Mapping malaria risks by drone: case studies using aerial and satellite-based data in Southeast Asia and Africa

Kimberly Fornace

Machine Learning in Public Health
Joint International Tropical Medicine Meeting
Bangkok, 2018

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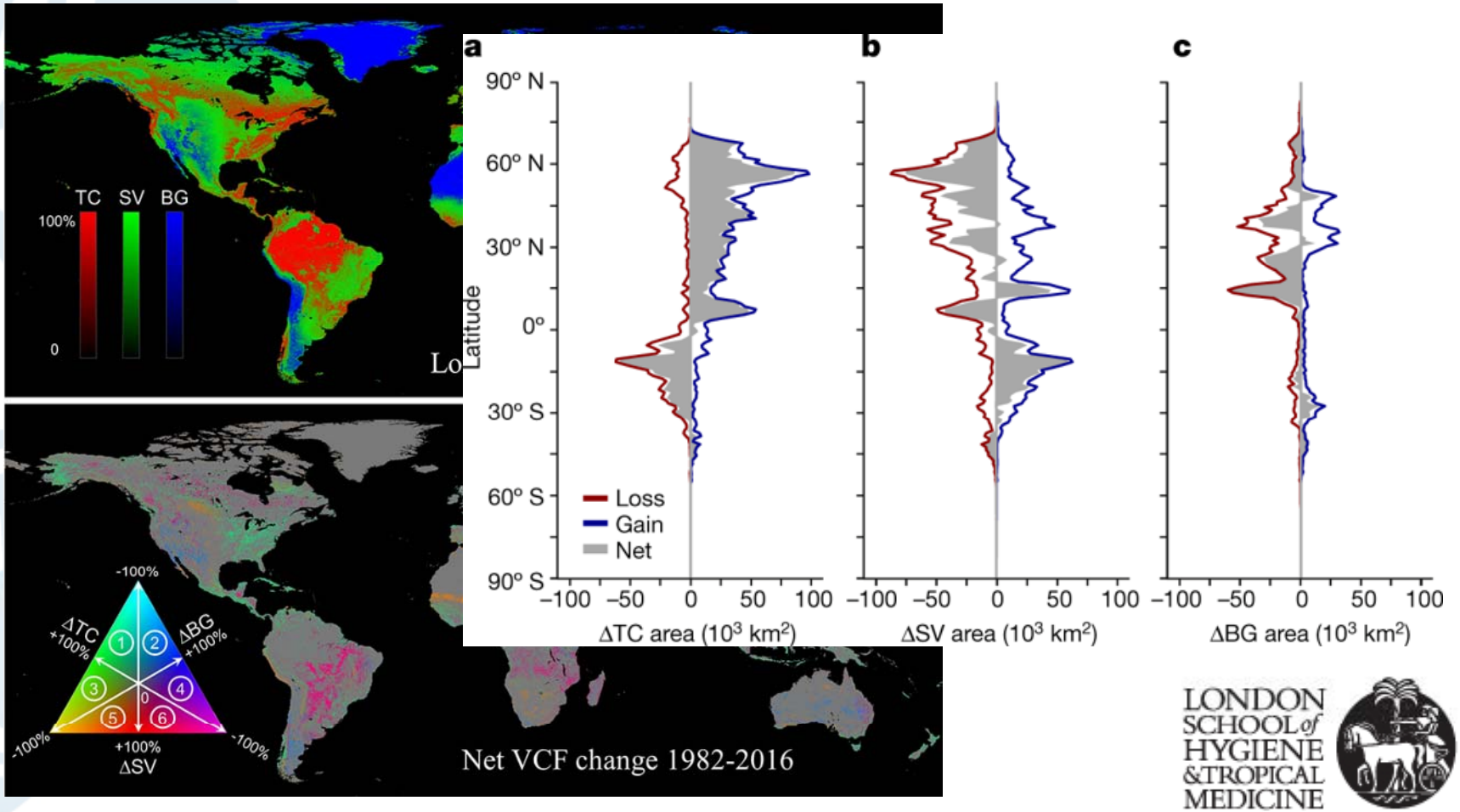
Current trends in land use change

- **Anthropocene:** over 75% of Earth's ice-free surfaces transformed by human activity



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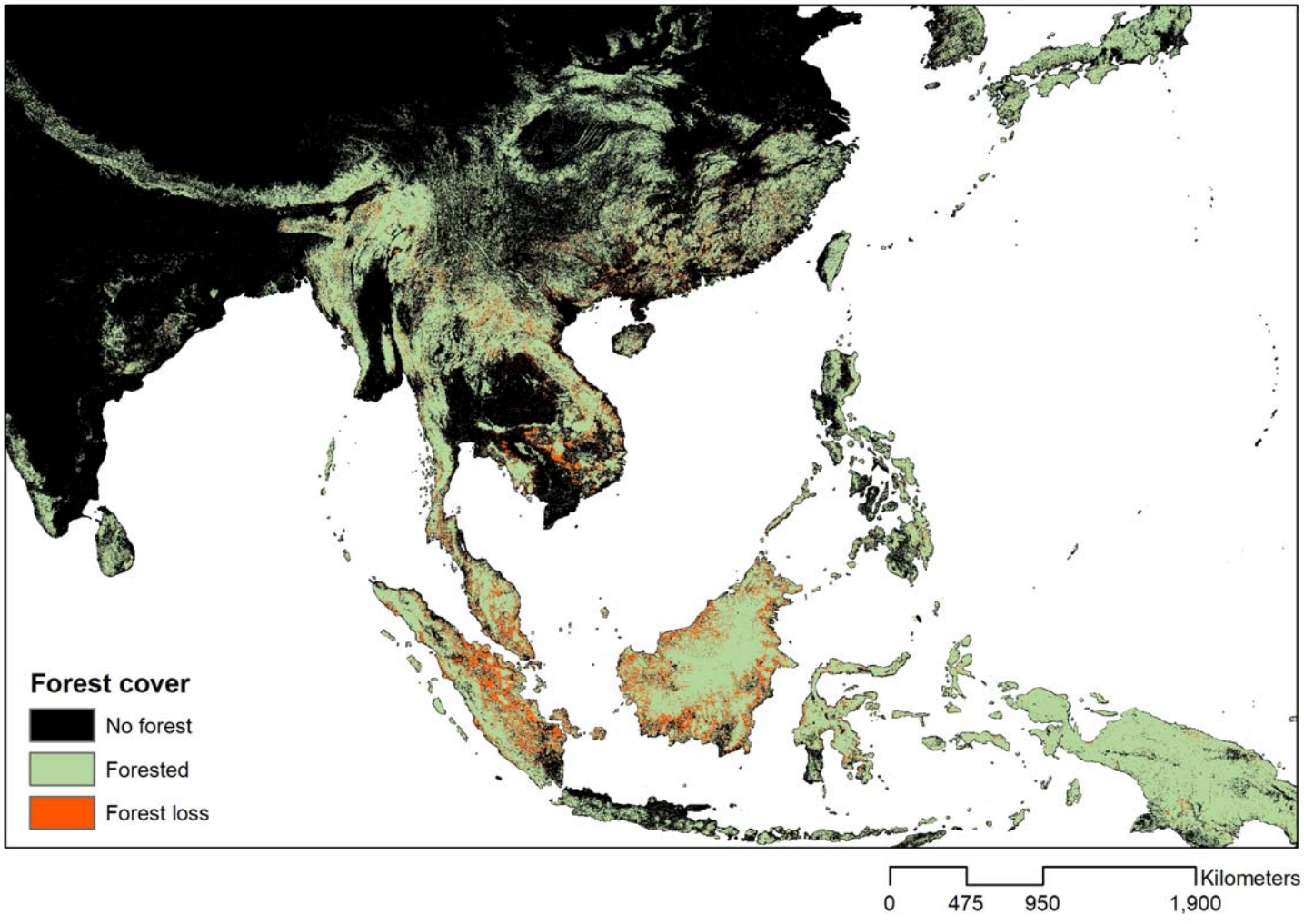
Song et. al, UMD GLAD 2017

Deforestation in Southeast Asia



Forest loss 2000-2016
Hansen et. al, 2013

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Anopheline densities & land use change

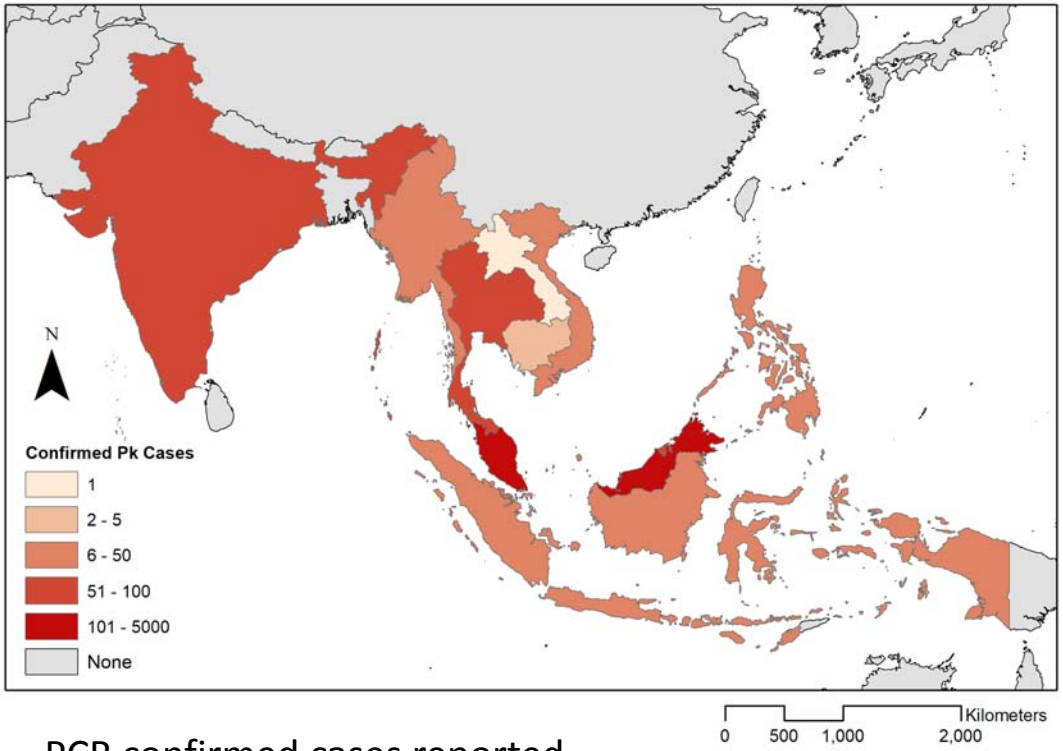
- Differing effects of land use change in different settings
- Increases in anopheline densities not always correlated with increases in malaria (paddies paradox)

LULCC	Location	Anopheles density	Malaria cases
Deforestation	Thailand	Decreased *An. dirus*	-
Deforestation	Sri Lanka	Decreased *An. Barbirostris* Increased *An. annularis*, *An. jamesii*, *An. nigerrimus, An. subpictus*	+
Rice	Indonesia	Increased *An. aconitus*	+
Rice	Africa	Increased *An. funestus*, *An. gambiae*	
Irrigated crops	India	Increased *An. culcifacies*	+

Yasuoka & Levins, 2007

Plasmodium knowlesi transmission in Malaysia and the Philippines

- Identified in macaques in 1930s
- Little evidence of widespread infection in humans until 2004 when improved diagnostics identified infections in Malaysian Borneo
- Main cause of human malaria in Malaysian Borneo



PCR confirmed cases reported until 2014, data from Moyes et. al, 2016

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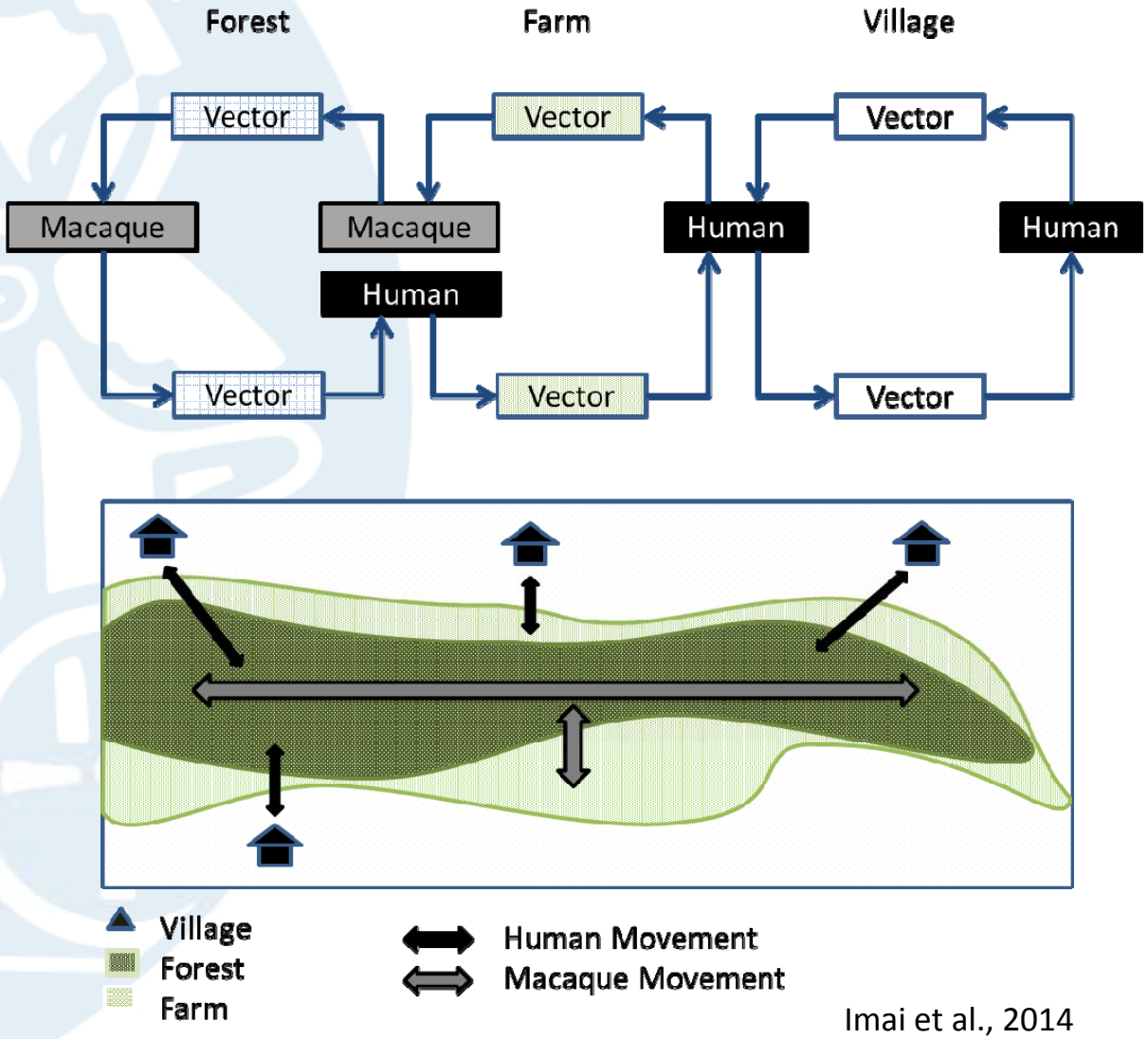
Environment and transmission dynamics



Imai et al., 2014

How does environmental change and landscape affect interactions between populations and disease transmission?

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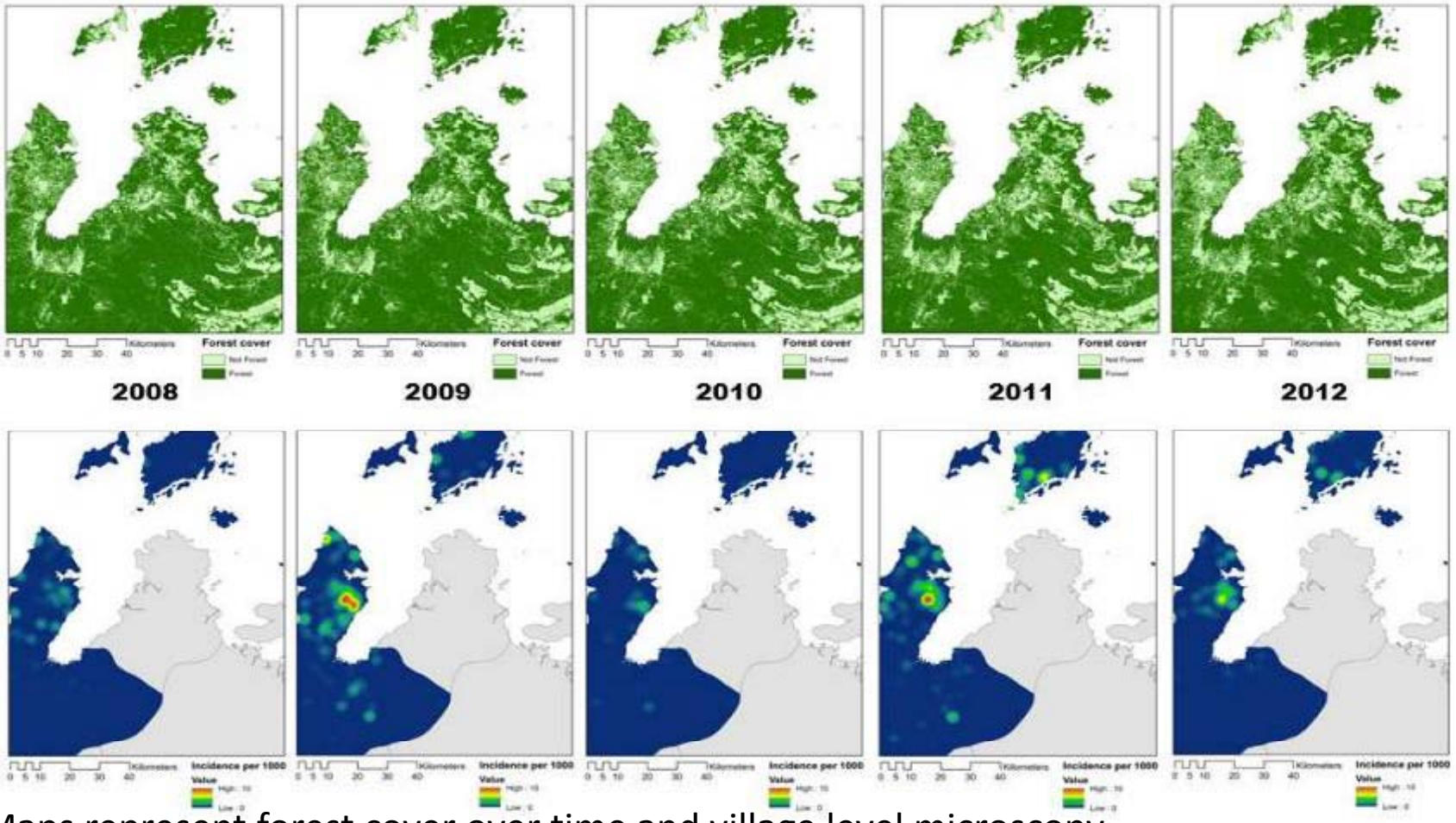
Deforestation and *P. knowlesi* incidence



Maps represent forest cover over time and village level microscopy records

Significant positive correlations with proximity to forest and recent forest loss

Fornace et al EID 2015

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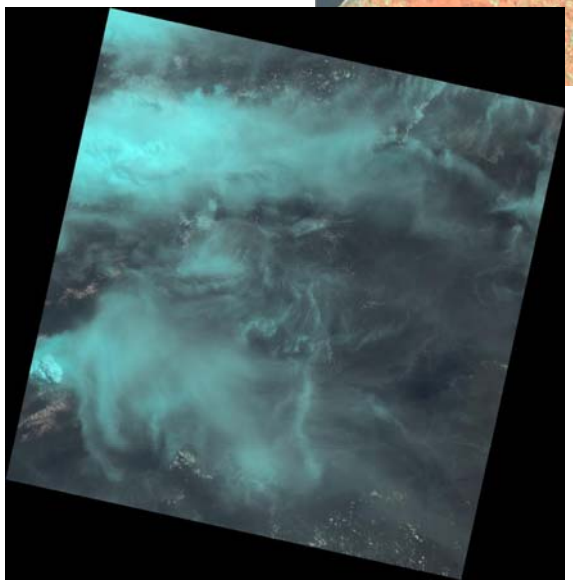
Land cover mapping and classification

- Ability to continuously monitor land cover change at a fine spatial scale

- Satellite data (LANDSAT)
  - High spectral resolution
  - Freely available
  - Coverage of large areas

- Limitations of satellite data
  - Low spatial and temporal resolution (30m/px)
  - Limited by cloud cover and availability



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Land cover mapping

UAV (drone)- Sensefly eBee

- 700g, 1m wingspan
- 350 – 400 m above ground
- Average 124 ha (1.24km^2) per flight
- Resolution ~ 11 cm/ pixel

Opinion

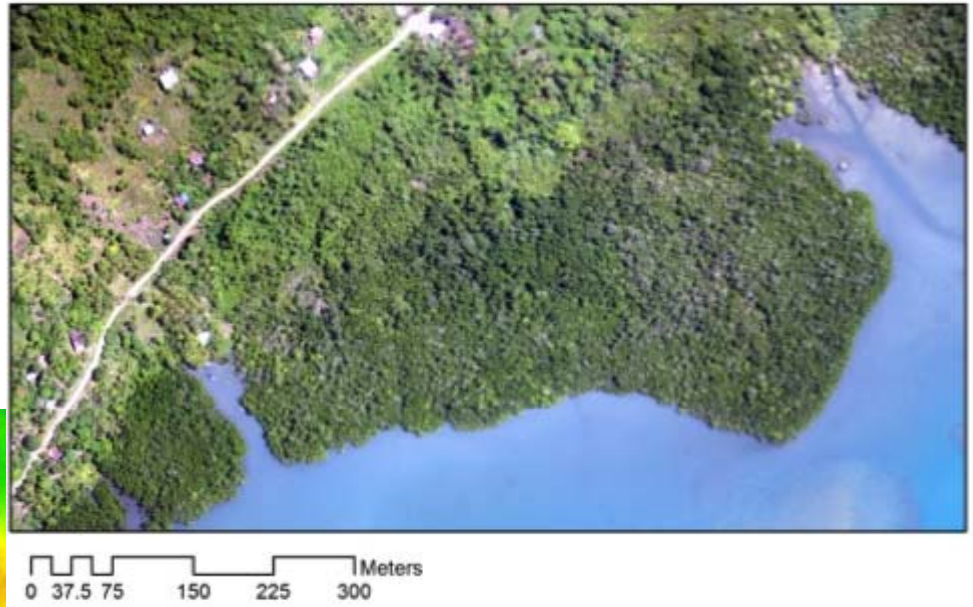
CellPress

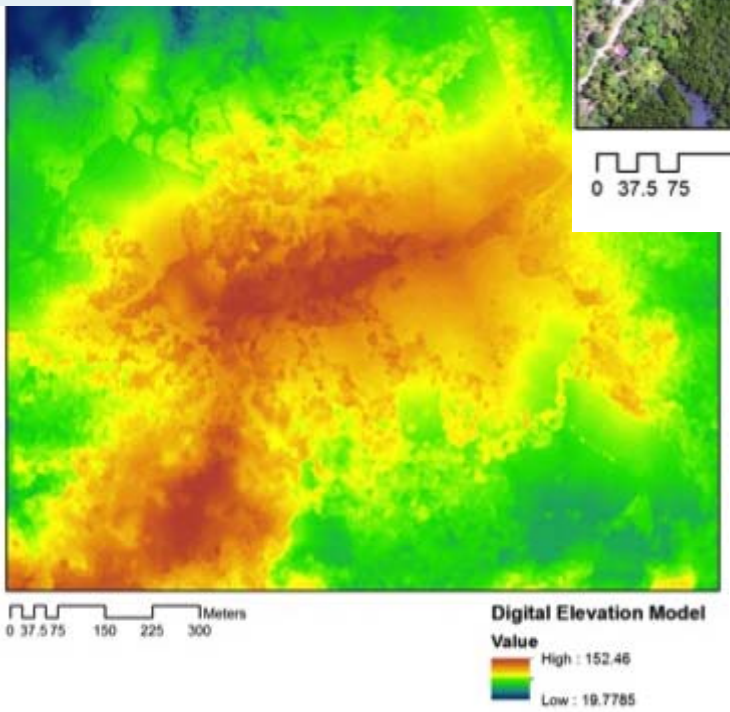
Mapping infectious disease landscapes: unmanned aerial vehicles and epidemiology

Kimberly M. Fornace[1], Chris J. Drakeley[1], Timothy William[2,3,4], Fe Espino[5], and Jonathan Cox[1]

Land cover mapping and classification

- Aerial images of land cover
- Digital surface models (elevation)





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Land cover mapping and classification

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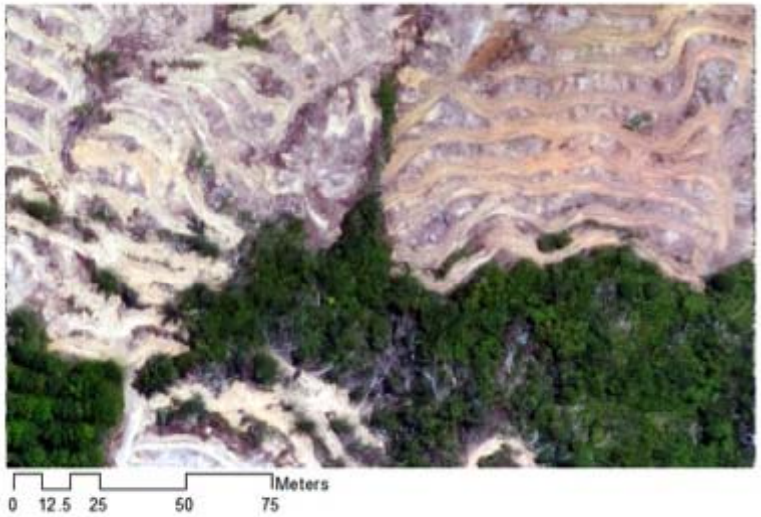
Land cover mapping and classification

- Repeat mapping to characterise fine-scale changes in land use

February 2014

May 2014



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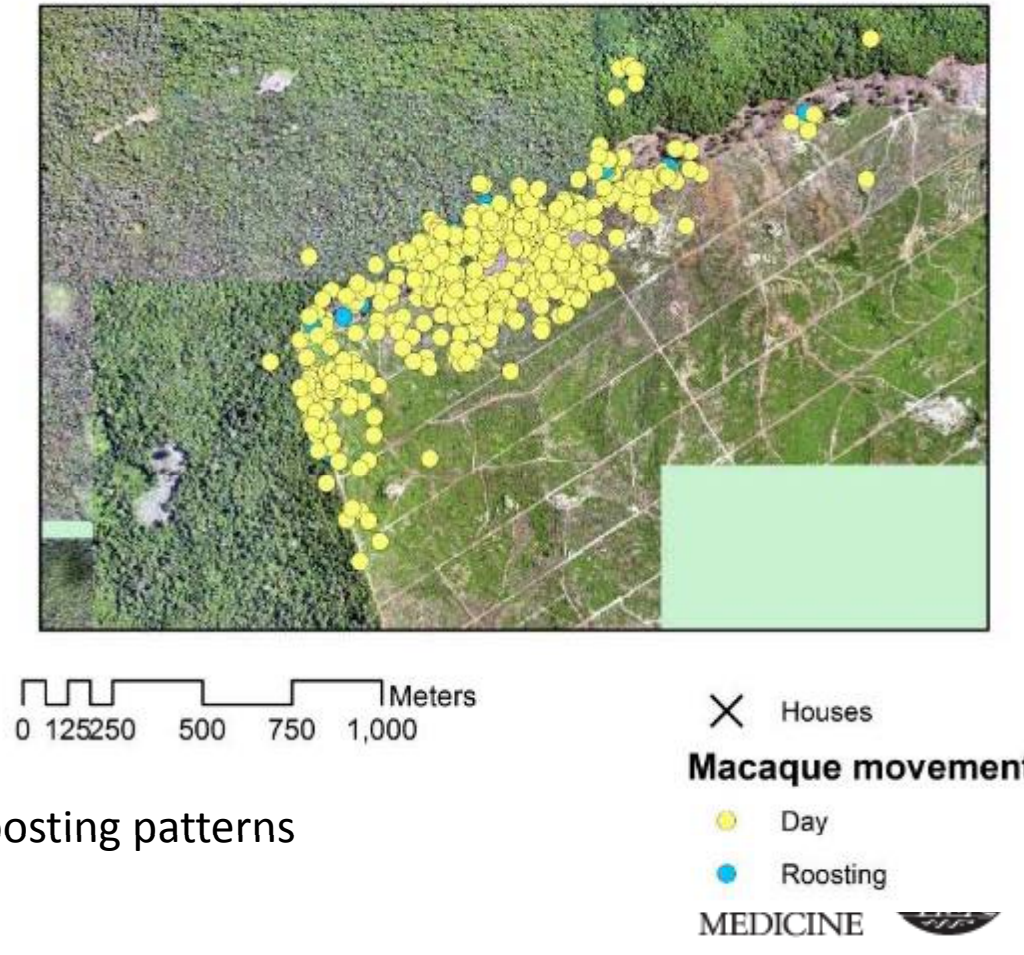
Primatology

What is the range of a macaque troop?

Where do they roost and in what numbers?

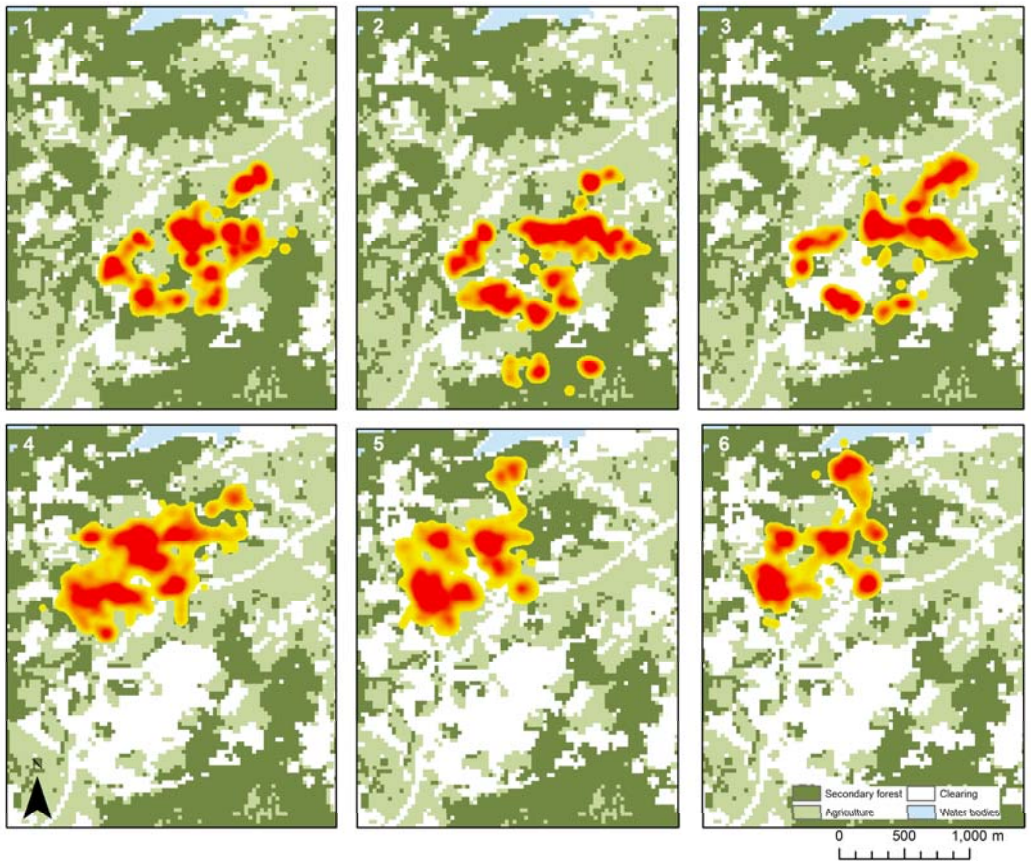
Image Amy Klegarth, Uni Notre Dame

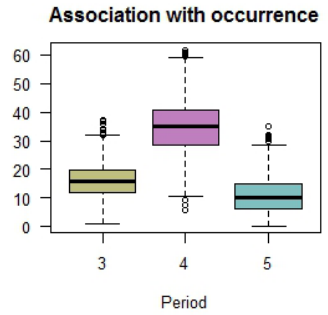


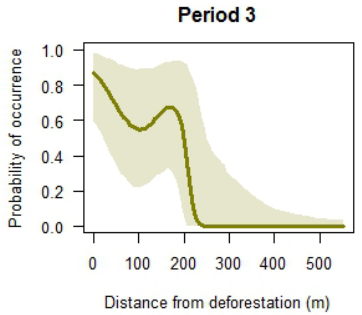
Collaring highlights movement and roosting patterns

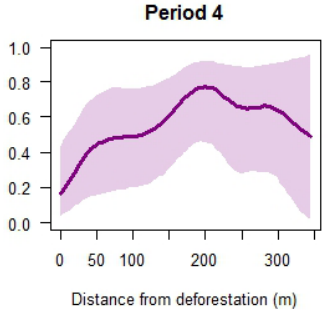
Primatology:

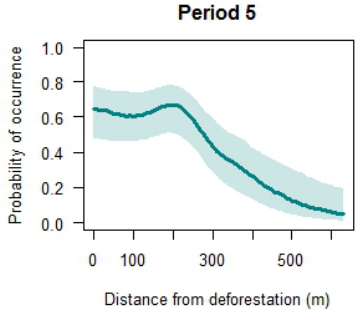
- How does macaque movement change following habitat disturbance?
  - Less predicable movements, away from recent clearing





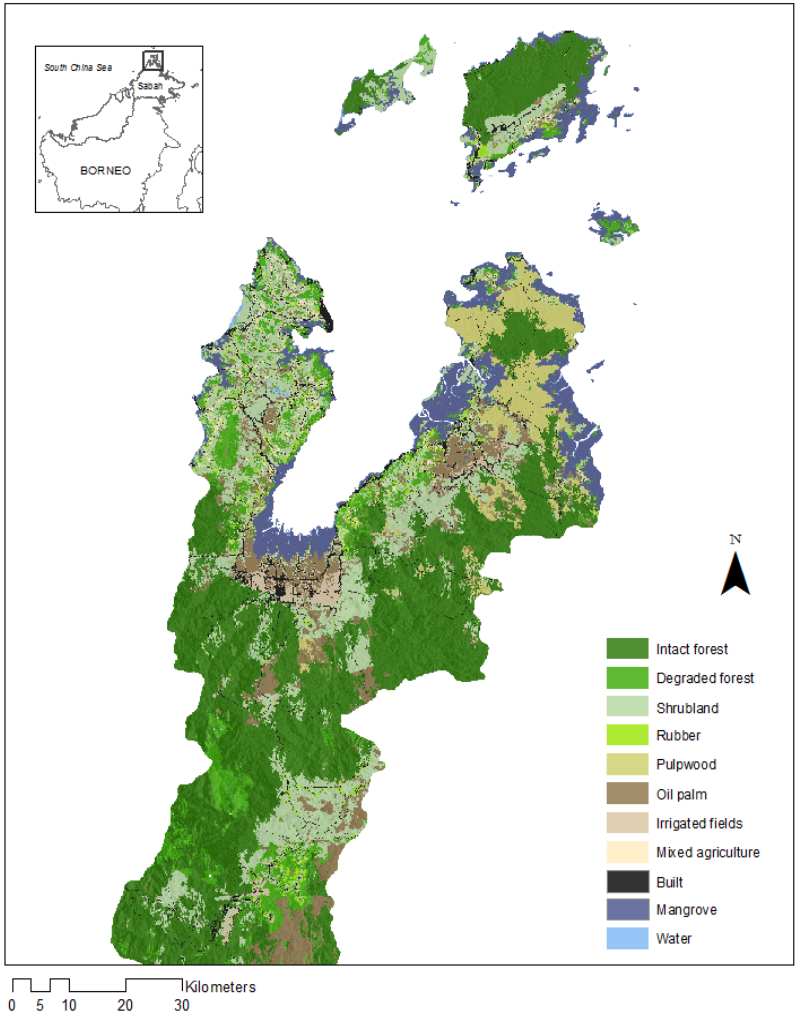






Land use classification: large scale

- Use of aerial imagery as training data for land cover classification using random forests
- Integration of aerial and satellite based remote sensing to develop maps of land cover



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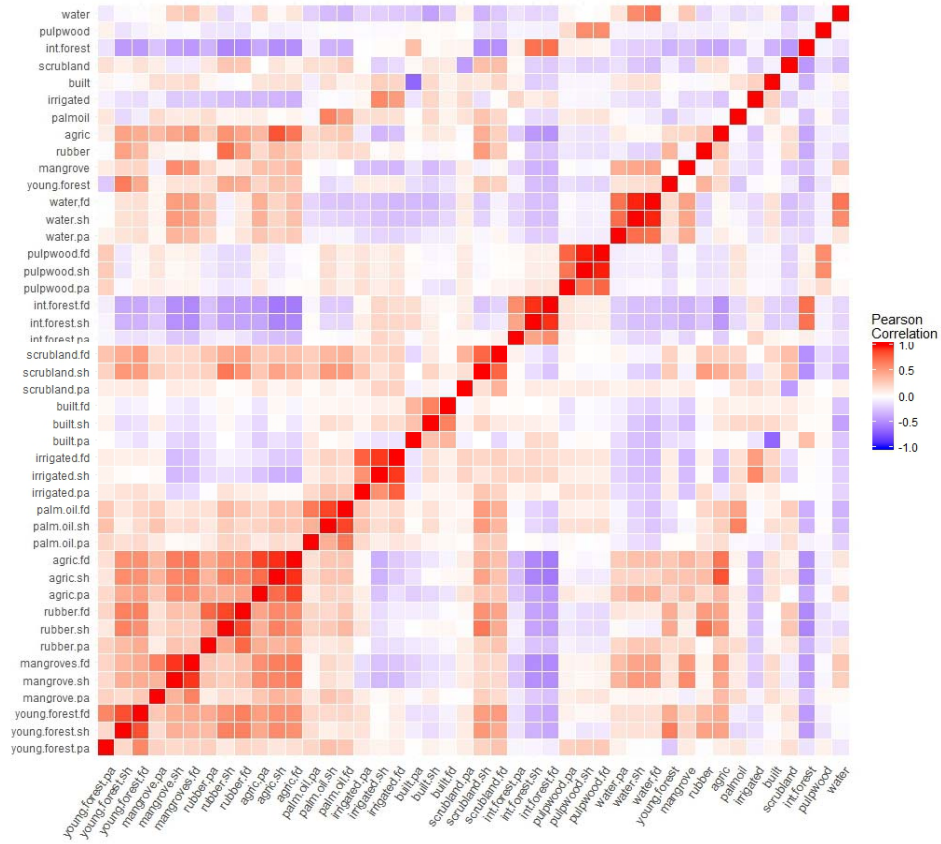
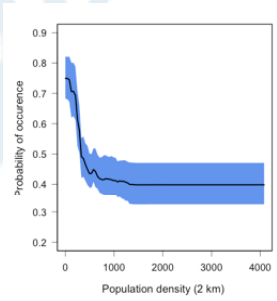
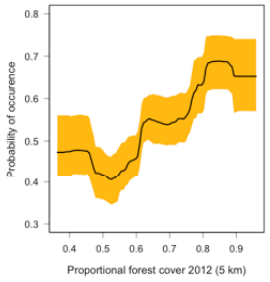
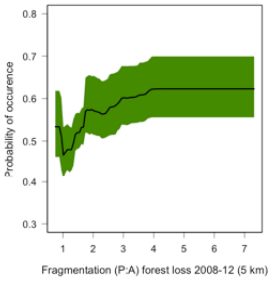
Associating environmental variables with risk

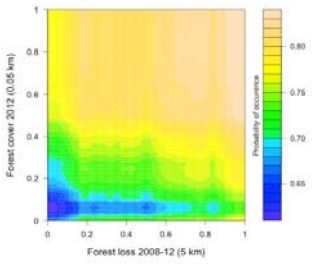
- Land cover and fragmentation metrics at different distances around households
- **Total variables assessed: 352 x 2849 – high dimensionality**
- **High levels of collinearity**











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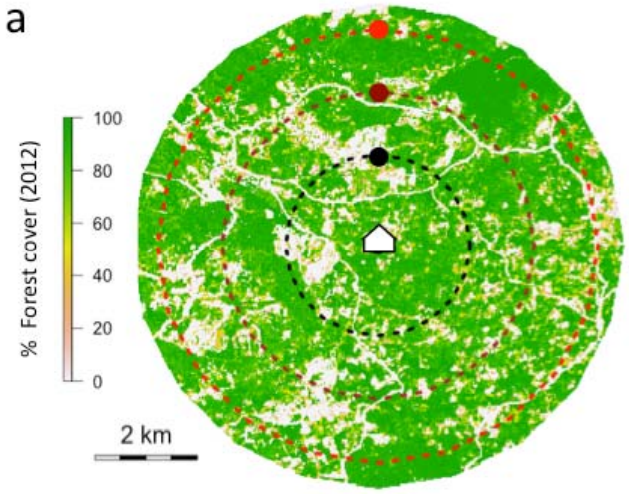
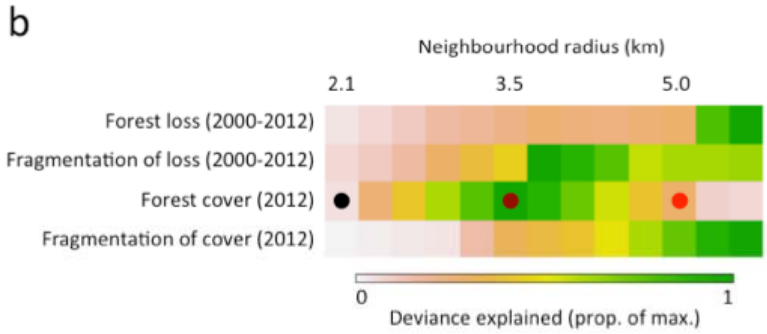
Identifying predictive variables using data mining pathways

Understanding spatial scale



Three example neighbourhood sizes around a case household, showing % forest cover



The deviance explained by four example forest variables at thirteen neighbourhood sizes in univariate generalised additive models of infection status

Brock et al. 2016 Parasitology

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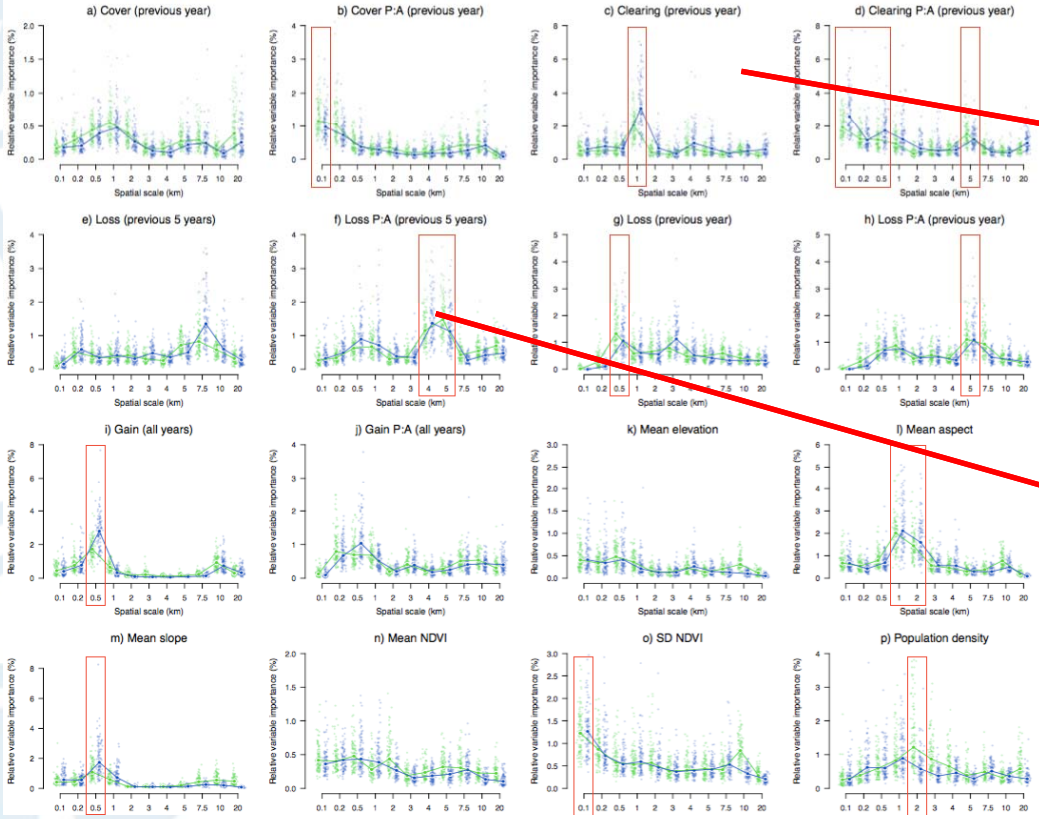
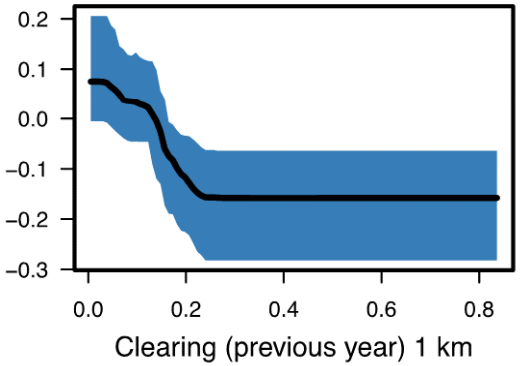
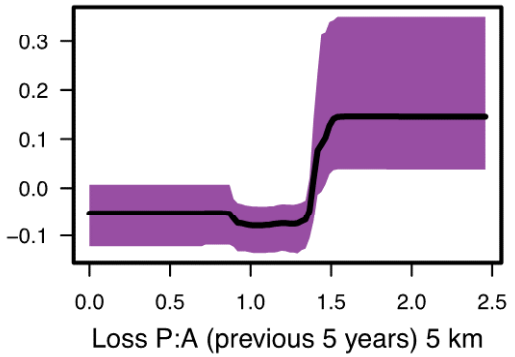
Identifying predictive variables using data mining pathways

Boosted regression trees







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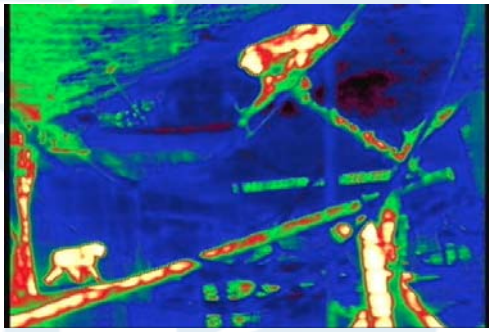
Primatology

Estimating macaque troop size

Thermal Camera



Ground-based studies for validation and optimisation

Camera on drone

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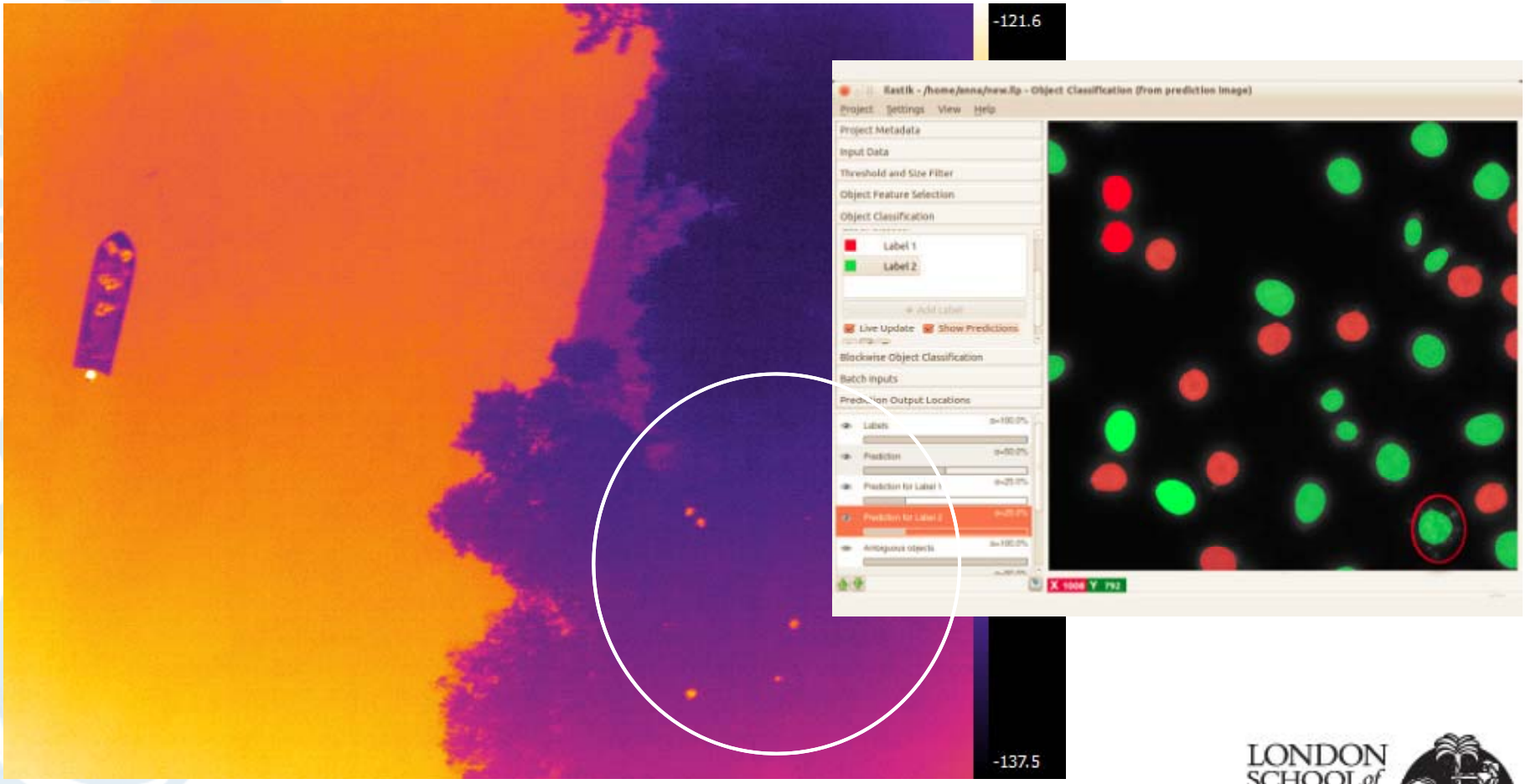
Primatology

Estimating macaque troop size using object oriented programming



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Mapping vector habitats

- Mapping mosquito habitats in Burkina Faso
  - How to identify sites to target larval source management?
- Use of UAV to conduct detailed mapping of targeted high malaria transmission areas
- Classification of satellite data and development of risk maps?

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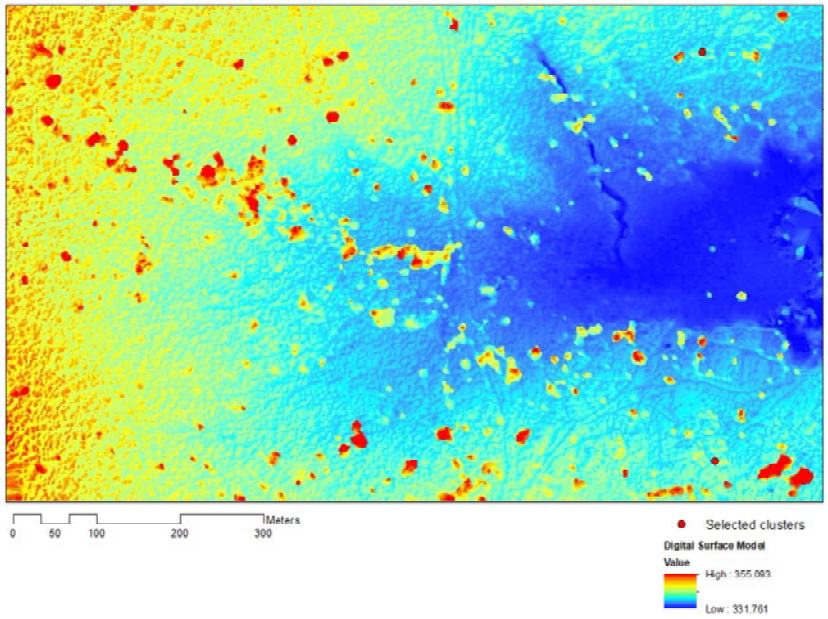
Mapping vector habitats

Mapping vector habitats



- Digital surface models generated using photogrammetric methods from stereo images
- Using both spectral data and point cloud density
- Extend to evaluate use of multispectral camera (collecting NIR and other wavelengths)

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Conclusions

- Satellite and drone imagery have different utility based on spatial, temporal and spectral resolutions
- Remote sensing technology can inform public health control programmes
- Machine learning approaches allow classification of remote sensing data as well as identifying important factors for malaria transmission

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Thank you

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