Spatial modelling of Ebola virus transmission in a changing forest landscape

Larisa Lee-Cruz, Pascal Degenne, Maxime Lenormand, Julien Cappelle, Alexandre Caron, Hélène De Nys, Elodie Schloesing, Thibault Pouliquen, François Roger, Annelise Tran

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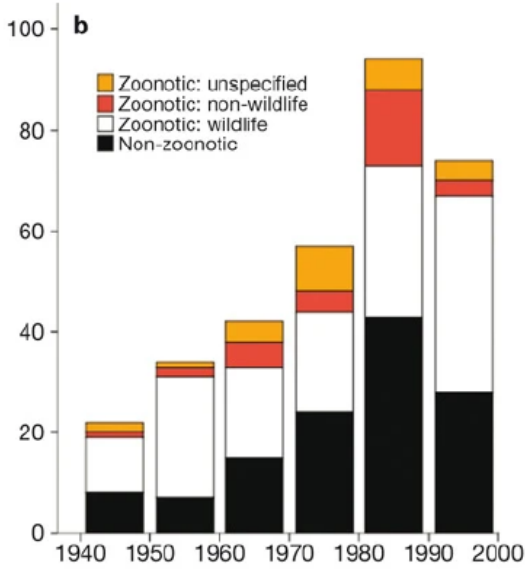
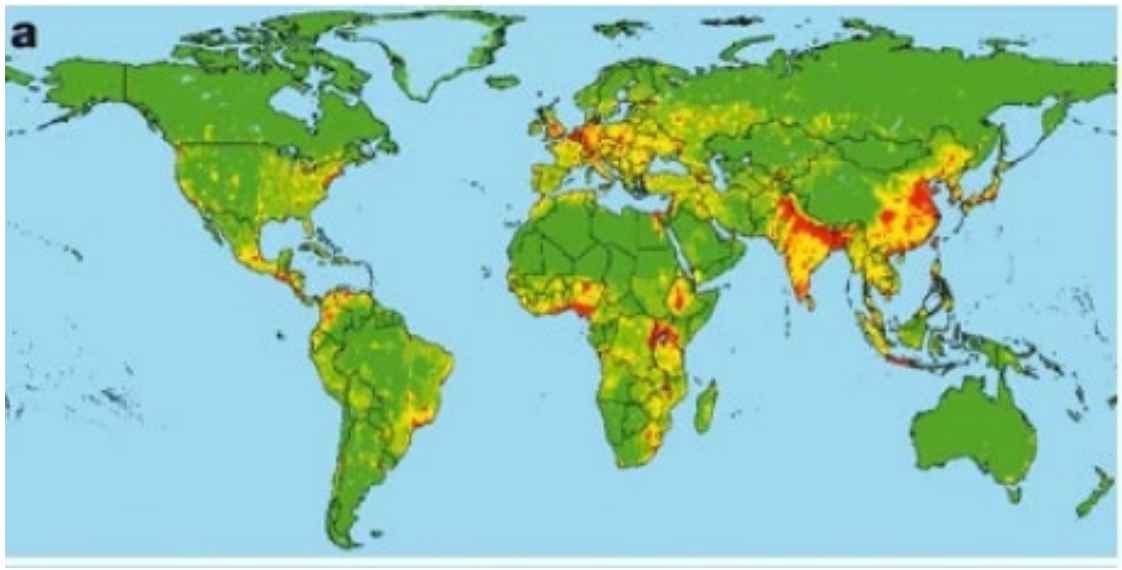
EboHEALTH

Emerging infectious diseases

25% mortality worldwide
60% animal origin



Increase in incidence of EID



'Hotspots' for EID

Jones et al. 2008
Doi 10.1038/nature06536

Global changes, drivers of EID

Forest loss and fragmentation

ELSEVIER
Current Opinion in Virology
Volume 3, Issue 1, February 2013, Pages 79-83

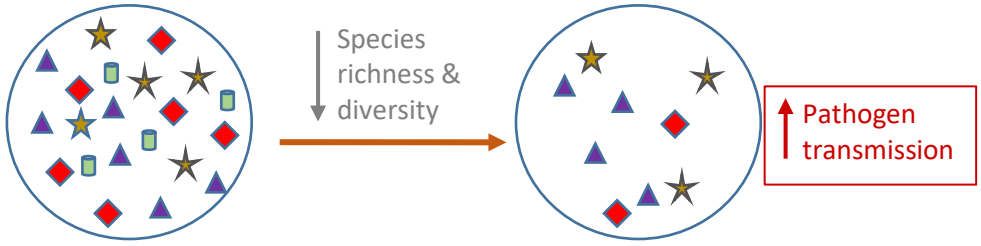
Human ecology in pathogenic landscapes: two hypotheses on how land use change drives viral emergence

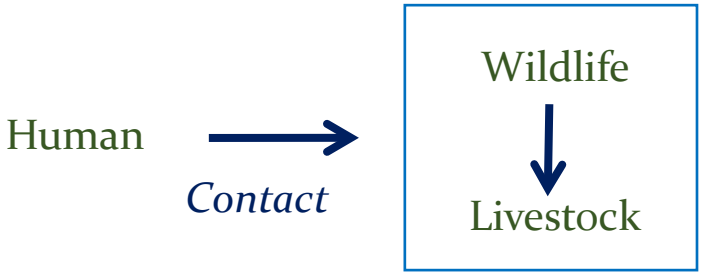
Kris A Murray, Peter Daszak

Show more

Bats, Coronaviruses, and Deforestation: Toward the Emergence of Novel Infectious Diseases?

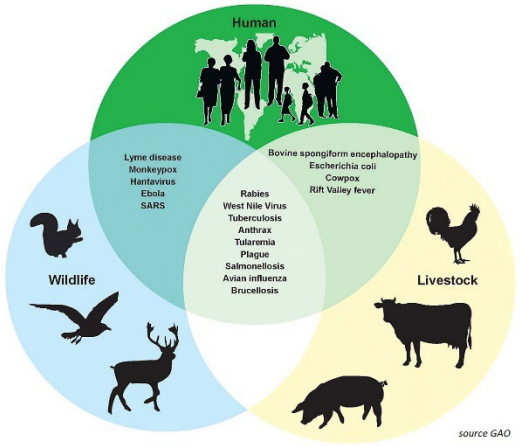
Aneta Afelt[1], Roger Frutos[2,3] and Christian Devaux[4]*



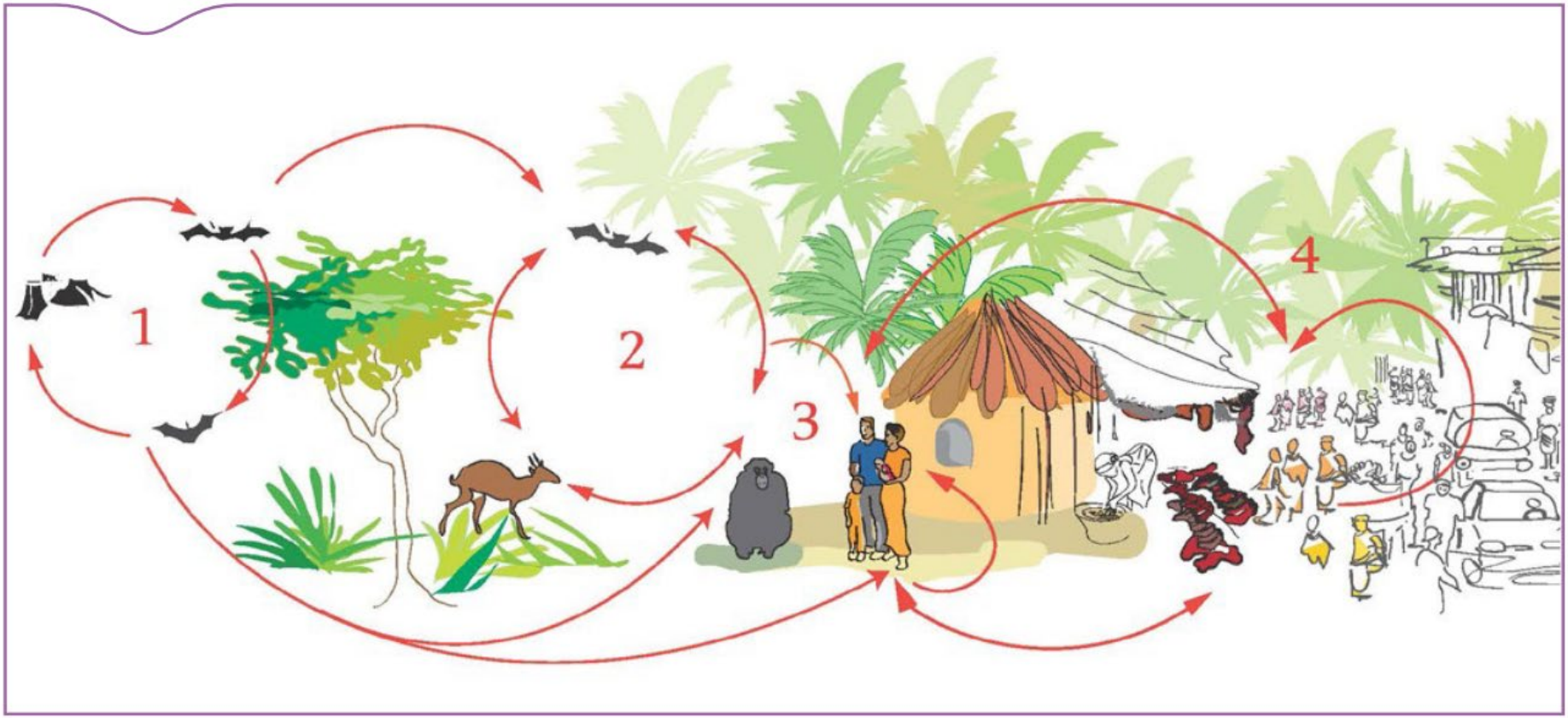


SCIENTIFIC REPORTS
OPEN

Recent loss of closed forests is associated with Ebola virus disease outbreaks



Ebola virus dynamics



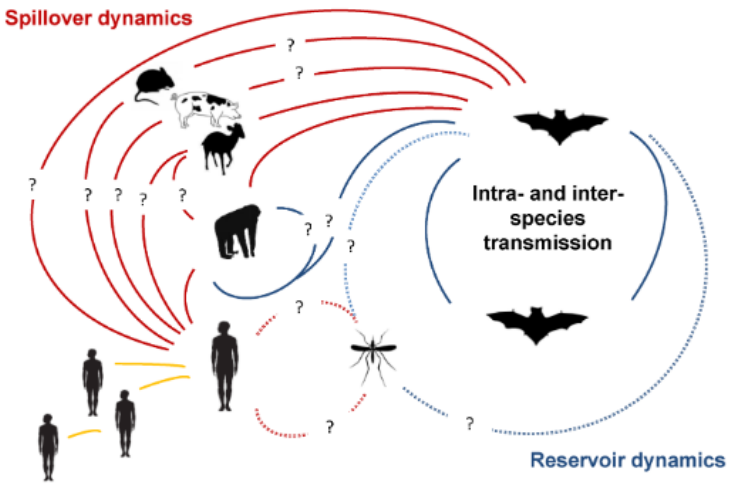
Ebola virus circulation and transmission in a forested socio-ecosystem: (1) bats, (2) wildlife, (3) human – wildlife contact, (4) human communities. © D. Guard-Lavastre/Cirad, modified from CDC: http://www.cdc.gov/vhf/ebola/resources/virus-ecology.html

Human – Human transmission by direct or indirect (body fluids or contaminated surface)

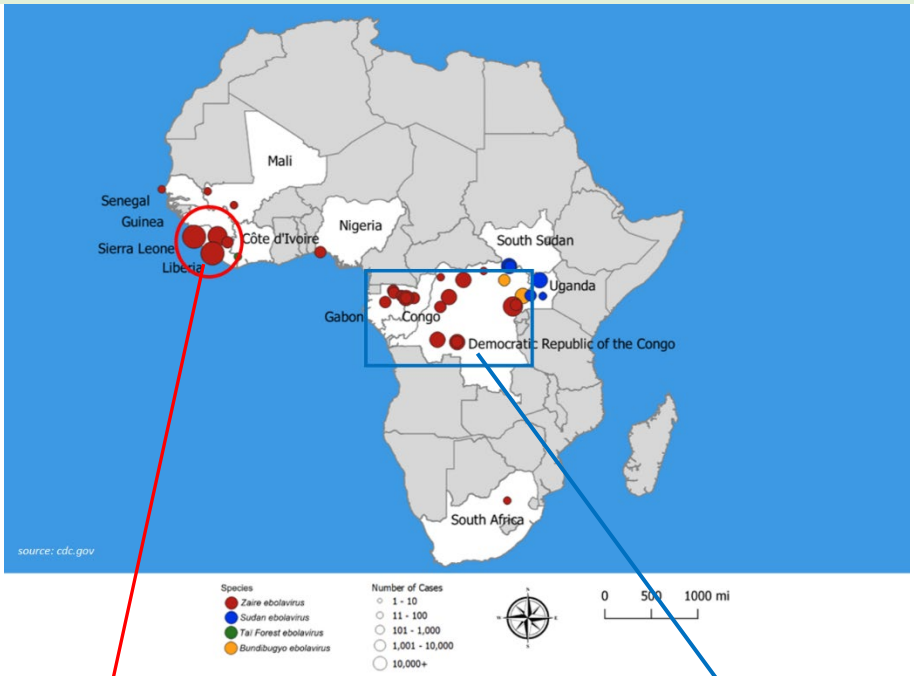
- Mortality rate ≈ 50%
- 1st case in DRC in 1976
- ≈ 22 outbreaks; 16 since 2001.
- West Africa (2013 - 2016) >28 600 cases 11 325 deaths

Ebola virus dynamics

(Zaire ebolavirus)

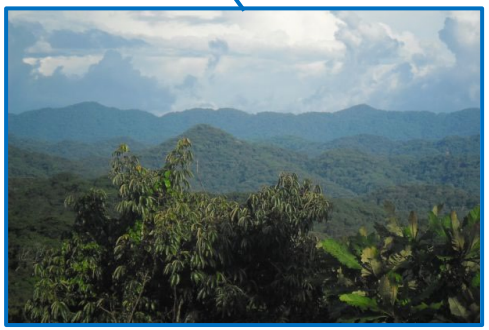


Olival & Hayman 2014
DOI:10.3390/v6041759



Guinea

Fragmented forest
(mosaic of forest and cultivated land)

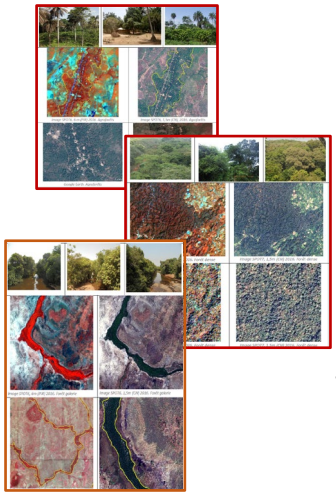


Congo Basin

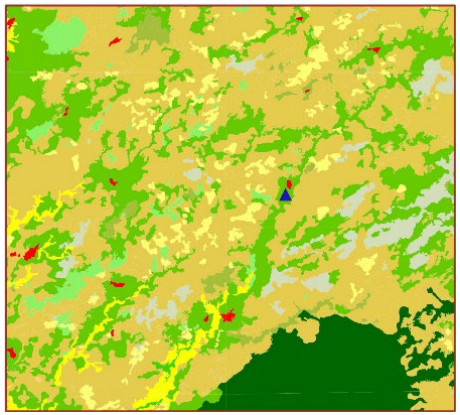
Primary and secondary forest

Explore transmission dynamics in a potential Ebola virus reservoir in a changing forest landscape

Earth observation for land cover mapping



52 land cover classes



Ecology of *Hypsignathus monstrosus*

Z. Tierpsychol., 45, 225—255 (1977)
© 1977 Verlag Paul Parey, Berlin und Hamburg
ISSN 0044-3573 / ASTM-Codes: ZETAG

University of California, San Diego, Department La Jolla, California

Lek Mating Behavior in the Hammer-headed Bat

By Jack W. Bradbury

PLOS ONE

Lek-associated movement of a putative Ebolavirus reservoir, the hammer-headed fruit bat (*Hypsignathus monstrosus*), in northern Republic of Congo

Mammalian Species No. 357, pp. 1–4, 4 figs.

Hypsignathus monstrosus. By Paul Langevin and Robert M. R. Barclay

Published 26 April 1990 by The American Society of Mammalogists

Afrique SCIENCE *11(1) (2015) 227 - 236*
ISSN 1813-548X, http://www.afriquescience.info

Données préliminaires sur la distribution spatio-temporelle des chauves-souris à tête de marteau, *Hypsignathus monstrosus* H. Allen, 1861 dans la commune du Plateau (Abidjan, Côte d'Ivoire)

Coffi Jean Magloire NIAMIEN[1*], Blaise KADJO[2], Inza KONE[2] et Kouakou Eliézer N'GORAN[2]

+ current studies in Congo & Guinea

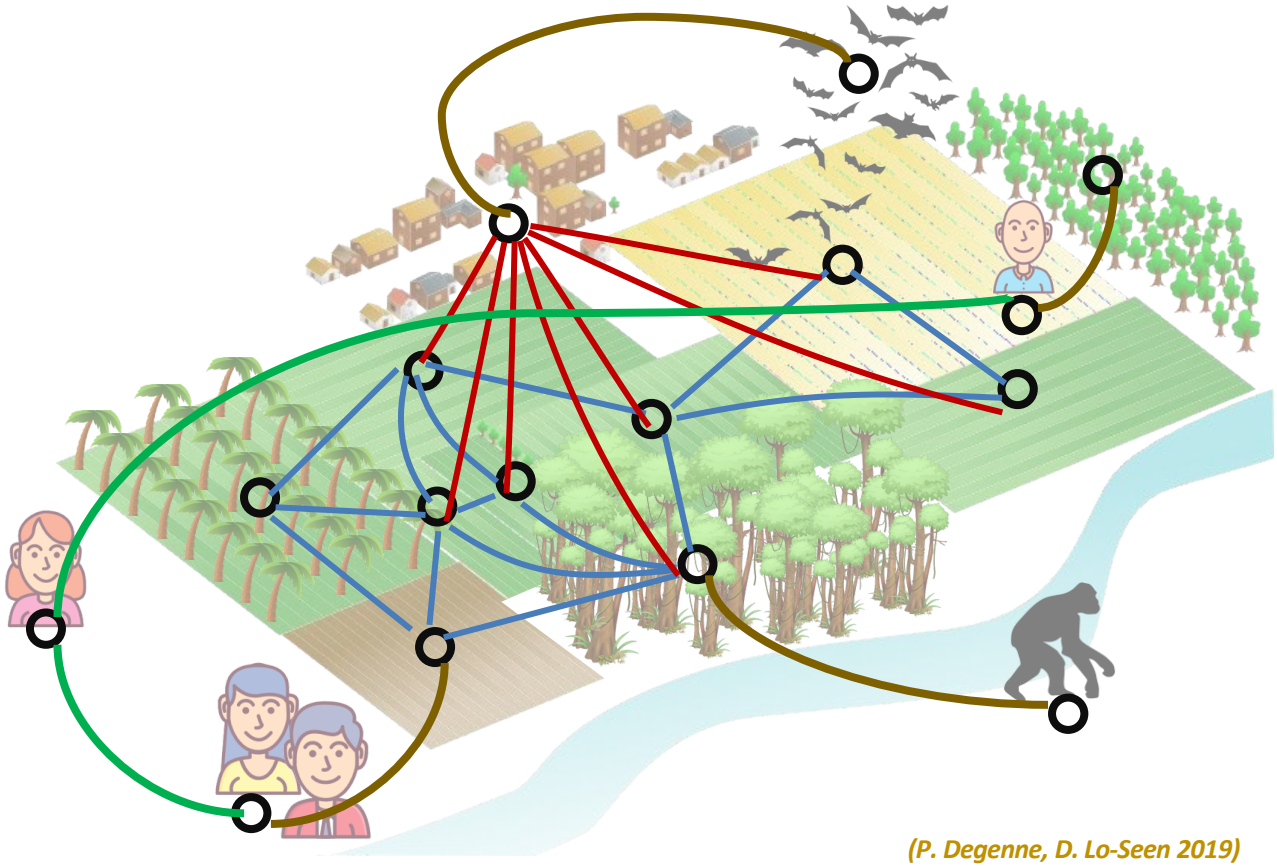
- Potential Ebola reservoir
- Capable of long migrations
- Concentration of displaying males during breeding season (leks)

In Guinea:
- Competes for resources (ex. mangoes) with humans
- 2 breeding seasons/year

Spatially explicit model

Domain specific language *(Ocelet)*

*Interaction graphs to model **relationships** between **entities***



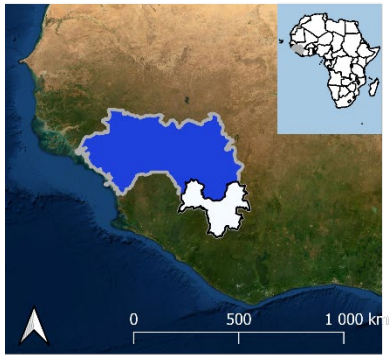
t_1

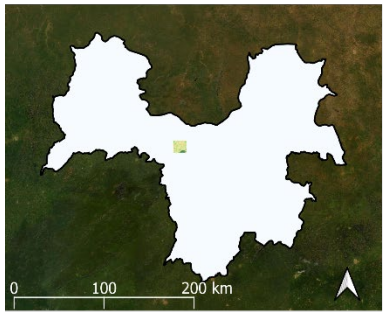
t_2

t_n

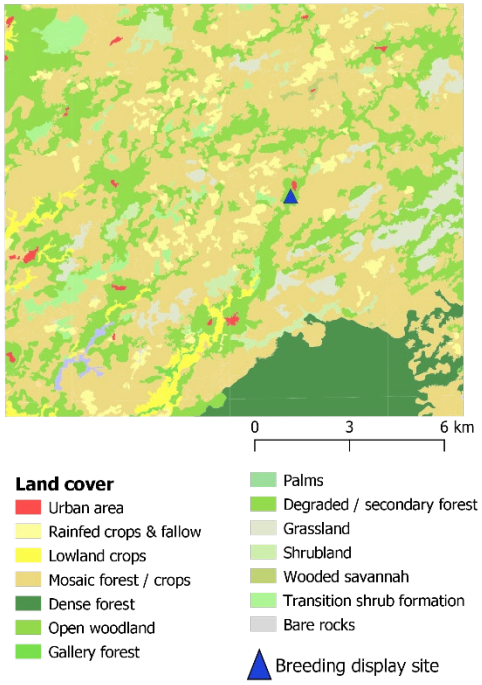
(P. Degenne, D. Lo-Seen 2019)

Changes in land cover (Guinée forestière)



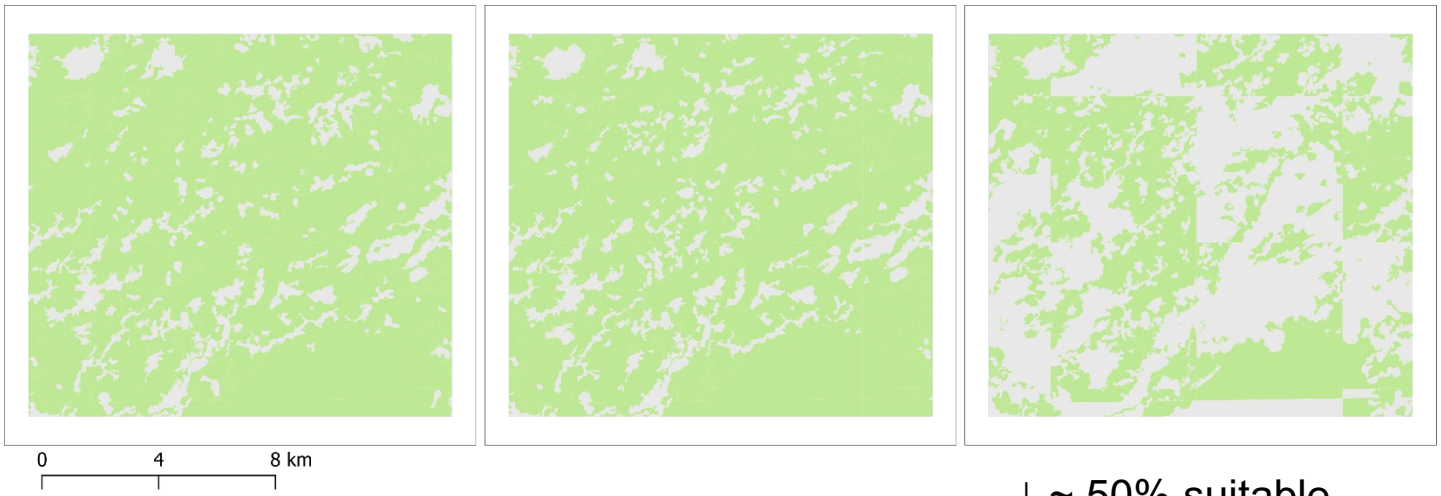


Guinée forestière



- Area of ~190 km^2
- Breeding site for fruit bats

Between 2005 – 2015, 1% of the surface occupied in the study area by degraded, secondary and transition forest has been **converted to a mosaic of crops and forests**… but ongoing change and fragmentation of forest

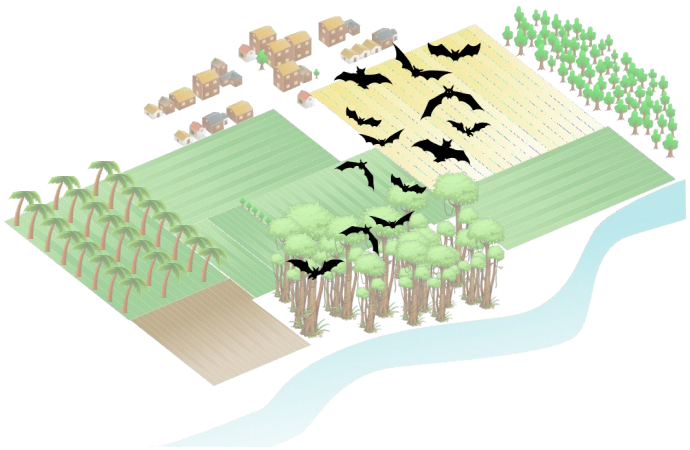


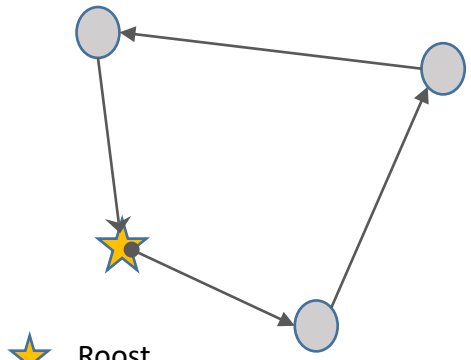
2005

2015

↓ ~ 50% suitable habitat

Ebola virus transmission model in fruit bats

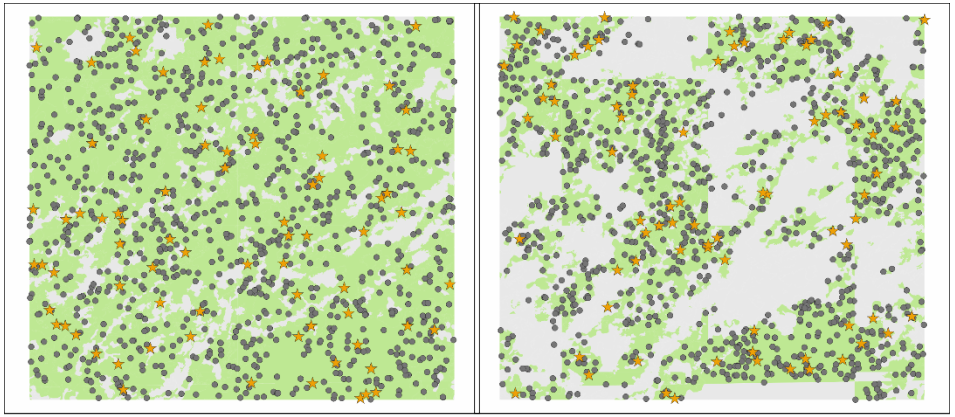




E.g. Nocturnal journey of a bat

Potential virus transmission
- Roosting
- Foraging

2005 *↓ ~ 50% suitable habitat*



Initial conditions

- No. bats in the population (1200)
- No. roosts in study area (80)
- No. foraging sites (1000)

Fixed parameters

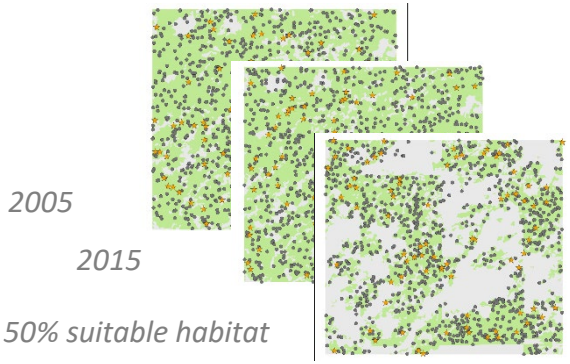
- Max. distance between roosts: 4 km
- No. days spent in the same roost: 1 – 10d
- Time spent in roost: 12h (6 am to 6 pm)
- Time spent in foraging site: 48 – 511 min
- No. foraging sites / night: 5
- Max. foraging distance: 14 km

Simulation parameters

- Location of roosts
- Location of foraging sites
- Length of simulation (7d)
- Time steps (20min)
- (Starting date)

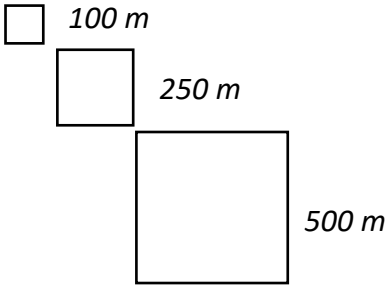
Spatio-temporal variation on bat density

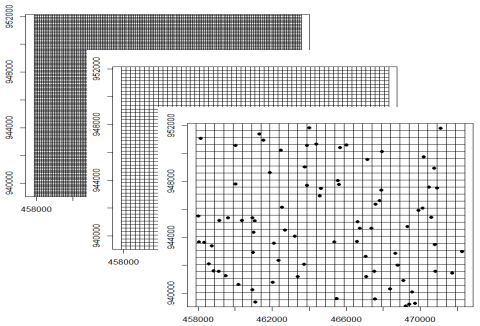
3 scenarios



↓ ~ 50% suitable habitat

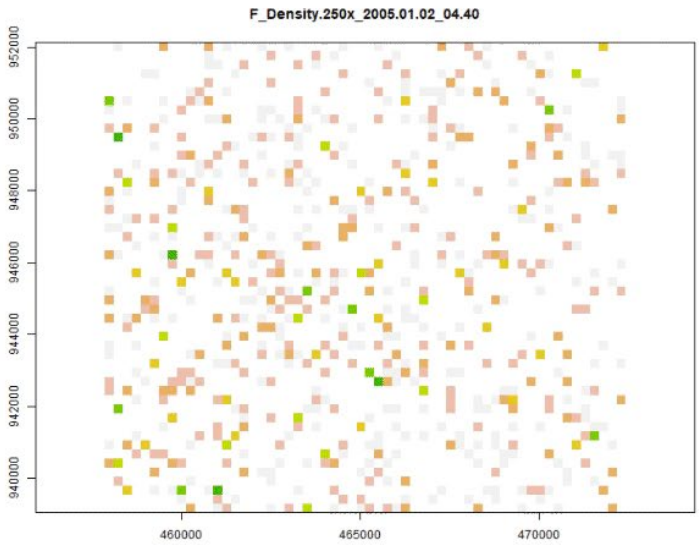
3 resolutions

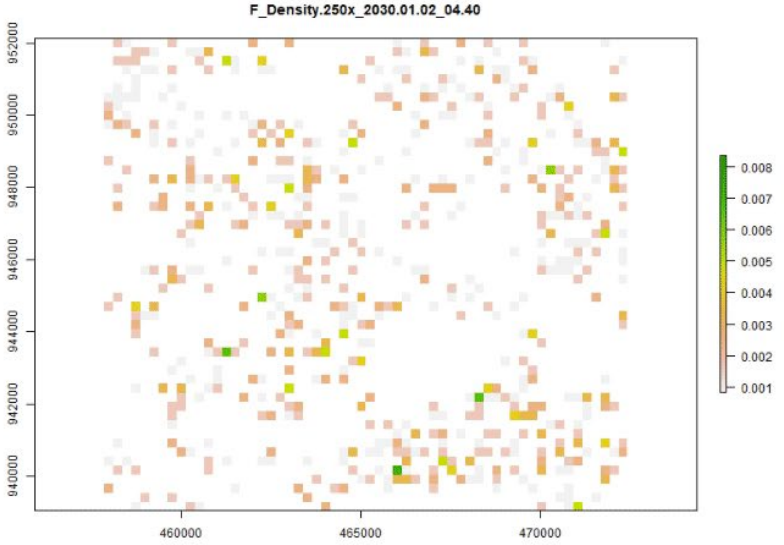




Bat density at foraging sites

250m





2005

↓ ~ 50% suitable habitat

Bat density (Entropy)

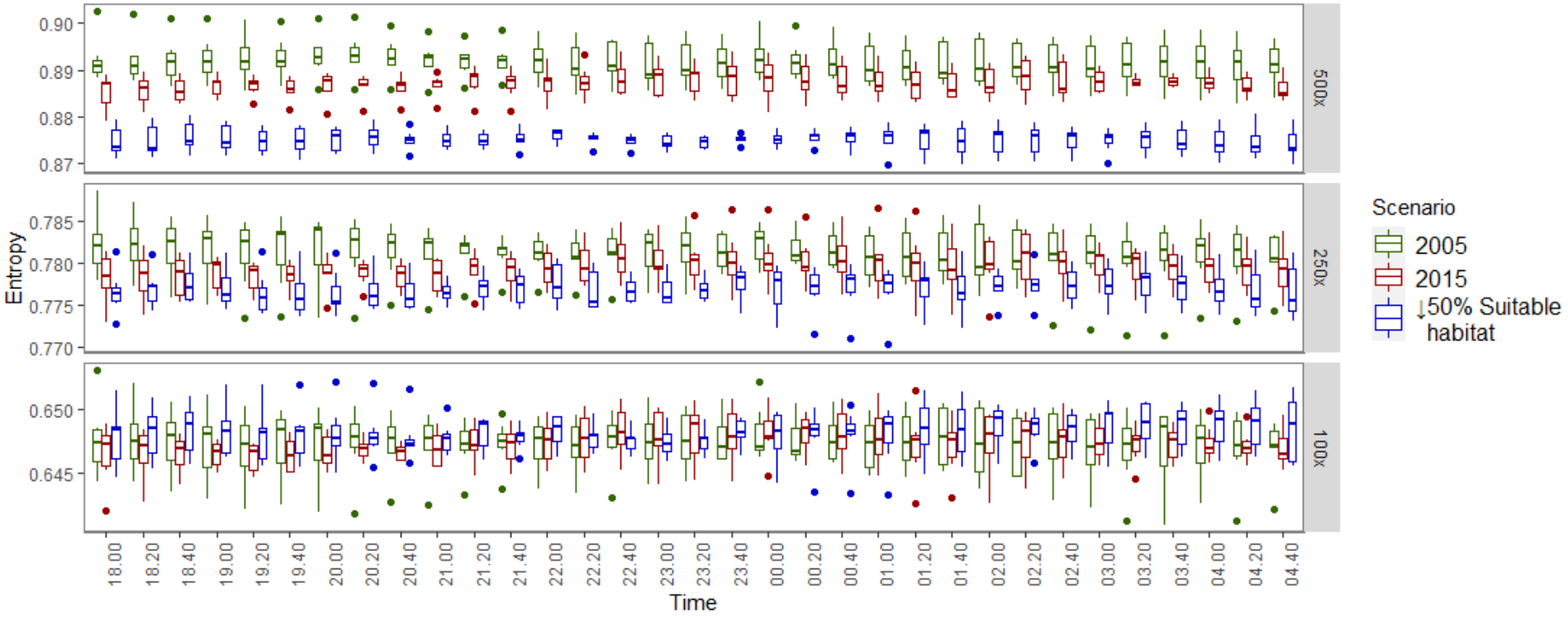
$$-\sum_{i=1}^{N} P_k \log(P_k)/\log(N)$$

P_k is the probability of a bat being located in cell$_i$ of the raster.

N is the total number of cells in the raster

Higher entropy → bats are more dispersed in space

Foraging



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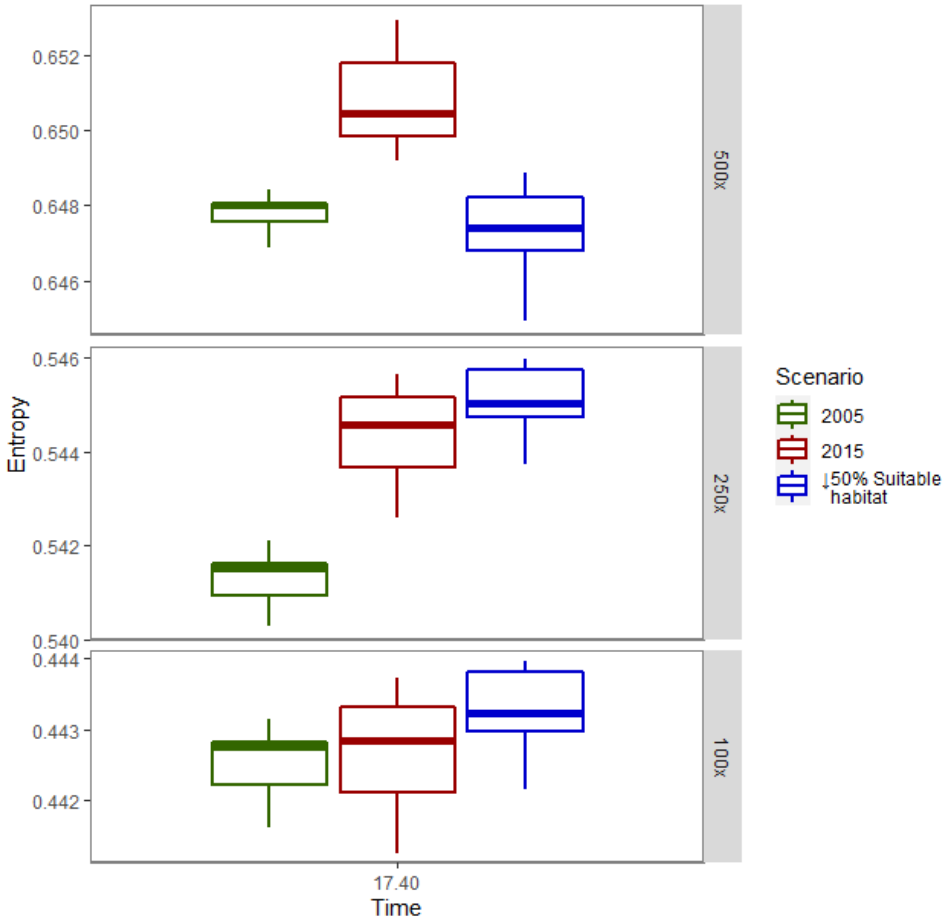
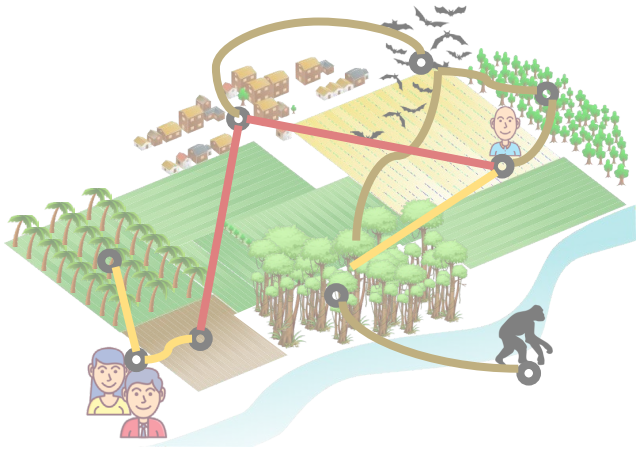
Roosts



Further work…

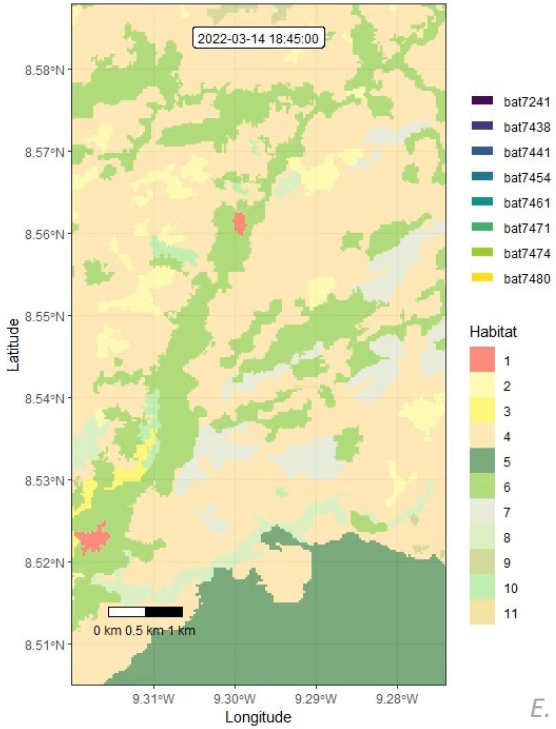
- Improve movement of bats
  - Network analysis
  - Flow analysis
- *Fragmented landscape* scenario
- Add other factors
  - Seasonality
  - Reproduction
- Model validation
  - GPS data of bats in Guinea

A more complex model



Indicators of higher transmission

- Super spreaders
- Areas of increased contact



E. Schloesing