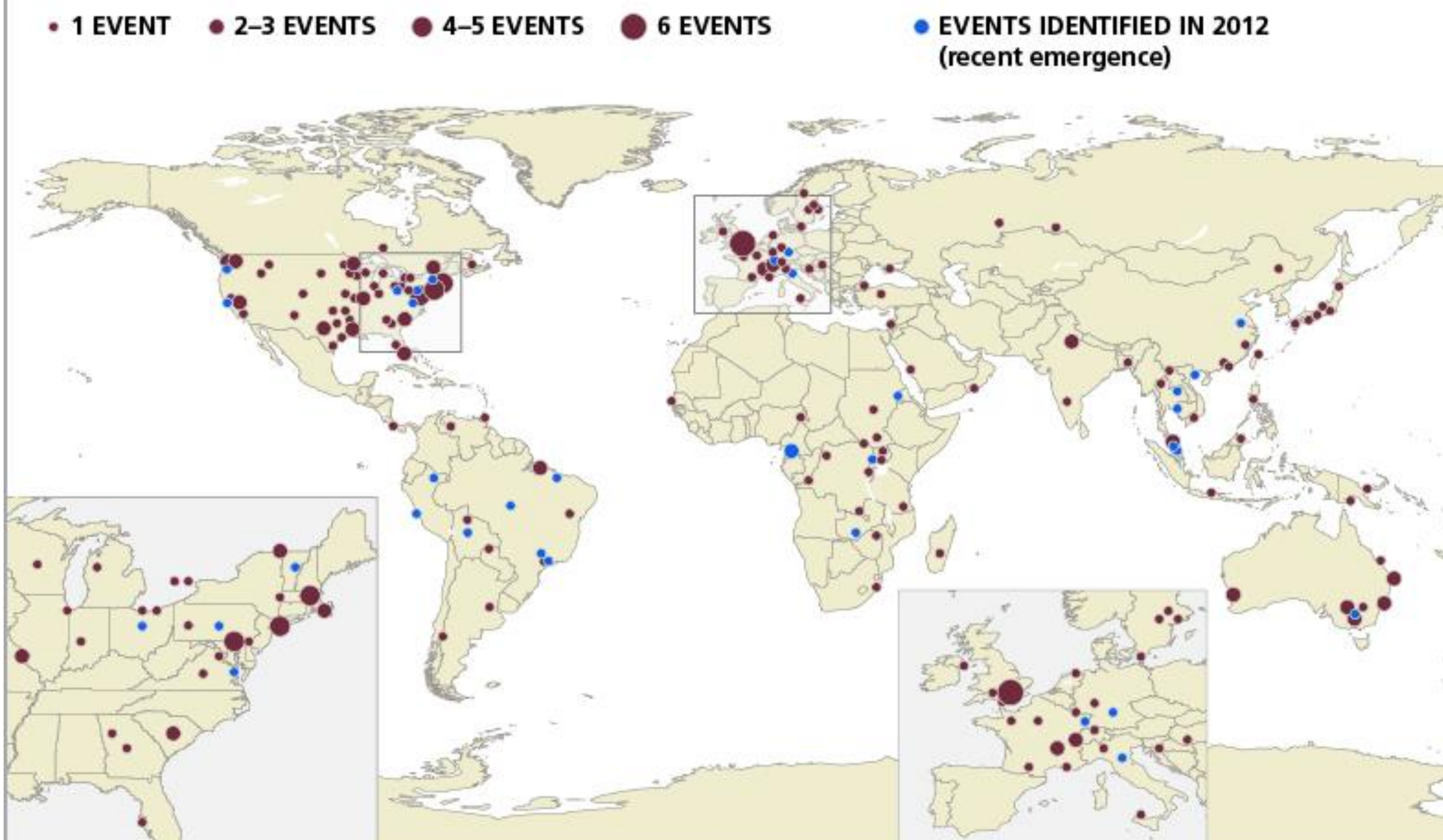
- Which diseases?
  - EID twice as likely to be zoonotic than non-zoonotic (zoonotic viruses and protozoa had highest proportion)
  - Quick mutations- typically ssRNA
- Where?
  - rapid intensification, increasing interactions between animals, humans and ecosystems, often rapidly changing habits and practices


Ecosystem
Livestock
LH
WL
X
Humans
WH
Wildlife
Disease transmission
Spillover event

Emerging Zoonotic Disease Events, 1940-2012

Potential Hotspots in US, Western Europe, Brazil, Southeast Asia

Most emerging human diseases come from animals. This map locates zoonotic events over the past 72 years, with recent events (identified by an ILRI-led study in 2012) in blue. Like earlier analyses, the study shows western Europe and western USA are hotspots; recent events, however, show an increasingly higher representation of developing countries.



Map by IOZ, published in an ILRI report to DFID: *Mapping of Poverty and Likely Zoonoses Hotspots*, 2012.

Why are vector-borne diseases emerging?

Climate & climate changes
Globalisation
Urbanization
Land-use changes

Vector capacity and competence

k= Probability that a vector feeding on an infected host gets infected.

P_f= Probability that a vector survives from one meal to the next.

P_e= Probability that a vector survives the Extrinsic incubation period, EIP

Q= Probability that a vector feeds from the right host – blood index for the host.

H_{Br}= Host biting rate, the number of vectors feeding from an animal per day.

v= Probability of pathogens becoming infectious in the vector

C= Vector capacity

$$C = H_{Br}\, Qvk\, P_e/(1 - P_f)$$

Infectious disease driver: urbanization

Japanese Encephalitis Virus-
risks with urban agriculture

Is urbanization important? Why is it a driver of disease?

- 7 billion people
- 50% urban inhabitants – continuous urbanisation
- It involves approximately 800 million people and produces 15-20 % of the food in the world

ILRI

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Urban inhabitants need food

- Large problems to supply from rural areas
- Difficulties with cold chain

The benefits and problems

- Local markets with living and dead animals

The benefits and problems

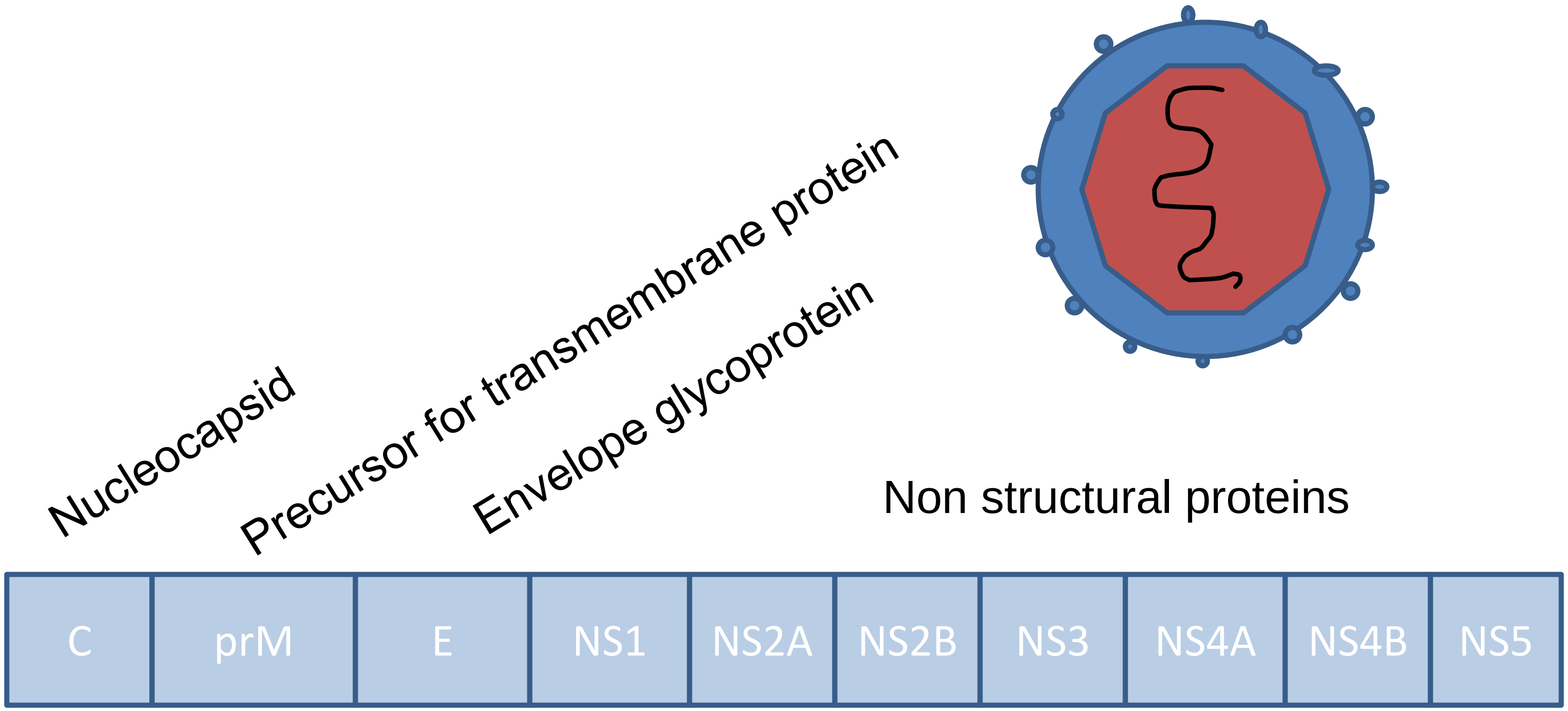
- Possibility to use urban wastes and waste water
- Lacking sanitation

Pathogens in the urban agriculture

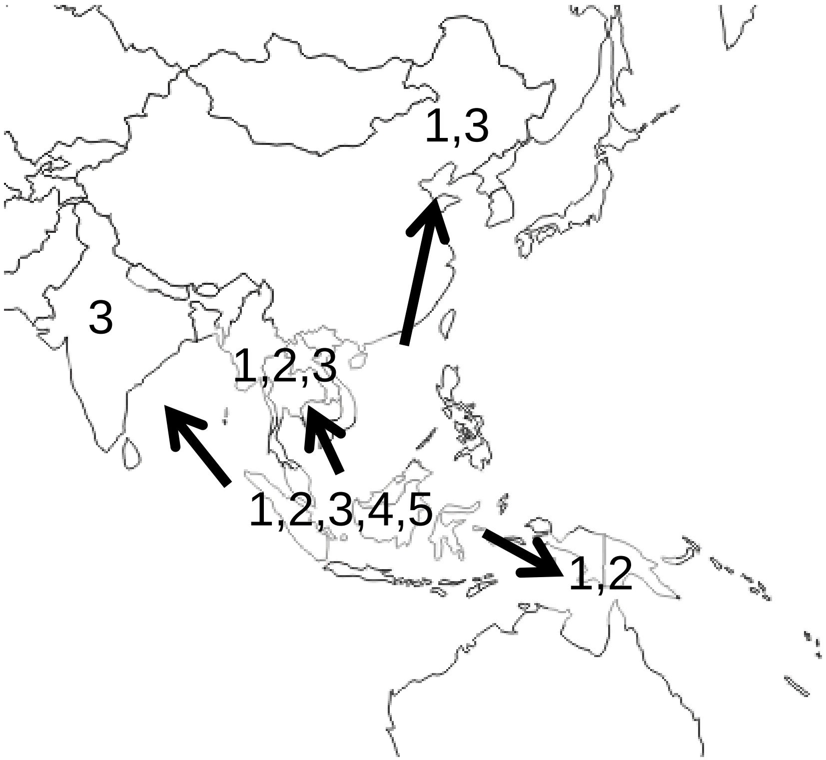
- Food-borne pathogens
- Zoonotic animal diseases
- Vector-borne diseases

Japanese Encephalitis Virus

- Flavivirus, + ssRNA
- Known to be a rural disease



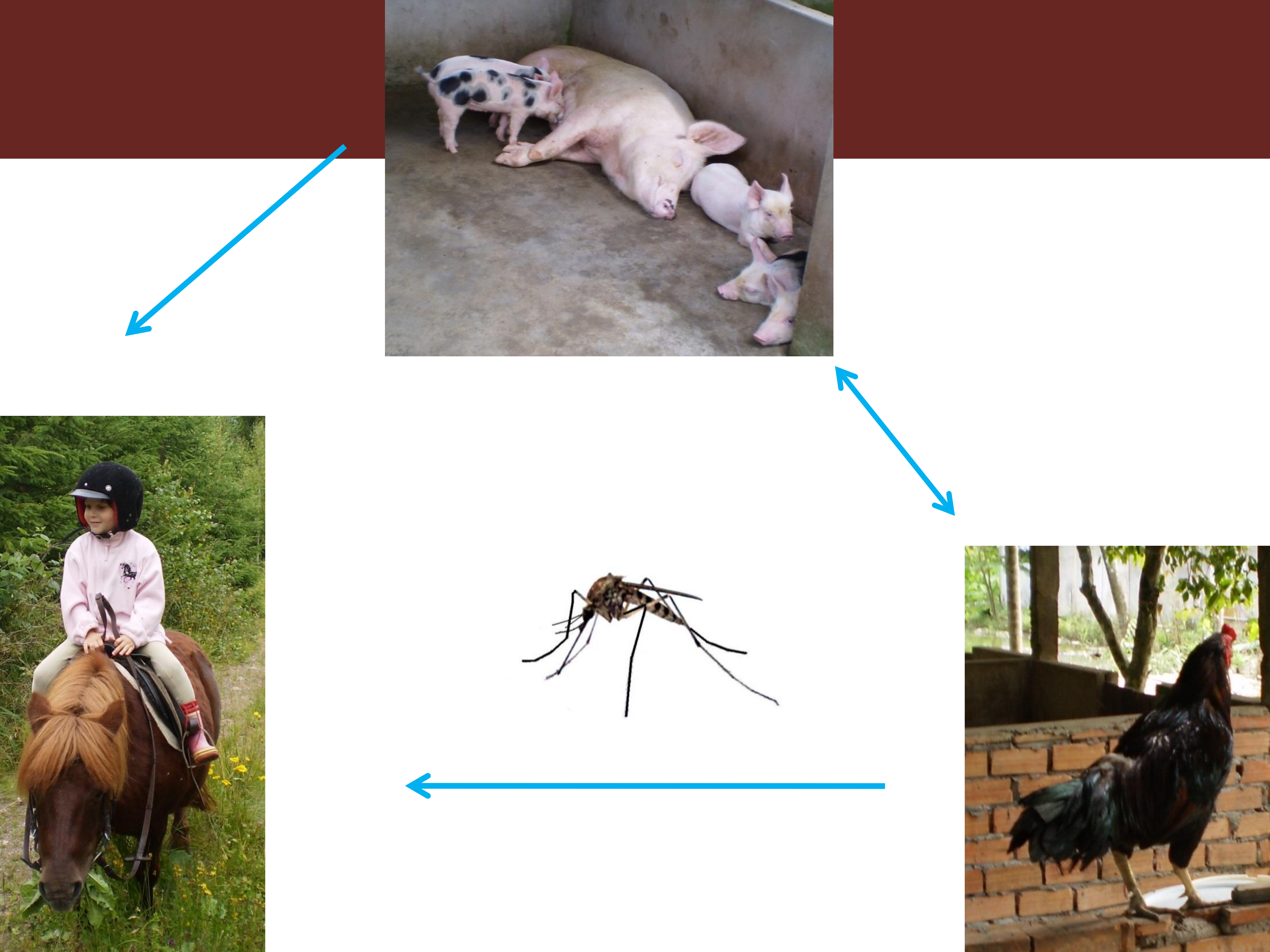
Genotypes distribution and spread



A Flavivirus

…and an Arbovirus

- Culicidae, genus Culex
  - Culex pseudovishnui
  - Culex tritaeniorhyncus
  - Culex gelidus
  - Culex fuscocephala
  - Culex annulirostris
  - Culex quinquefasciatus



Disease in humans and horses

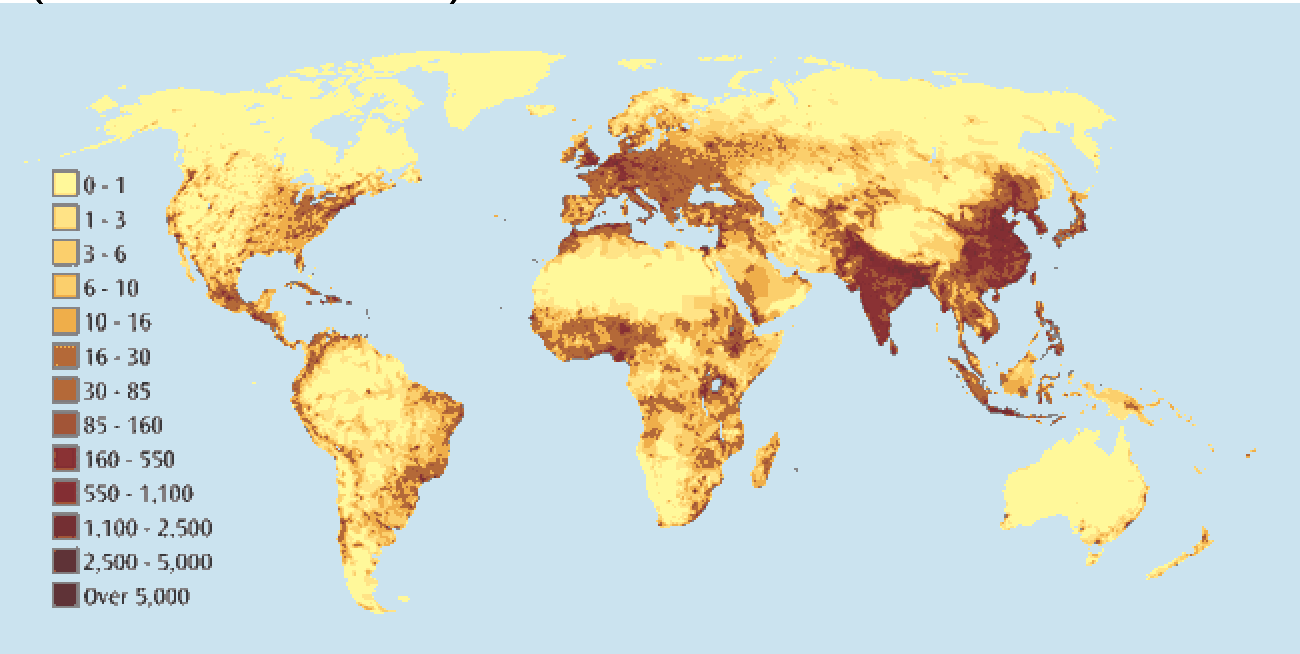
- Often asymptomatic
- Incubation period 6-10 days
- Fever, headache and meningitis
- Acute flaccid paralysis
- Coma, death

JEV and reproduction- pigs

- SMEDI: Stillbirth, Mummification, Embryonal death, infertility
- Middle third of pregnancy most affected
- Immunocompetence after 65-70 days
- Boars: orchitis, aspermia
- Can be experimentally venerally transmitted

Geographic spread

Population density
(FAO stat estimates)



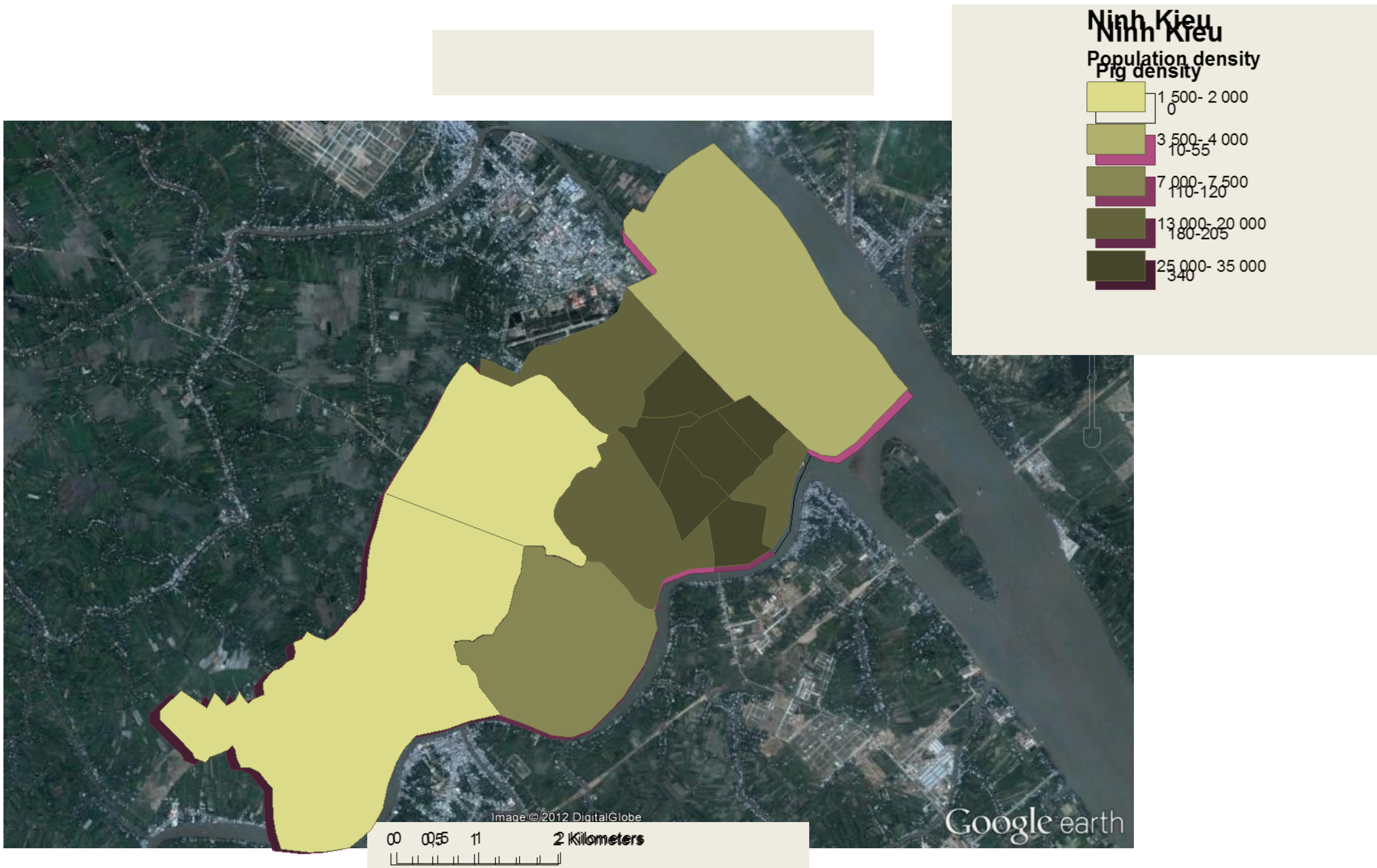
- 3 billion live in endemic areas
- 50 000 cases per year
- Case fatality 30%

Our project in Vietnam

Ninh Kieu district-Can Tho city

- Around 4800 pigs on 288 pig farms
  - <17 pigs per farm
  - 1-2 sows
- No poultry reported
- Not many paddy fields

Ninh kieu district, ”Can Tho city”



Mosquito collections

Collected mosquitoes

- *Culex tritaeniorhynchus* (36%)
- *Culex gelidus* (24%)
- *Culex quinquefasciatus* (15%)

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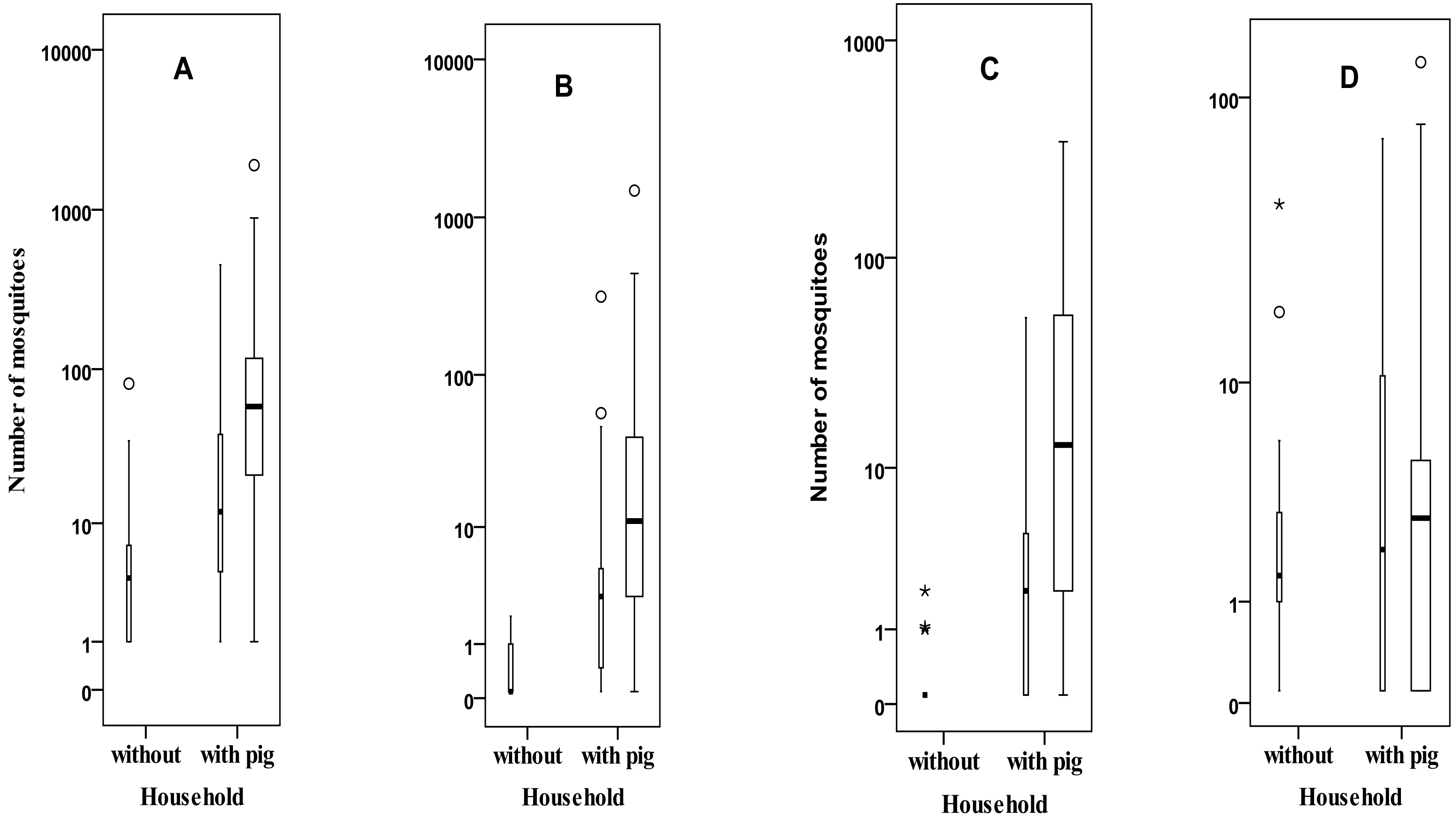
Pigs and mosquitoes



Graphs showing the mosquitoes collected in households with and without pigs in Ninh Kieu district, Can Tho city, Vietnam. Collections made close to humans are shown with thin boxes and collections close to pigs are shown with thick boxes.
A; total number of mosquitoes, B; *Culex tritaeniorhynchus* C; *Culex gelidus* D; *Culex quinquefasciatus*.
Circles depict outliers > 1.5 x the interquartile range and stars extreme outliers > 3 x the interquartile range.

Serum from urban pigs

- Competitive ELISA
- All seropositive

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Conclusions

- The urban Ninh Kieu district is densely populated with extensive pig keeping
- Most mosquitoes at urban households are potential vectors
- Pig keeping increase the number of vectors

Am. J. Trop. Med. Hyg., 00(0), 2012, pp. 000–000
doi:10.4269/ajtmh.2012.12-0315

JEV- infected mosquitoes

Household with JEV-positive mosquito pool close to pigs

Household with pigs, no positive pools

Household without pigs, no positive pools

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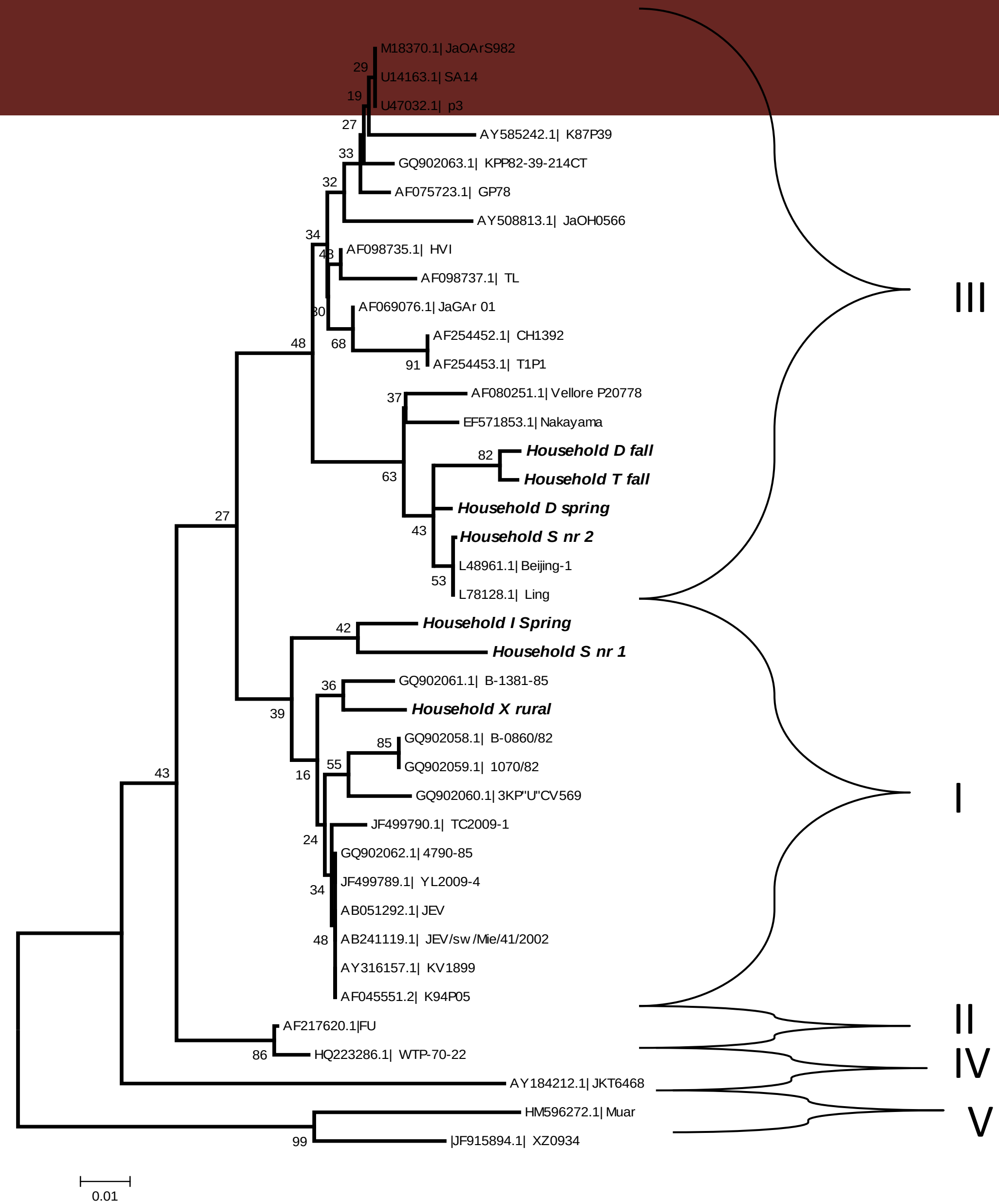
Genotypes



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JEV infection rate

Positive pool
9 *Cx. tritaeniorhynchus*
39 *Cx. tritaeniorhynchus*
25 *Cx. tritaeniorhynchus*
30 *Cx. quinquefasciatus*
50 unsorted
50 unsorted
50 unsorted

7885 mosquitoes, 352 mosquito pools, 7 positive

Minimum infection rate per 1000 mosquitoes	
All mosquitoes	0.89
Females (including unidentified mosquitoes)	0.98
Cx. tritaeniorhynchus	1.59
Cx. quinquefasciatus	1.27

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Conclusions

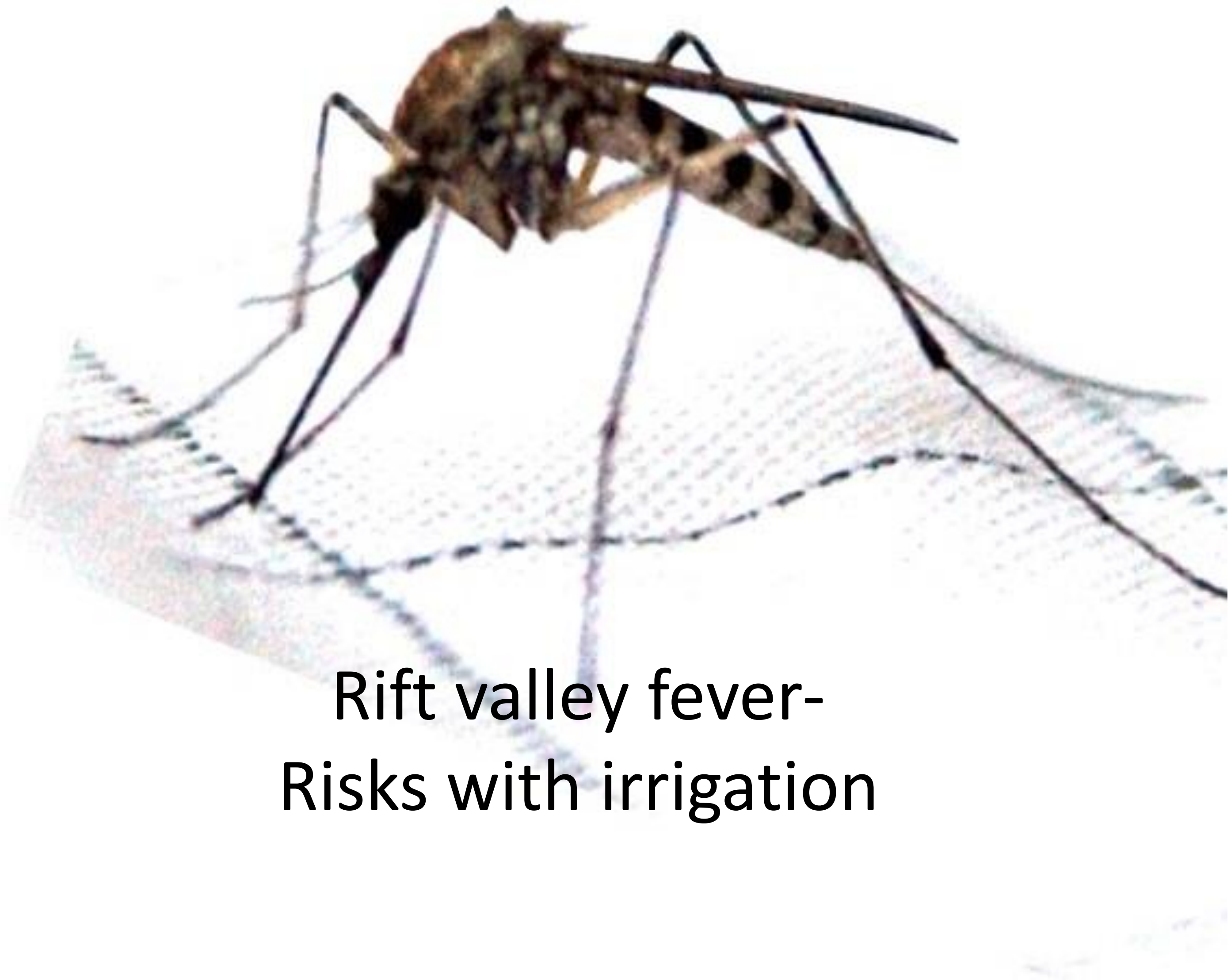
- Important with high sensitivity to circumvent inhibition in the PCR
- Both genotype I and III can circulate within the same city
- One per thousand mosquitoes can be infected in an urban area

OPEN ACCESS Freely available online — PLOS | NEGLECTED TROPICAL DISEASES

Circulation of Japanese Encephalitis Virus in Pigs and Mosquito Vectors within Can Tho City, Vietnam

Johanna F. Lindahl[1], Karl Ståhl[2¤], Jan Chirico[3], Sofia Boqvist[2], Ho Thi Viet Thu[4], Ulf Magnusson[1*]

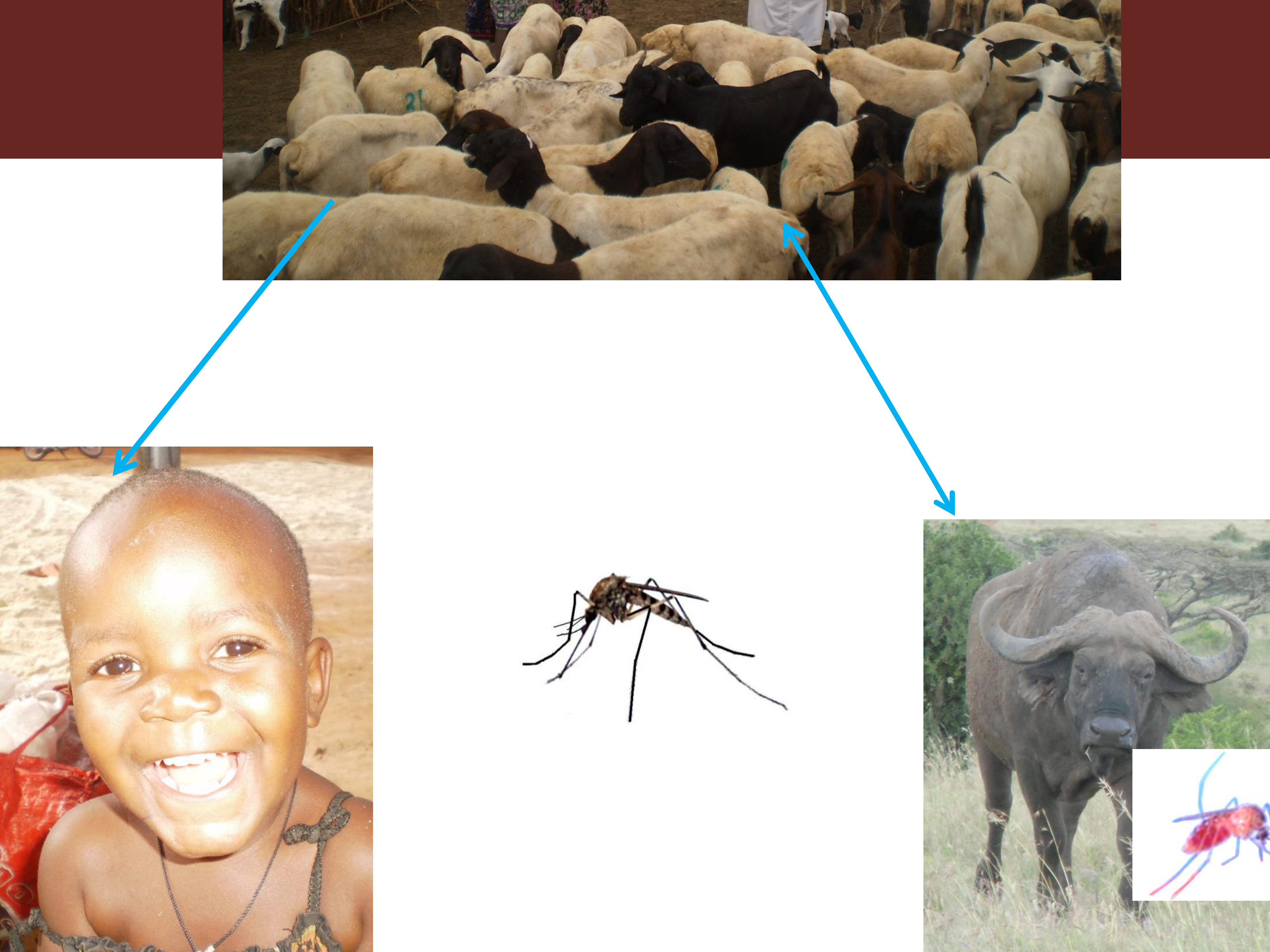
Infectious disease driver: Land use changes



Rift valley fever-
Risks with irrigation

RVF

- Bunyaviridae, phlebovirus
- High mortality, abortions in ruminants
- Hemorrhagic fever, encephalitis in humans
- Arbovirus- but also directly transmitted



Why irrigation?

More and more range lands in Africa are being converted to crop lands through irrigation to alleviate food insecurity

Results: major trade-offs in ecosystem services

- More food produced (provisioning services) at the expense of biodiversity and regulatory services (disease, flooding, erosion)

Most drivers are desired- and not constantly leading to disease

Anthropogenic action:

Increased irrigation

Effect on ecosystem:

Creates more larval habitats

Vector consequence:

More infected vectors

Epidemiologic consequence:

More individuals exposed

Increased disease

Hypothesis

- Irrigation in an arid and semi-arid area increases the risk for RVF
- But other diseases can also be affected by this…
- … and the doctors don't know if it is RVF

Study site with stagnant water in irrigation canals – source of water for the locals but also breeding grounds for mosquitoes

Solving that problem

- Including possible differential diagnoses:
  - Leptospira, Q-fever, malaria, WNV, Dengue, Chikungunya, Crimean-Congo hemorrhagic fever, *Brucella*

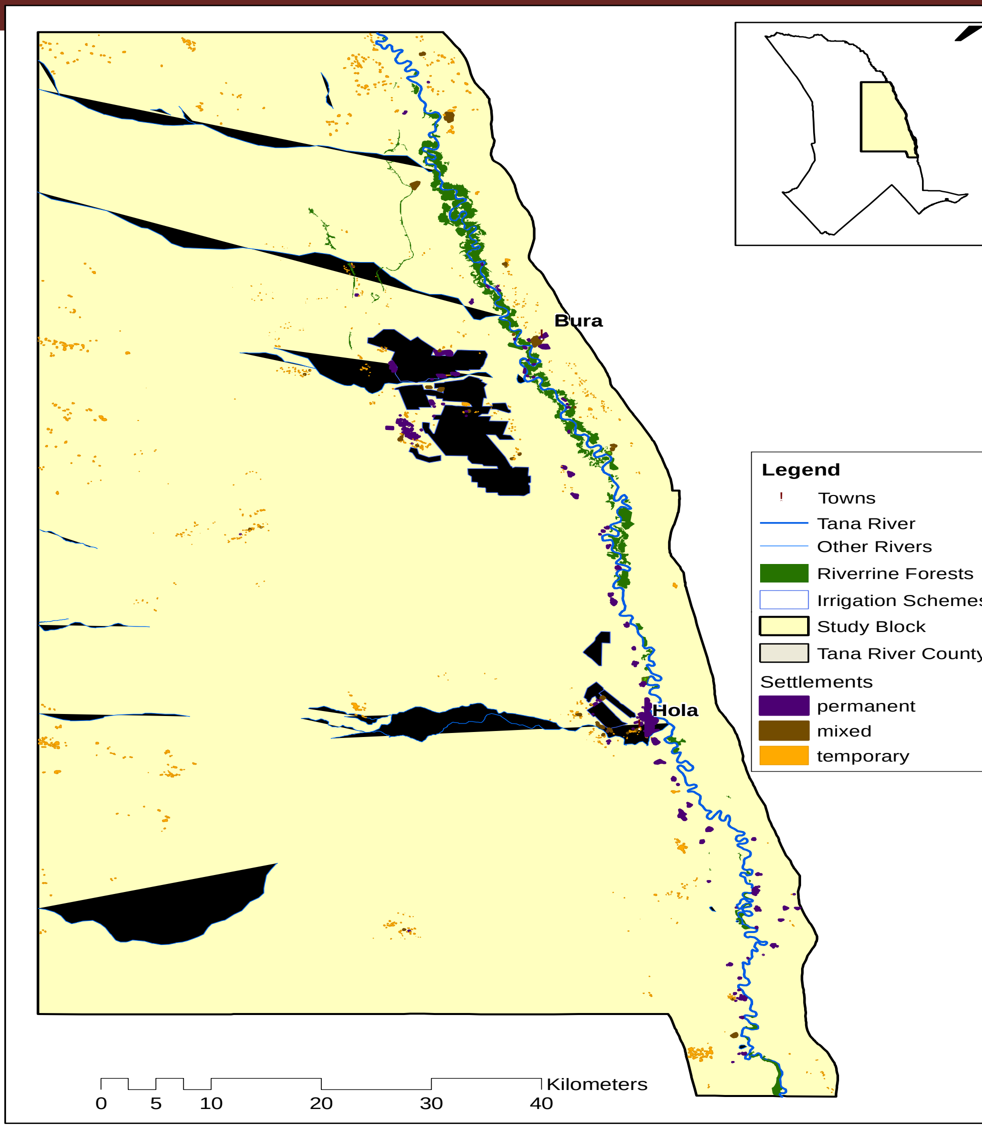
Pastoralists in the study site

Components

- Cross-sectional
  - Humans
  - Livestock
  - Mosquitoes
  - Wildlife
  - Ticks
- Longitudinal
  - Human febrile cases
  - Livestock- shoats
  - Mosquitoes

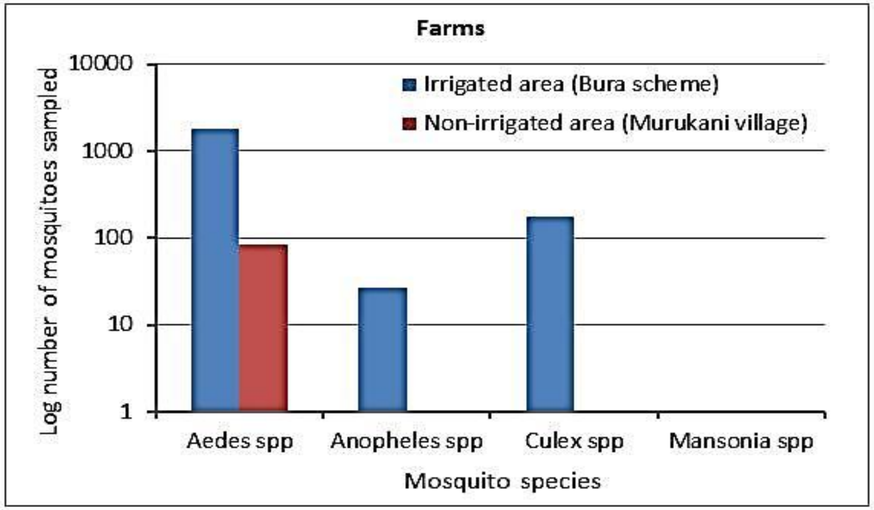
The study site:

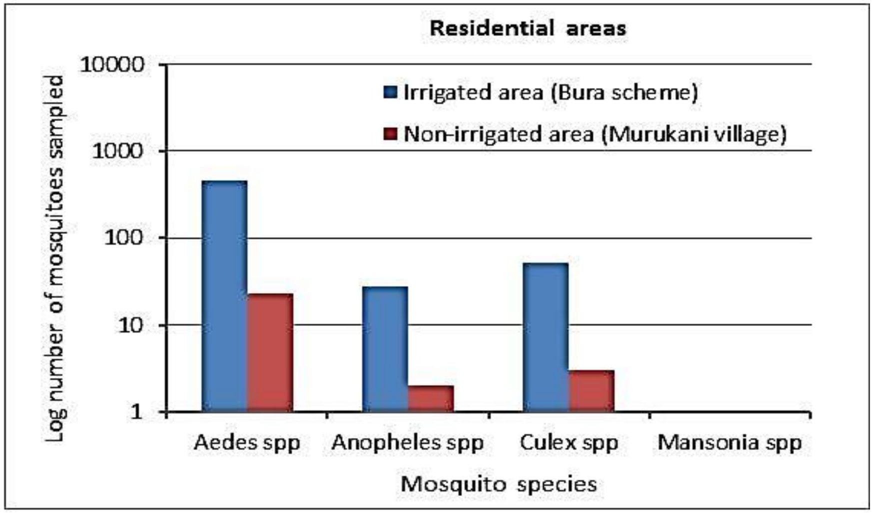
Tana River and Garissa counties, northeastern Kenya



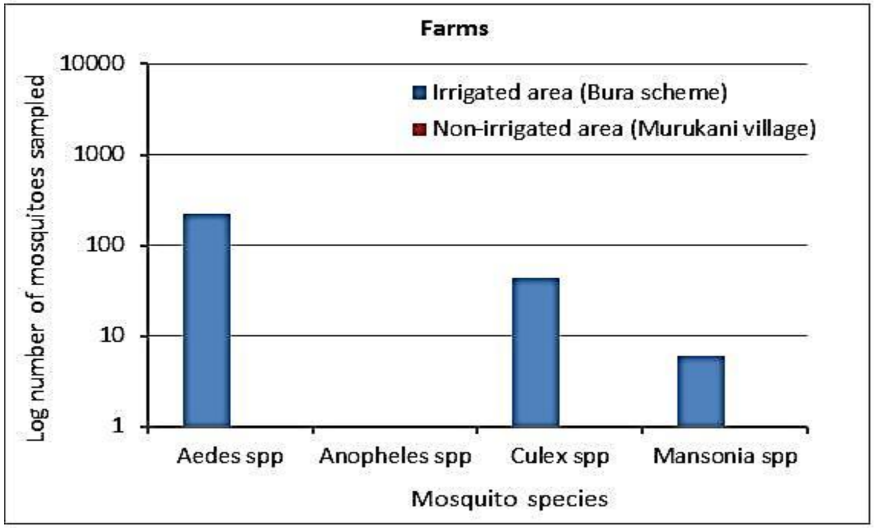
Mosquitoes trapped – relative abundance and species distribution

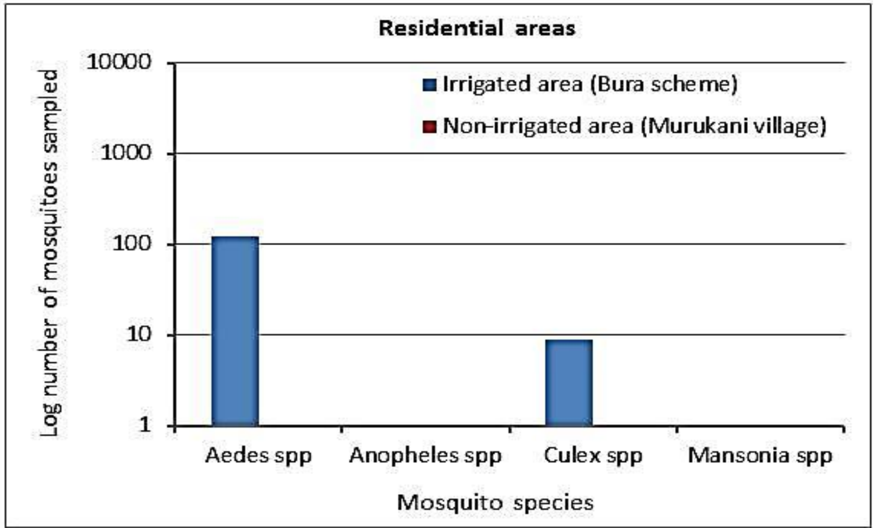
(a) Results from surveys done when irrigation was active





(b) Results from surveys done at the inactive phase of irrigation





Samples screened

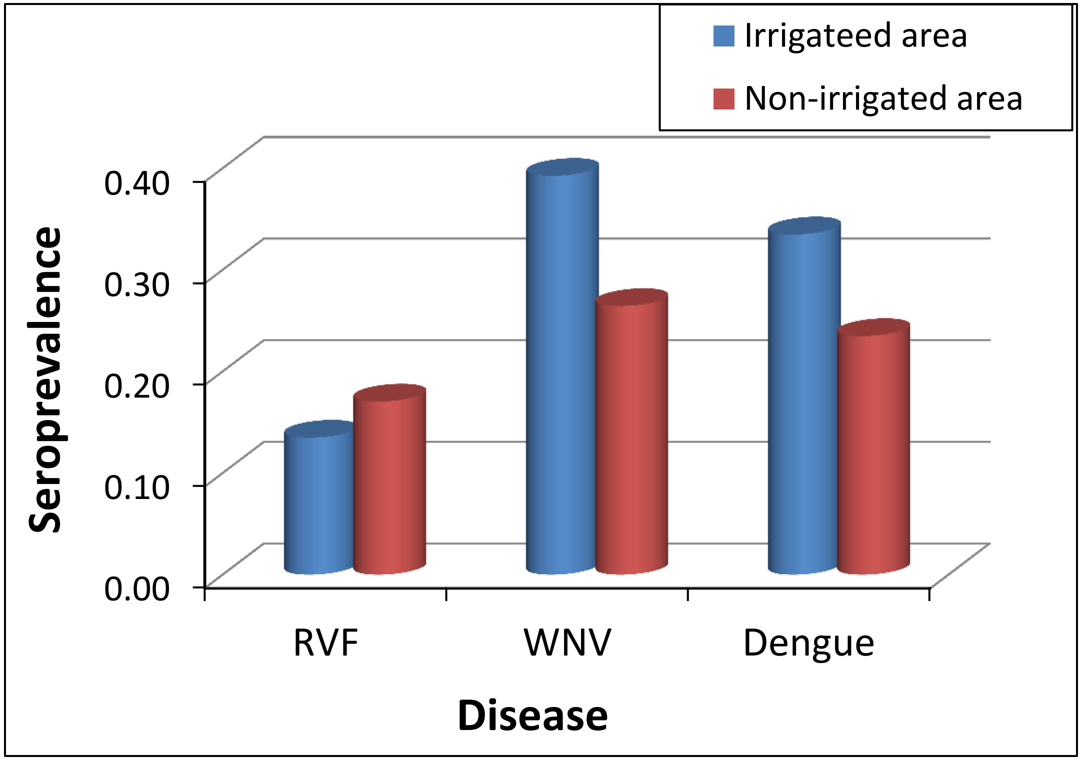
- 481 samples have been screened so far

- Questionnaires administered to 430 households

Serological tests

- WNV and Dengue sero-prevalence apparently higher than that for RVF though confirmatory are yet to be done

Relative seroprevalence of RVF, WNV and Dengue



Risk factor analysis - findings

For WNV and Dengue model:

I. Males have a higher risk of exposure than females

II. Farmers have a higher risk compared to pastoralists

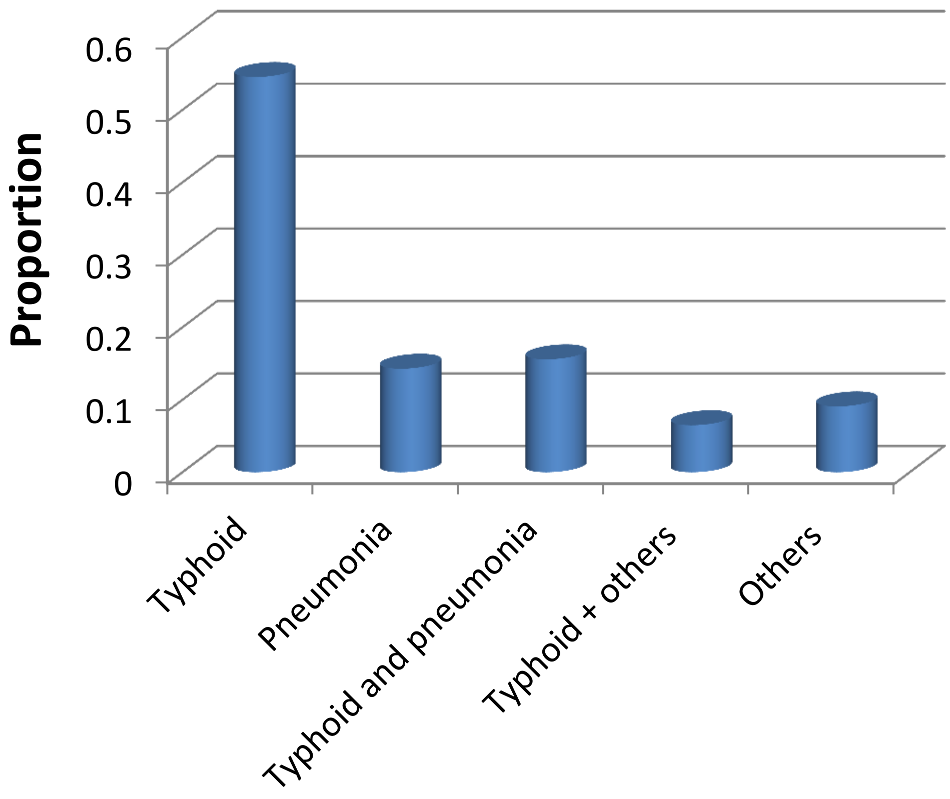
For RVF model:

I Males have a higher risk of exposure than females

Intervention points

- Build capacity on differential diagnosis of febrile illnesses in the local health centres. Currently, most cases are treated as:
  - Malaria
  - Brucellosis
  - Typhoid

Communities' perceptions on diseases that manifest similar signs as malaria – limited knowledge on arboviruses



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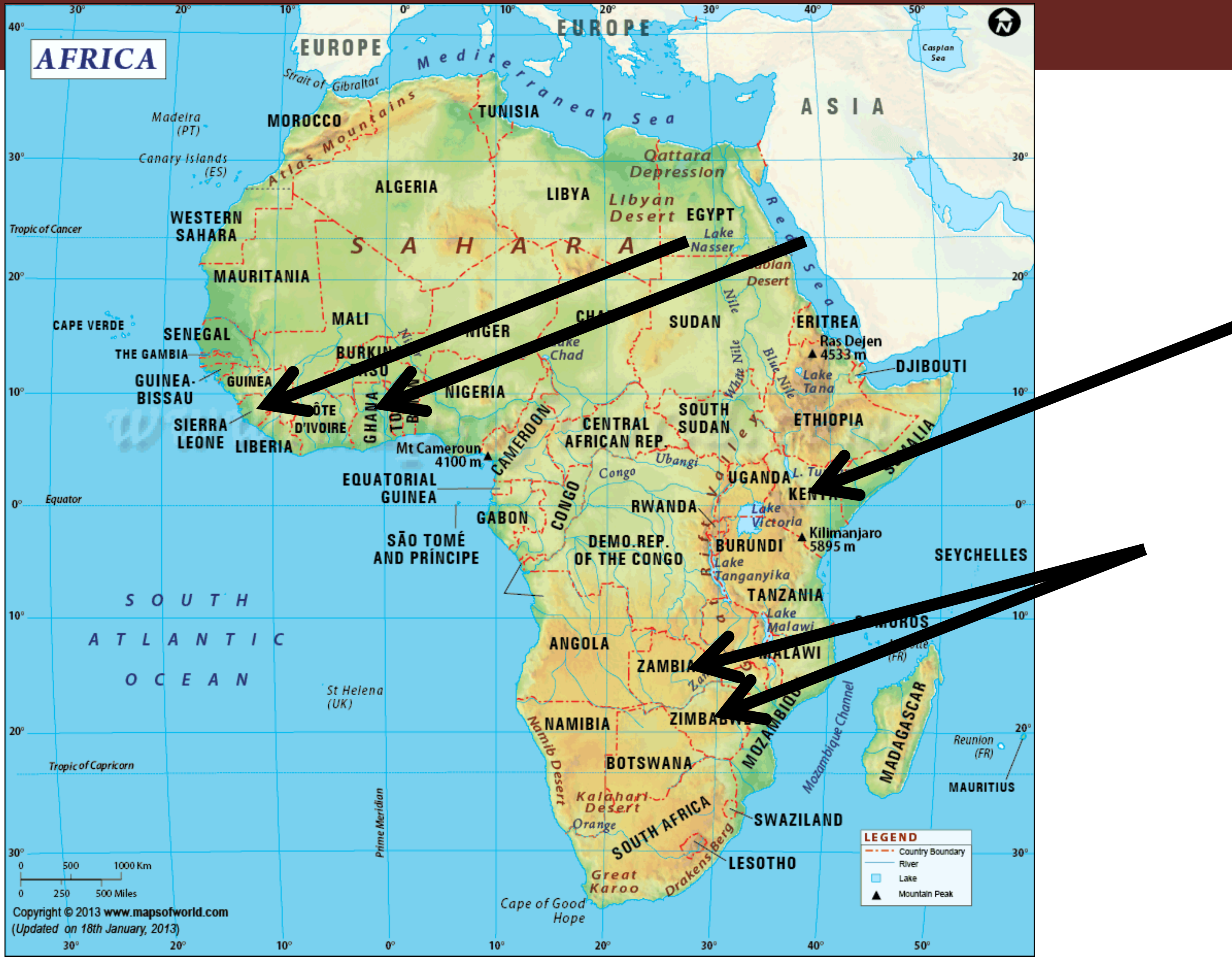
AFRICA
EUROPE
Mediterranean Sea
ASIA
Caspian Sea
Strait of Gibraltar
Madeira (PT)
Canary Islands (ES)
Atlas Mountains
MOROCCO
TUNISIA
ALGERIA
LIBYA
EGYPT
Qattara Depression
Libyan Desert
Lake Nasser
Nubian Desert
Red Sea
WESTERN SAHARA
Tropic of Cancer
SAHARA
MAURITANIA
MALI
NIGER
SUDAN
ERITREA
Ras Dejen 4533 m
DJIBOUTI
Lake Tana
ETHIOPIA
CAPE VERDE
SENEGAL
THE GAMBIA
GUINEA-BISSAU
GUINEA
SIERRA LEONE
LIBERIA
D'IVOIRE
GHANA
NIGERIA
Lake Chad
CAMEROON
Mt Cameroun 4100 m
CENTRAL AFRICAN REP.
SOUTH SUDAN
White Nile
Blue Nile
Nile
Ubangi
Congo
UGANDA
EQUATORIAL GUINEA
Equator
GABON
CONGO
RWANDA
Lake Victoria
Kilimanjaro 5895 m
SÃO TOMÉ AND PRÍNCIPE
DEMO.REP. OF THE CONGO
BURUNDI
Lake Tanganyika
TANZANIA
SEYCHELLES
Lake Malawi
SOUTH ATLANTIC OCEAN
ANGOLA
ZAMBIA
MALAWI
St Helena (UK)
NAMIBIA
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Mozambique Channel
MADAGASCAR
Reunion (FR)
MAURITIUS
Tropic of Capricorn
Namib Desert
BOTSWANA
Kalahari Desert
Orange
SOUTH AFRICA
SWAZILAND
LESOTHO
Drakensberg
Great Karoo
Cape of Good Hope
Prime Meridian
LEGEND
Country Boundary
River
Lake
Mountain Peak
0 500 1000 Km
0 250 500 Miles
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Case study: Zambia/ Zimbabwe

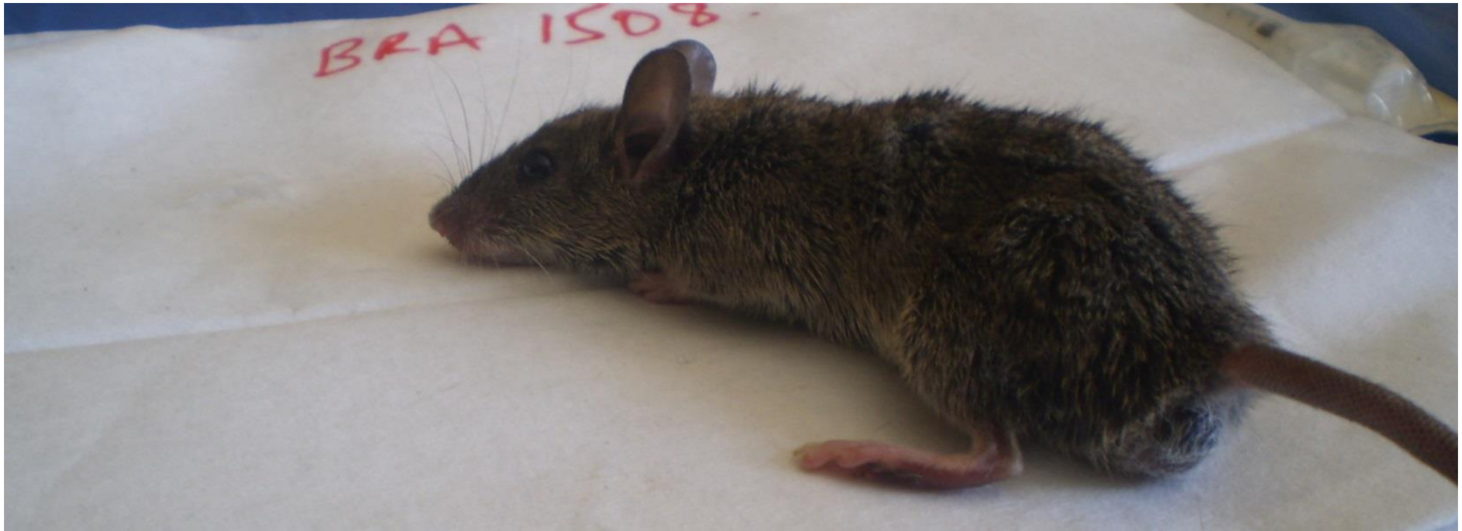
- Trypanosomiasis/tse tse
- Land use changes
  - Protected area
  - Area where livestock has been increasing
  - Former large-scale farms with low biodiversity

Case study: Ghana

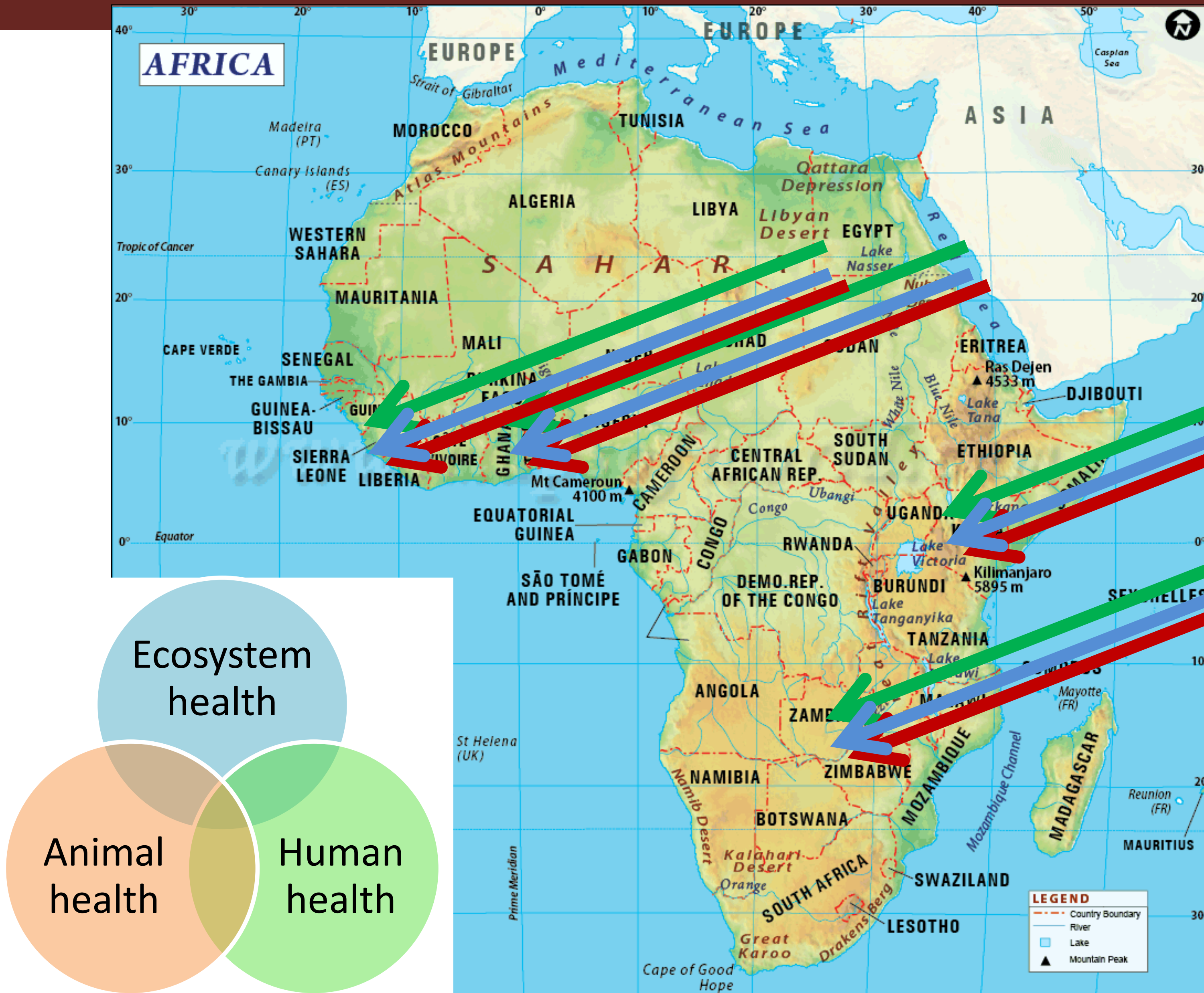
- Henipa virus/ bats
- Urban –rural migration
- Livelihoods, poverty, ecology and the association with disease
  – How do humans interact with bats and what perceptions do they have of the risks
  – Protected/sacred area
  – Urban area

Case study: Sierra Leone

- Lassa fever/ multimammate rats
- Land use changes and rodent ecology
  - Urban-rural
  - Irrigation and precipitation
  - Human-rat interaction and risk perceptions



The perfect model?



Not the end….
….but the beginning

Open to questions

Open to discussion

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