University of Glasgow

INSPIRING PEOPLE

Socio-economic and epidemiological perspectives of endemic foot-and-mouth disease in Africa

Tiziana Lembo
Institute of Biodiversity, Animal Health and Comparative Medicine

Tiziana.Lembo@glasgow.ac.uk

University of Glasgow

- Richard Reeve
- Dan Haydon
- Sarah Cleaveland
- Miriam Casey-Bryars
- Divine Ekwem
- Harriet Auty
- Grant Hopcraft
- Thomas Morrison

Sokoine University of Agriculture

- Rudovick Kazwala
- Tito Kibona
- Ahmed Lugelo
- Gloria Ndhlovu

Tanzania Wildlife Research Institute

- Robert Fyumagwa

Tanzanian Veterinary Laboratory Agency

- Deogratius Mshanga

Nelson Mandela African Institution of Science and Technology

- Joram Buza
- Gabriel Shirima

FMD field team

- Mahemba Shabani
- Victor Sianga
- James Mwajombe
- Emmanuel Sindoya

The Pirbright Institute

- Don King
- David Paton
- Satya Parida
- Nick Knowles
- Kasia Bachanek-Bankowska
- Veronica Fowler
- Anna Ludi
- Krupali Parekh
- Jemma Wadsworth

IZSLER

- Emiliana Brocchi
- Santina Grazioli

Onderstepoort Veterinary Institute

- Francois Maree

Washington State University

- Tom Marsh
- Ashley Railey
- Umesh Bastola
- Guy Palmer
- Felix Lankester

University of Edinburgh

- Brian Perry
- Jess Enright

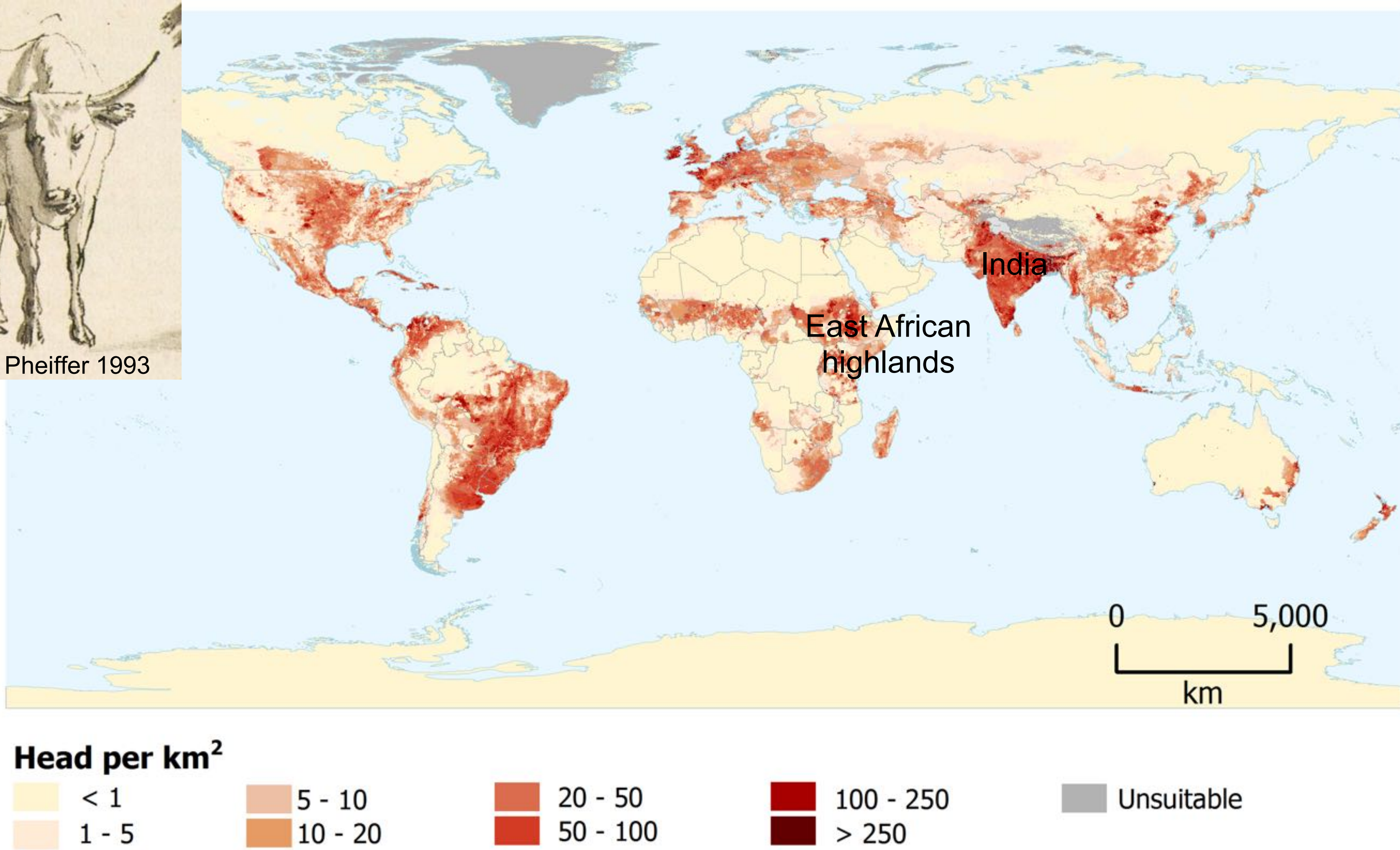
MSD/Merck Animal Health

- Alasdair King
- John Atkinson

Global distribution of cattle

- Estimated >1.4 billion cattle and >1.8 billion small ruminants
- ~1.3 billion in developing countries
- Expected increase by 40%

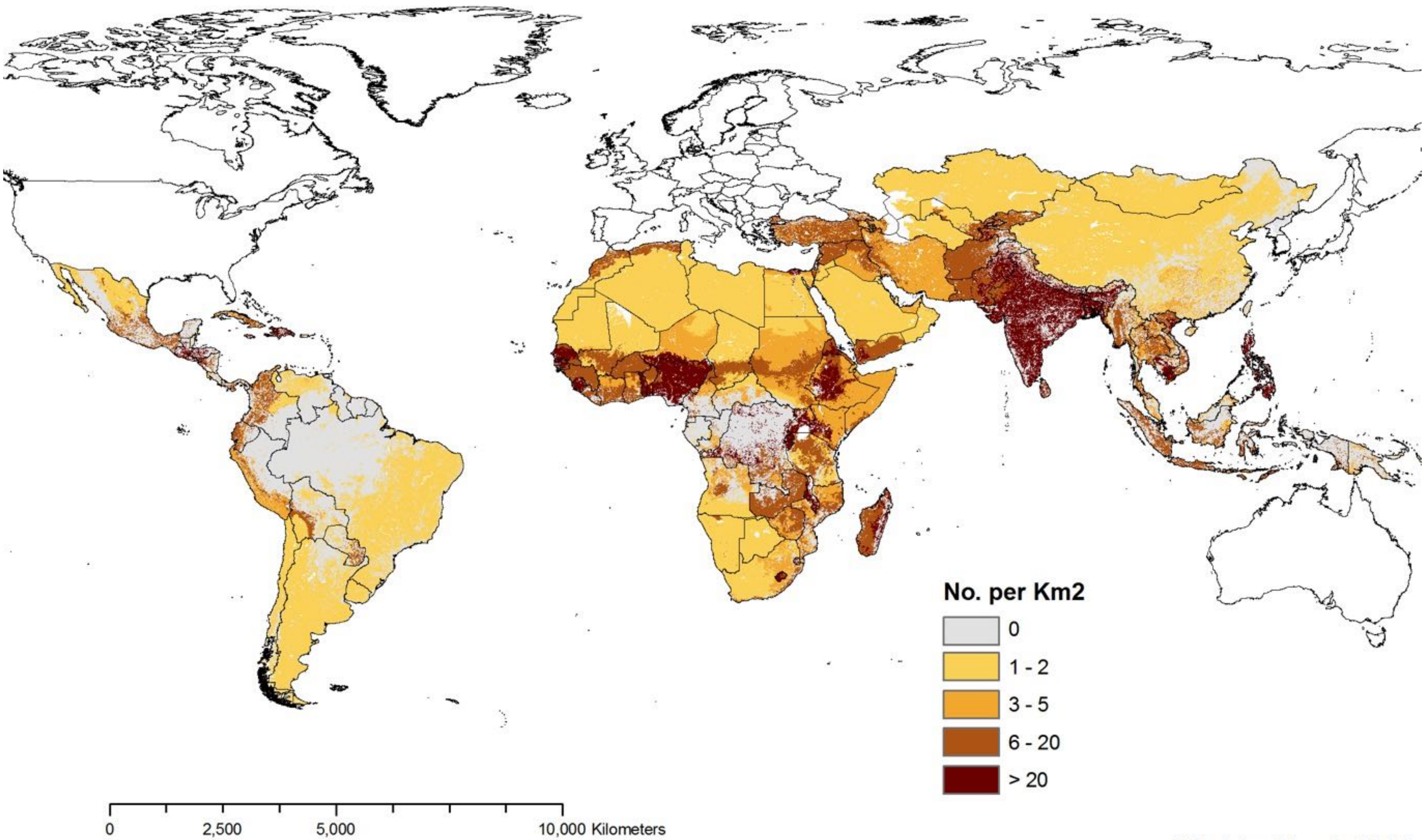
from: Smith & Pheiffer 1993



Robinson et al. (2014) Mapping the Global Distribution of Livestock. PLOS ONE 9(5): e96084.

Density of Poor Livestock Keepers

Year 2010*



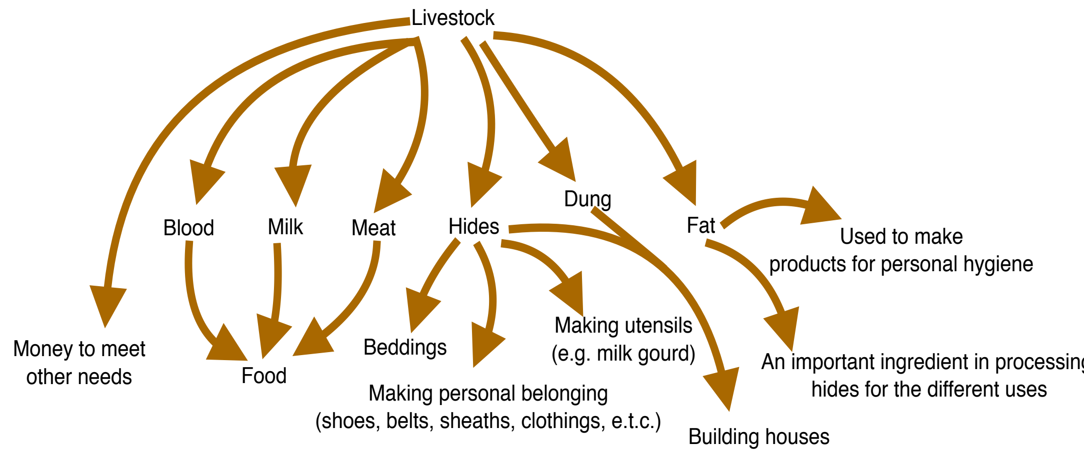
*Update: March 2012

(map credit: ILRI/Philip Thornton)

ILRI. Mapping of poverty and likely zoonoses hotspots. Zoonoses Project 4. Report to Department for International Development, UK. ILRI, Nairobi, Kenya (2012) 119 pp.

University of Glasgow

HOUSEHOLD USES OF LIVESTOCK AND THEIR PRODUCTS

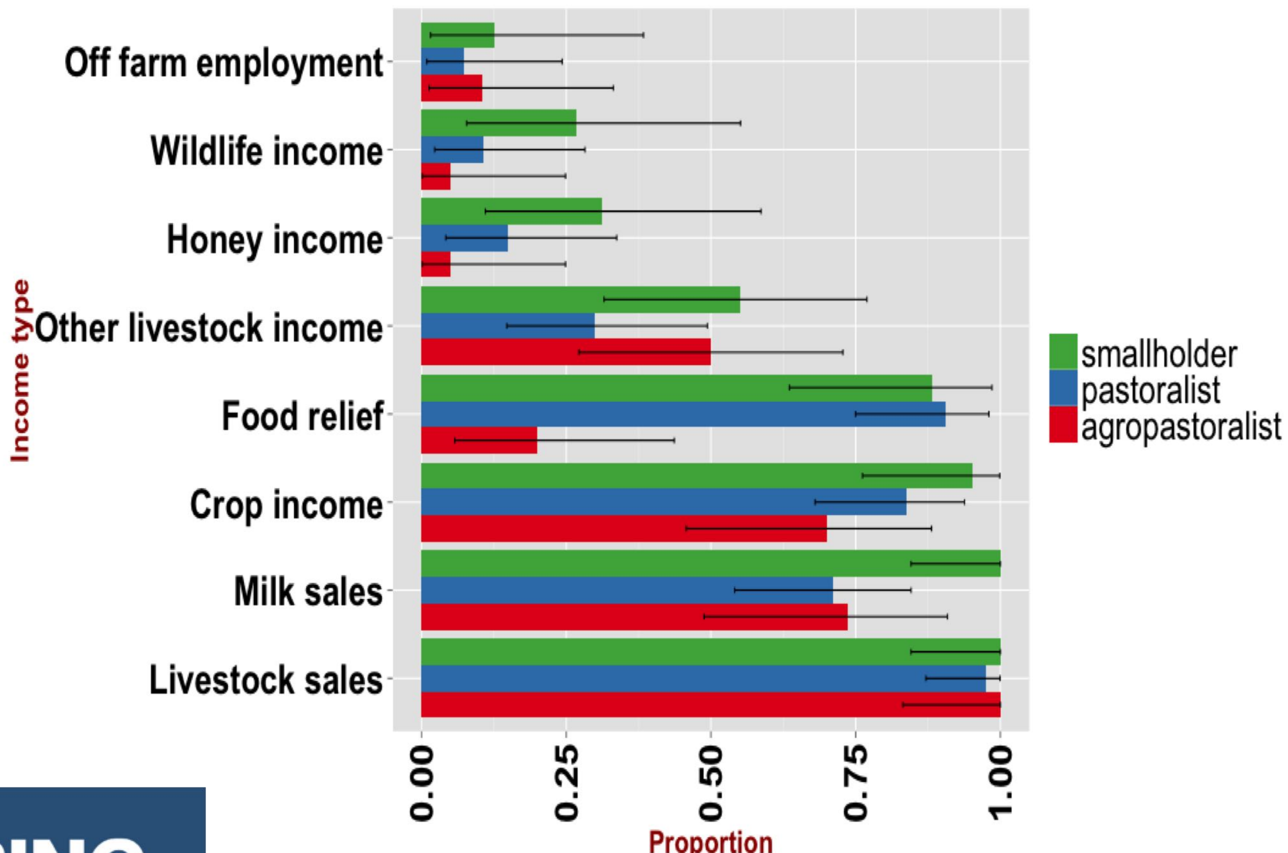


Data: R. Aminu

Photos: T. Lembo

INSPIRING PEOPLE

Importance of agriculture-related income in traditional livestock-keeping systems of northern Tanzania



n = 100 respondents

INSPIRING PEOPLE

Livestock production important role in poverty reduction

Poverty impacts of foot-and-mouth disease in Africa

@ Emmanuel Baliyanga

Casey-Bryars M, Reeve R, Bastola U, Knowles NJ, Auty H, Bachanek-Bankowska K, Fowler VL, Fyumagwa R, Kazwala R, Kibona T, King A, King DP, Lankester F, Ludi AB, Lugelo A, Maree FF, Mshanga D, Ndhlovu G, Parekh K, Paton DJ, Perry B, Wadsworth J, Parida S, Haydon DT, Marsh TL, Cleaveland S and Lembo T (2018). Waves of endemic foot-and-mouth disease in eastern Africa suggest feasibility of proactive vaccination approaches. Nature Ecology & Evolution 2: 1449–1457.

Economic, social and political considerations

- Annual aggregate-level impacts of US$2.3 billion (>0.1% of GDP) (*Knight-Jones & Rushton 2013*)
- Need to create the incentives and priorities for its control
- But FMD impacts, hence demands and incentives for its control, are heterogeneous
- Characterising such heterogeneities encompasses a whole range of economic, social and political considerations

Knight-Jones, T. J. D. & Rushton, J. (2013) The economic impacts of foot and mouth disease – what are they, how big are they and where do they occur? Prev. Vet. Med. 112: 161–173.

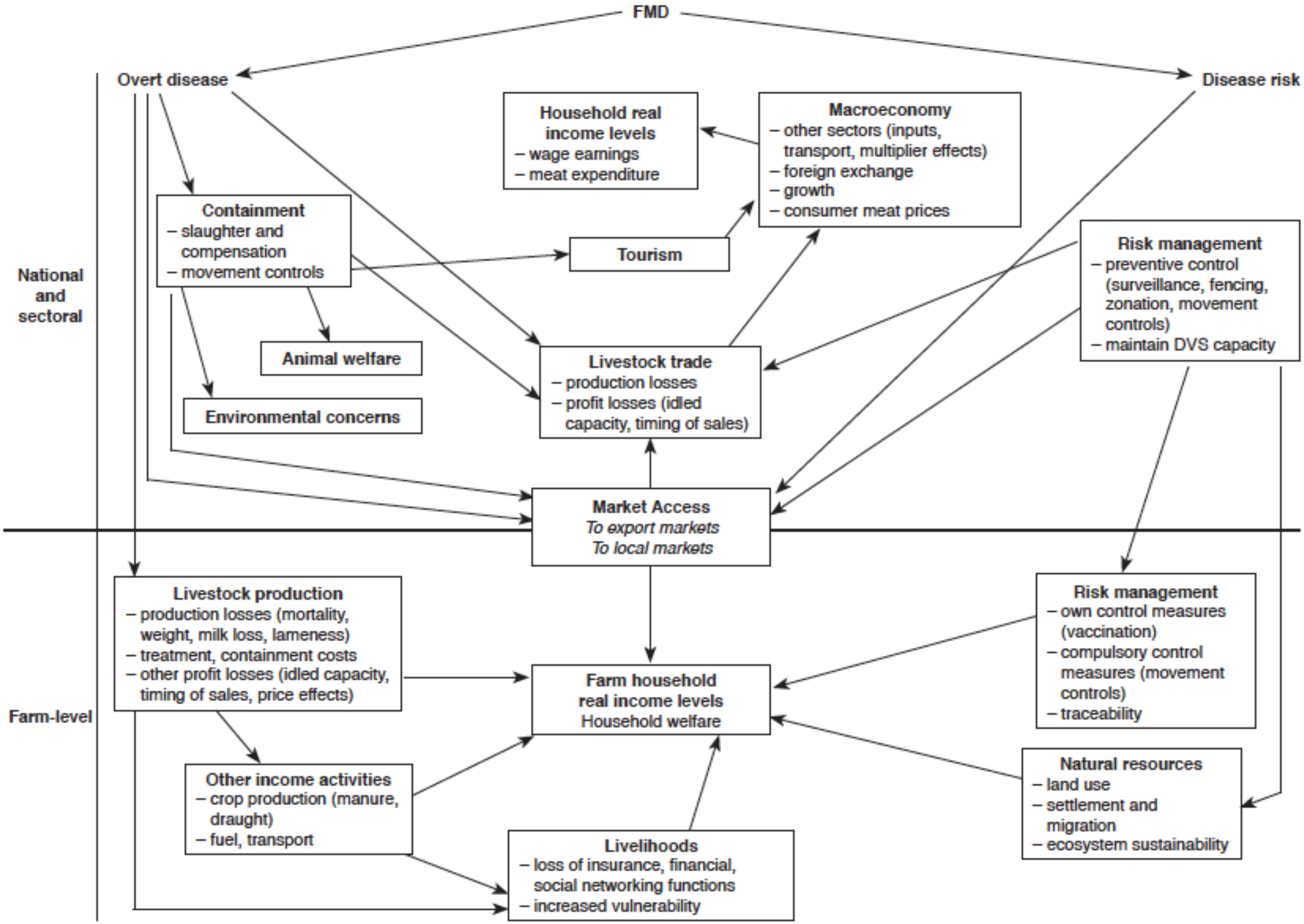
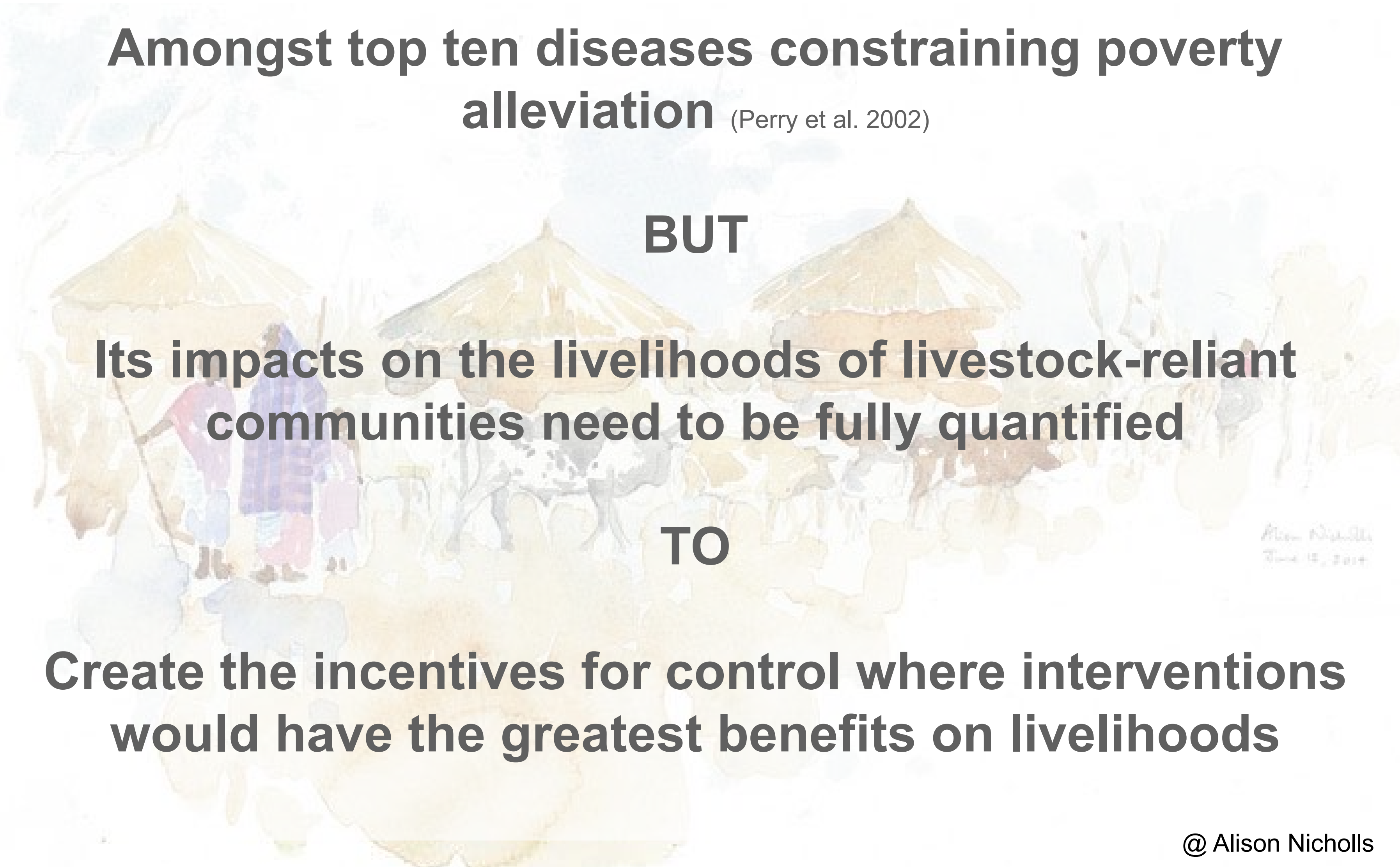


FIG 1: Impacts of FMD (adapted from Perry and Randolph 2003)

Perry and Rich (2007) Poverty impacts of food-and-mouth disease and the poverty reduction implications of its control. Vet. Record 160: 238-241.

Impacts of foot-and-mouth disease on the rural poor



Amongst top ten diseases constraining poverty alleviation (Perry et al. 2002)

BUT

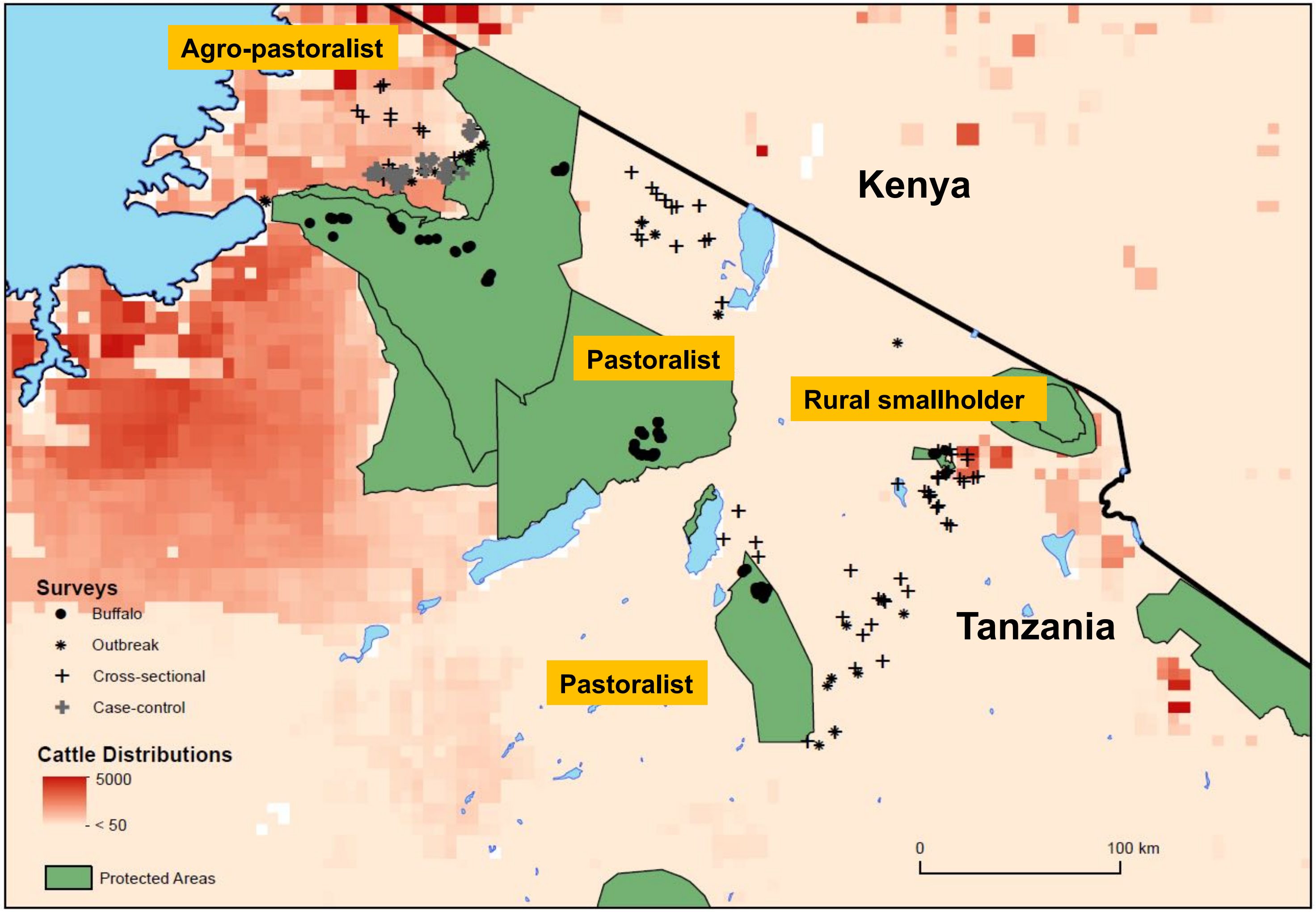
Its impacts on the livelihoods of livestock-reliant communities need to be fully quantified

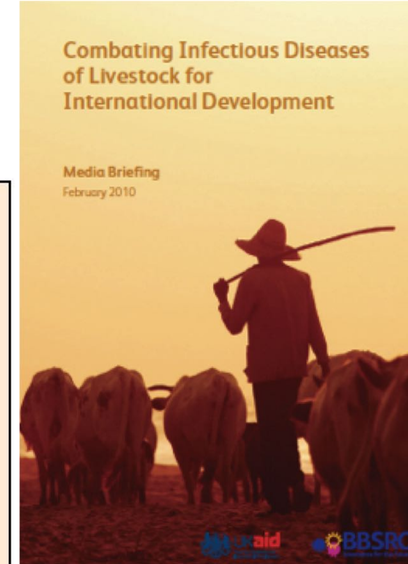
TO

Create the incentives for control where interventions would have the greatest benefits on livelihoods

@ Alison Nicholls

Field studies in northern Tanzania



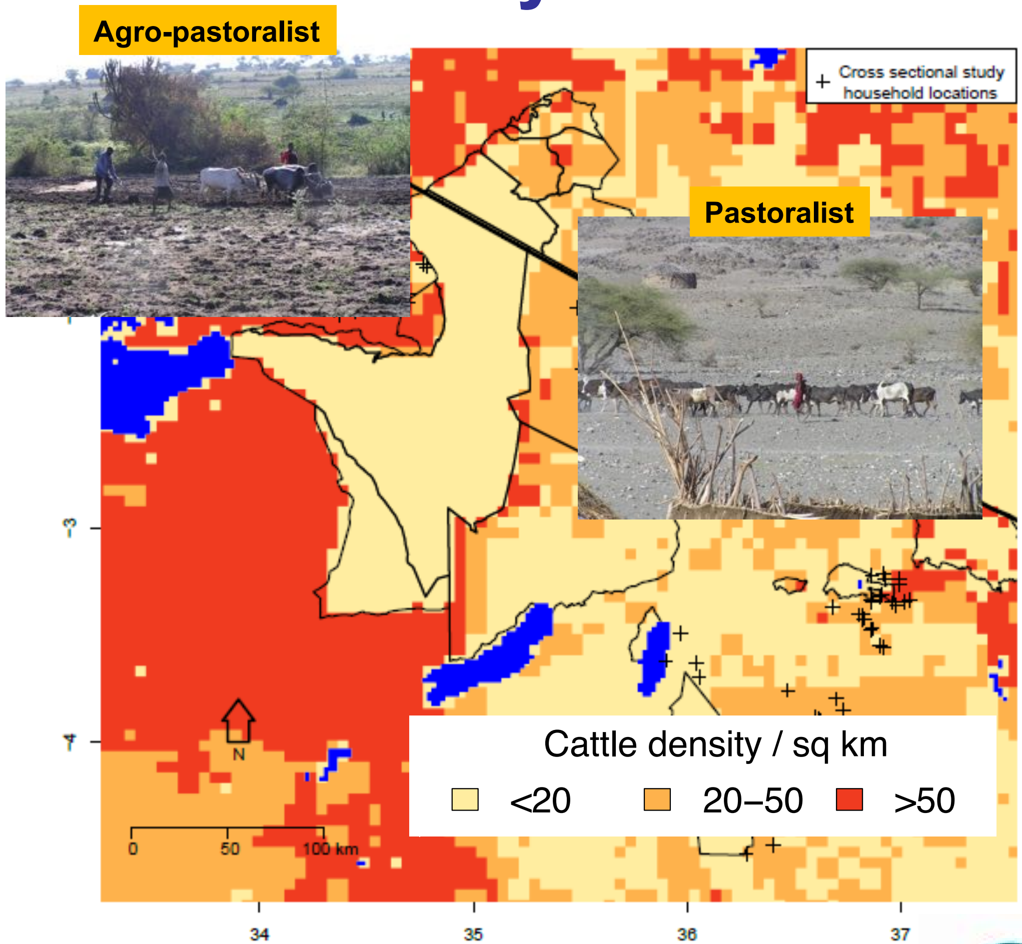


BBSRC
bioscience for the future

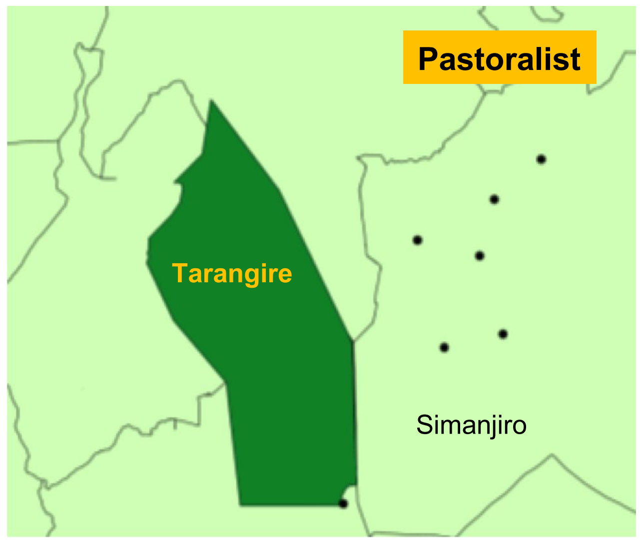
DFID Department for International Development

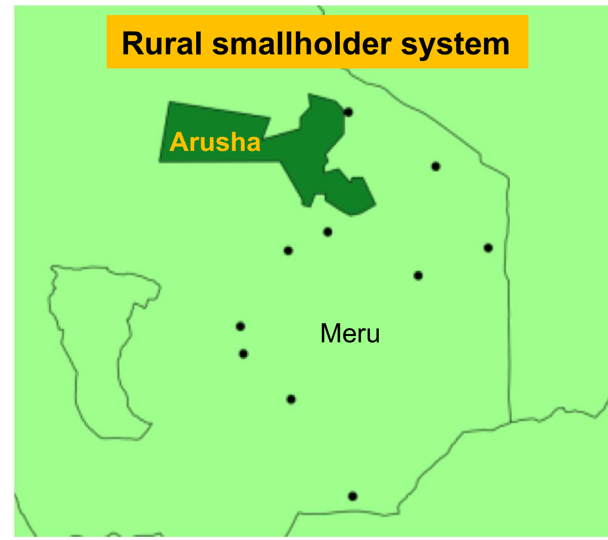
The Scottish Government

More intensive studies in the Serengeti ecosystem



BILL & MELINDA GATES foundation
AfricanBioServices
MSD Animal Health
SULSA
Scottish Universities Life Sciences Alliance



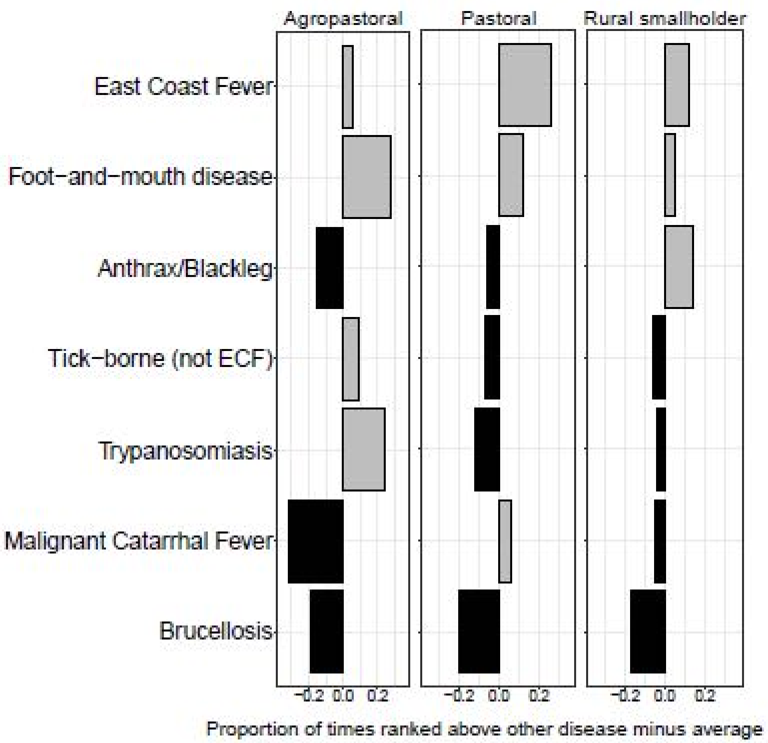


Agro-pastoralist and pastoralist systems - Very prevalent in livestock (especially cattle: >76% seroprevalence)

Rural smallholder systems – Less prevalent (cattle seroprevalence >42%)

n = 2,738 livestock

Photos: T. Lembo



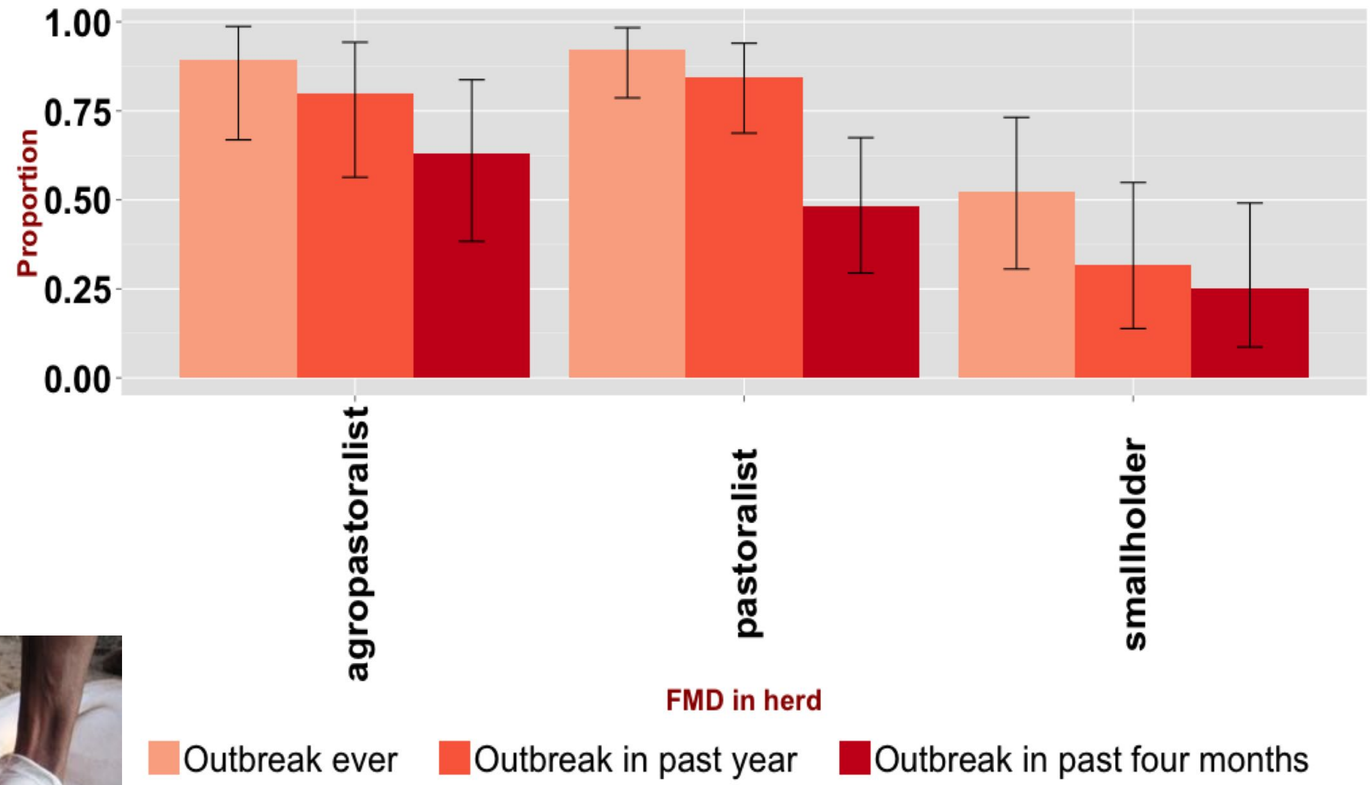
Of great concern to agro-pastoralists and pastoralists

n = 99 respondents

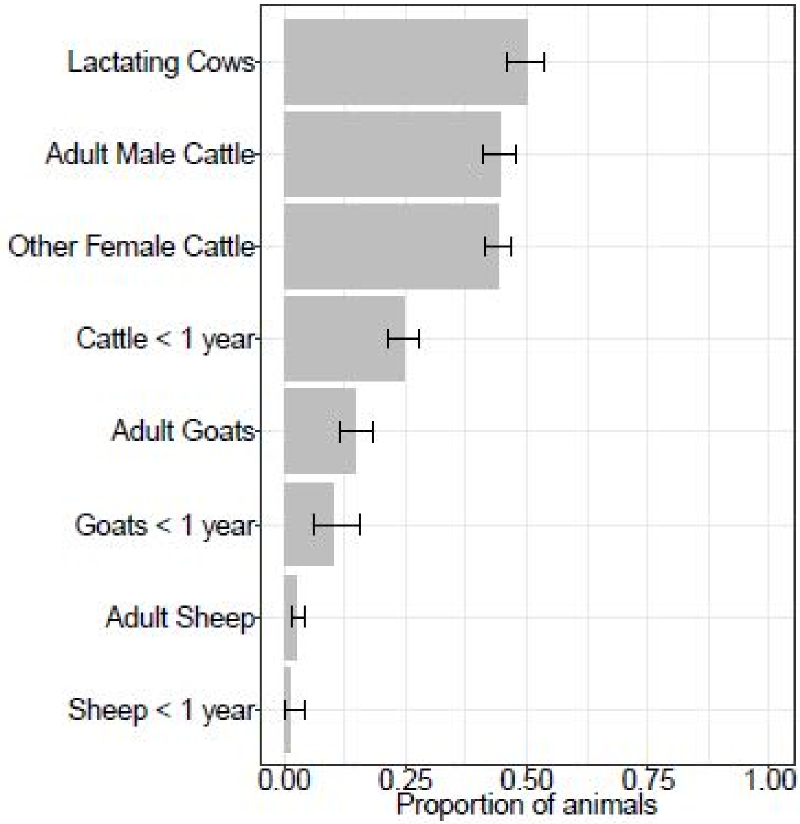
Photos: T. Lembo

Greatest frequency of outbreaks in pastoralist and agro-pastoralist households

Multiple outbreaks each year (80 – 90% in the past year, up to 63% in the past four months)

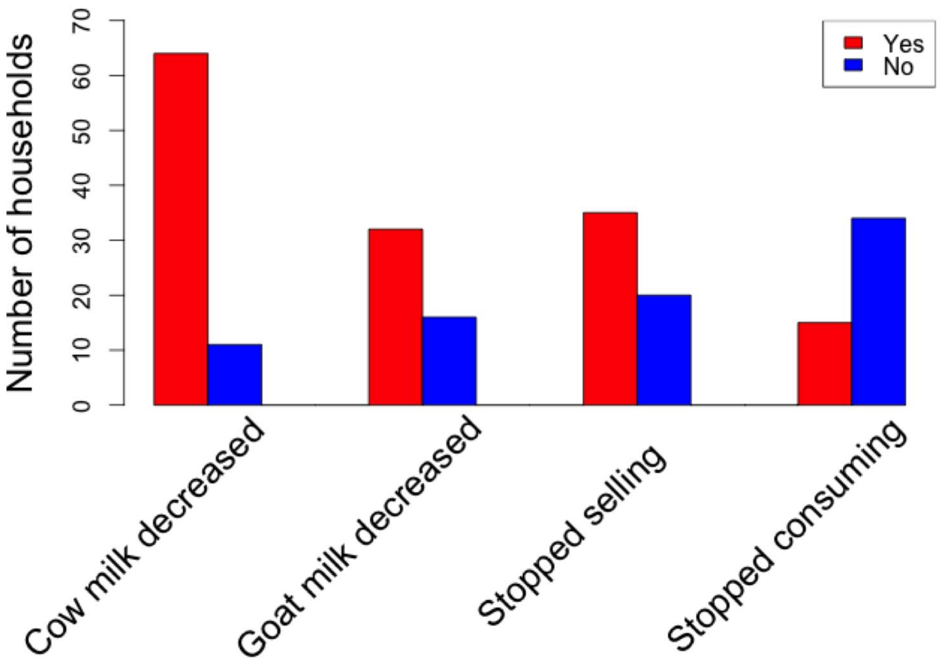


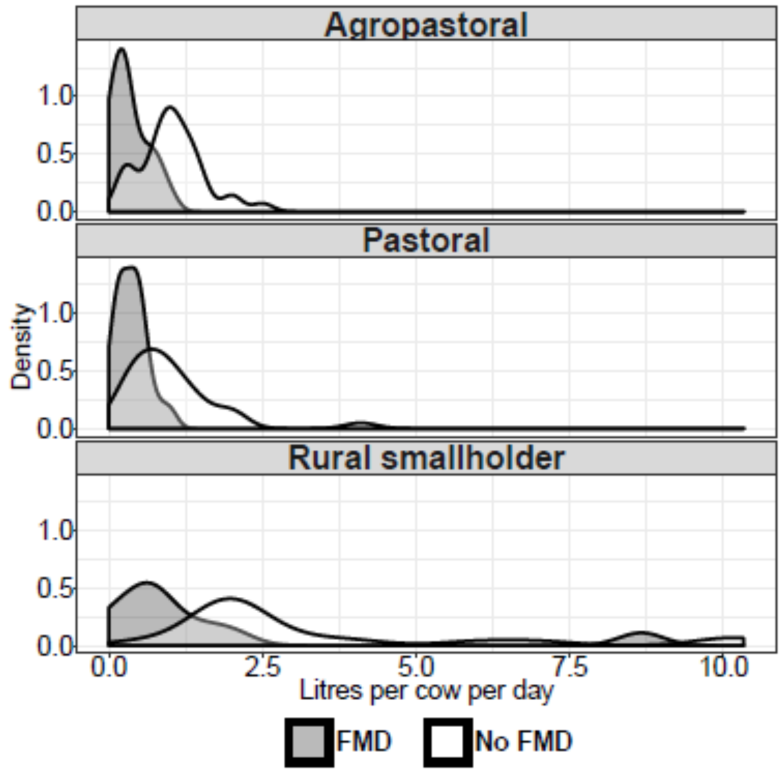
Morbidity impacts



n = 4,852 animals belonging to 45 households that had FMD outbreaks

Impacts on milk production, consumption and sale





Mean percentage decrease in milk yield of 67% of great concern due to the reliance on milk for child nutrition

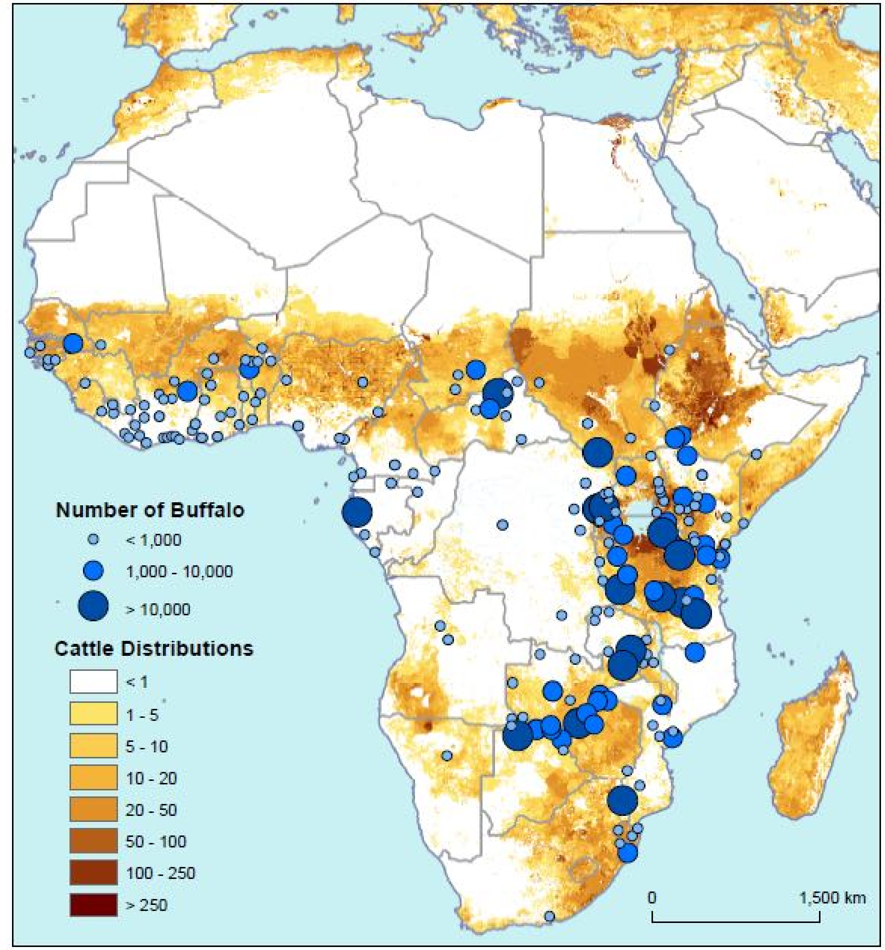
n = 86 respondents

Impacts on traction capacity and livestock sales

- A loss of traction capacity affects 73% of households, with 65% reporting negative impacts on crop production.

- Cash generation from livestock sales decreased by 27% (US$234/household) with consequences for human health (reduced expenditure by 25%).

Foot-and-mouth disease epidemiology in eastern Africa



Casey-Bryars M, Reeve R, Bastola U, Knowles NJ, Auty H, Bachanek-Bankowska K, Fowler VL, Fyumagwa R, Kazwala R, Kibona T, King A, King DP, Lankester F, Ludi AB, Lugelo A, Maree FF, Mshanga D, Ndhlovu G, Parekh K, Paton DJ, Perry B, Wadsworth J, Parida S, Haydon DT, Marsh TL, Cleaveland S and Lembo T (2018). Waves of endemic foot-and-mouth disease in eastern Africa suggest feasibility of proactive vaccination approaches. Nature Ecology & Evolution 2: 1449–1457.

Significant risk factors

	LRT Chi squared	Probability < Chi squared	Coefficient (95% CI)	Odds Ratio (95% CI)
Age (per extra year)	219.6	<10^-6	0.4 (0.3-0.4)	1.4 (1.4-1.5)
Species	144.9	<10^-16		
Cattle compared to small ruminants			1.2 (1-1.4)	3.3 (2.7-4)
Livestock practice	17.1	0.0002		
Agropastoral compared to smallholder			2.1 (1-3.2)	8.1 (2.8-23.6)
Pastoral compared to smallholder			2 (1.1-2.9)	7.1 (2.9-17.6)

n = 84 households, 2694 livestock serum sampled

	LRT Chi squared	Probability < Chi squared	Coefficient (95% CI)	Odds Ratio (95% CI)
Cattle in herd (per extra bovine)	12.9	<10^-3	0.02 (0-0.03)	1.02 (1-1.03)
New animals acquired in risk period (yes versus no)	4.6	0.03	1.72 (0.01-3.431)	5.57 (1.01-30.91)

n = 69 households

Non-significant variables

	LRT Chi squared	Probability < Chi square	Coefficient (95% CI)	Odds Ratio (95% CI)
Log (total cattle)	2.76	0.1	0.3 (0-0.6)	1.3 (1-1.8)
Log (maximum minutes walked to reach grazing and water)	2.37	0.12	0.1 (0-0.3)	1.1 (1-1.3)
Buffalo sighting weekly or more often	***1.32***	***0.3***	***-0.4 (-1-0.3)***	***0.7 (0.4-1.4)***
Log (distance to buffalo area)	***0.09***	***0.75***	***0 (-0.3-0.2)***	***1(0.7-1.3)***
Acquired livestock in the past four months (Y or N)	0.6	0.44	0.2 (-0.3-0.8)	1.2 (0.7-2.1)

n = 84 households, 2694 livestock serum sampled

	LRT Chi squared	Probability < Chi square	Coefficient (95% CI)	Odds Ratio (95% CI)
Buffalo sighting weekly or more often	***1.26***	***0.26***	***0.8 (-0.635-2.227)***	***2.22 (0.53-9.27)***
Grazing or watering area different to usual	1.03	0.31	-0.62 (-1.833-0.582)	0.54 (0.16-1.79)
Measure of livestock contacts during grazing and watering	1.3	0.26	0.04 (-0.03-0.122)	1.05 (0.97-1.13)
Measure of livestock contacts during dipping	0.19	0.66	-0.08 (-0.431-0.278)	0.92 (0.65-1.32)
Visitors in past month	0.03	0.87	0.11 (-1.204-1.418)	1.12 (0.3-4.13)

n = 69 households

Serotype dominance in cattle and buffalo

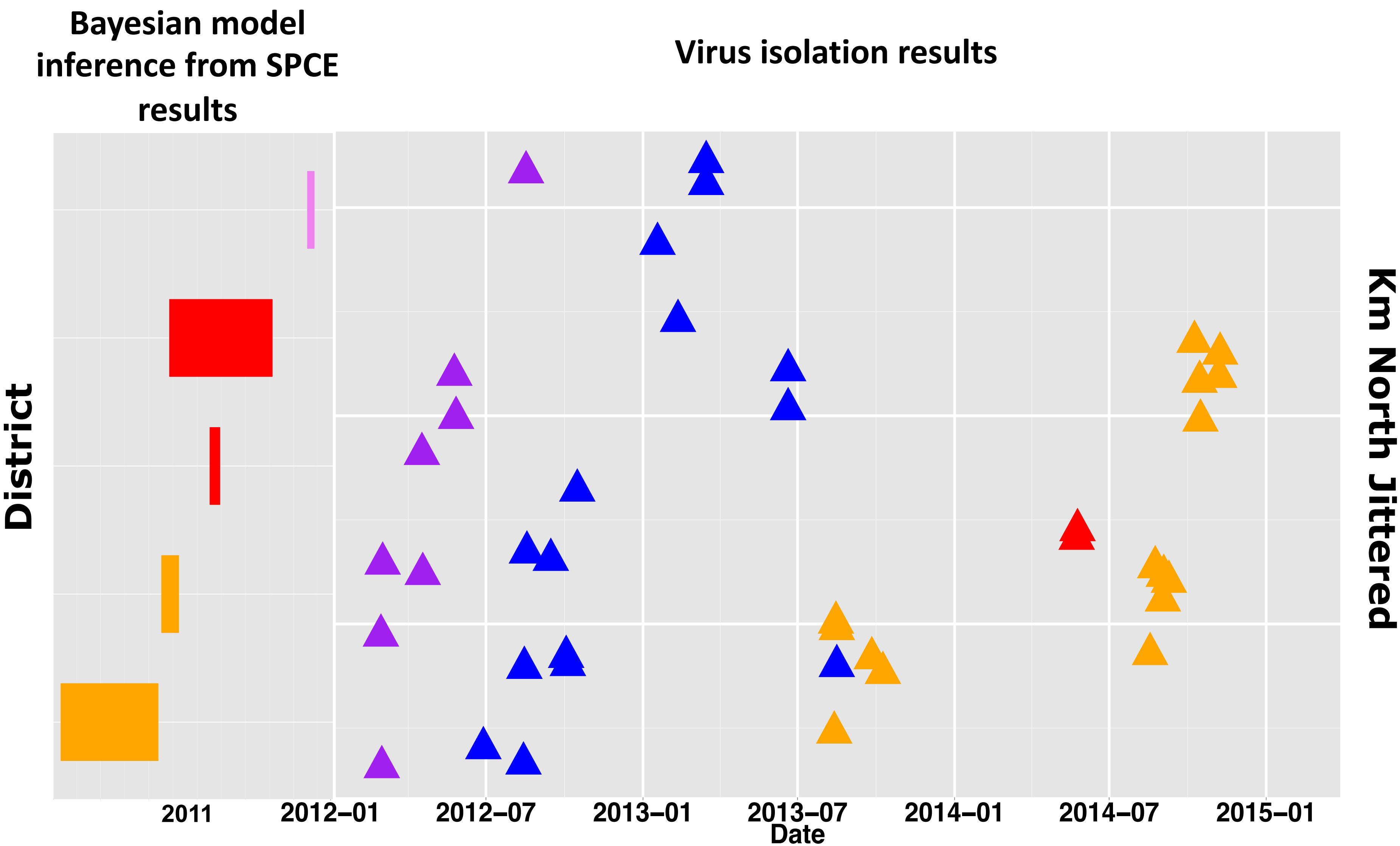
- Cattle:
  - Serotype O most prevalent
  - Serotype SAT2 least prevalent

- Buffalo
  - Serotype SAT1 most prevalent, followed by SAT2
  - Serotype A least prevalent

- No close genetic relationship between cattle and buffalo sequences for SAT serotypes, but small sample of buffalo sequences

- Low seroprevalence of serotypes O and A in buffalo possibly due to occasional spillover or cross-reactivity

Serotype frequency in cattle (2011 - 2015)



N
63 herds

N
38 outbreaks
in 27 herds

Implications for control through vaccination

- Temporal patterns of antigenic dominance offer opportunities for targeted vaccination through existing (monovalent) high-quality vaccines:
  - O and SAT2 vaccines provide $r1 \geq 0.3$ against Tanzanian isolates
  - Also for A and SAT1 $r1$ matching or consistent with protection

Identifying key transmission foci for targeted interventions

Watering points

Grazing locations

Dipping points

Salting points

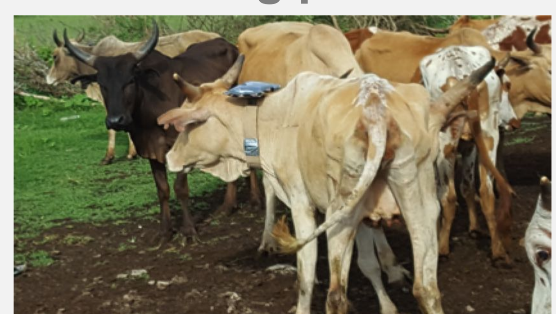


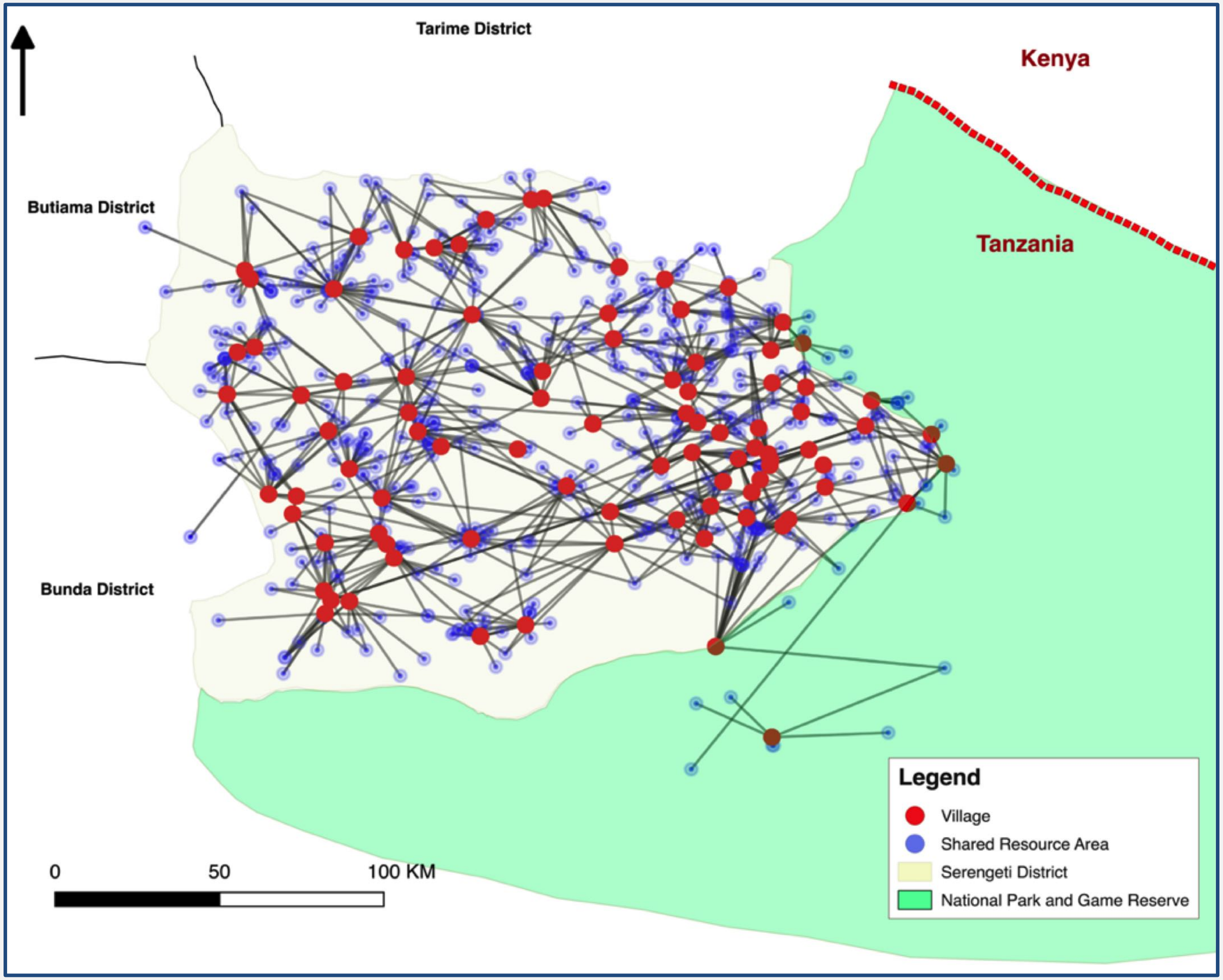
Photo credits: D. Ekwem

Mapping resource areas with local communities

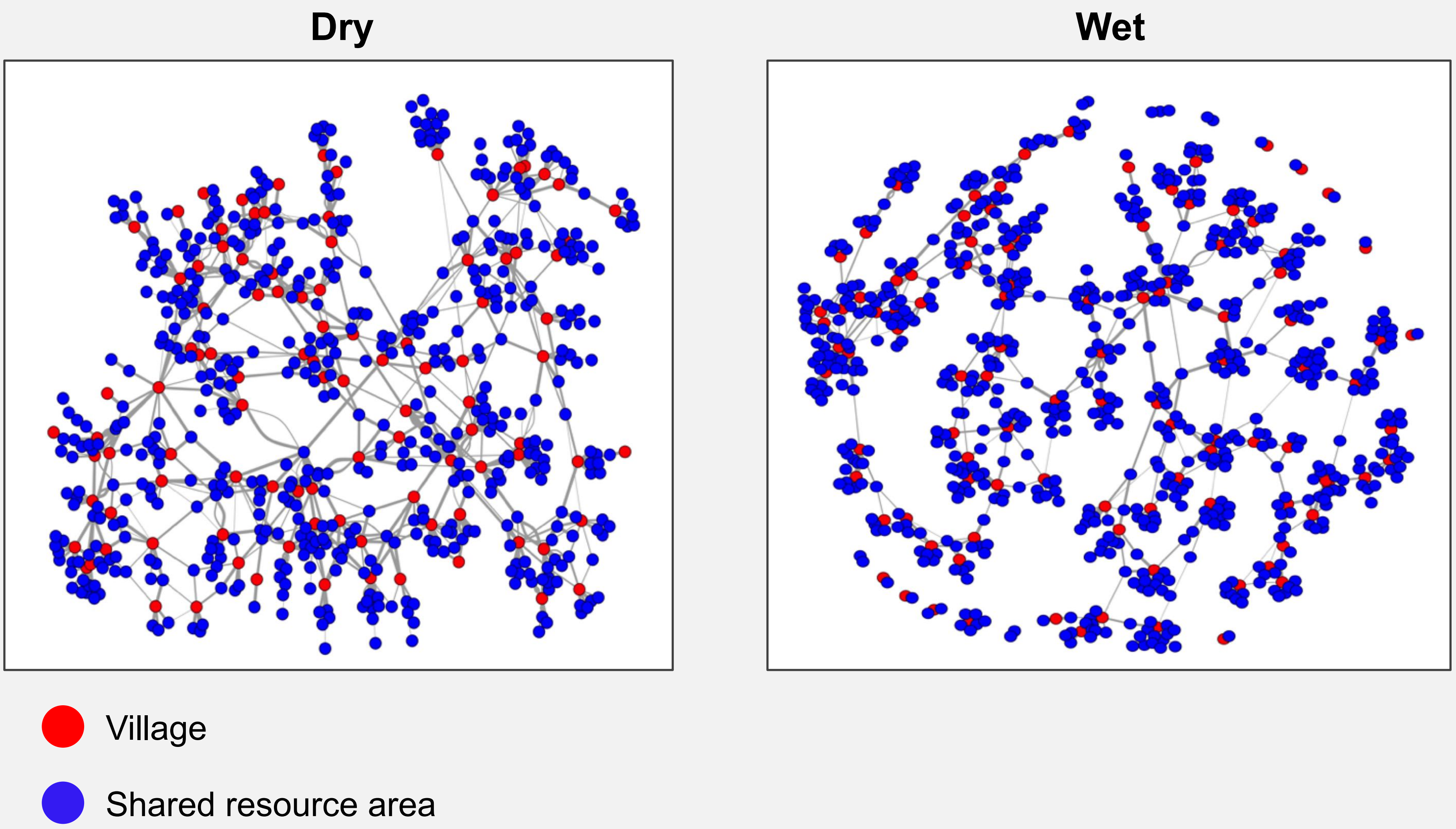
Divine Ekwem

Photo credits: T. Lembo

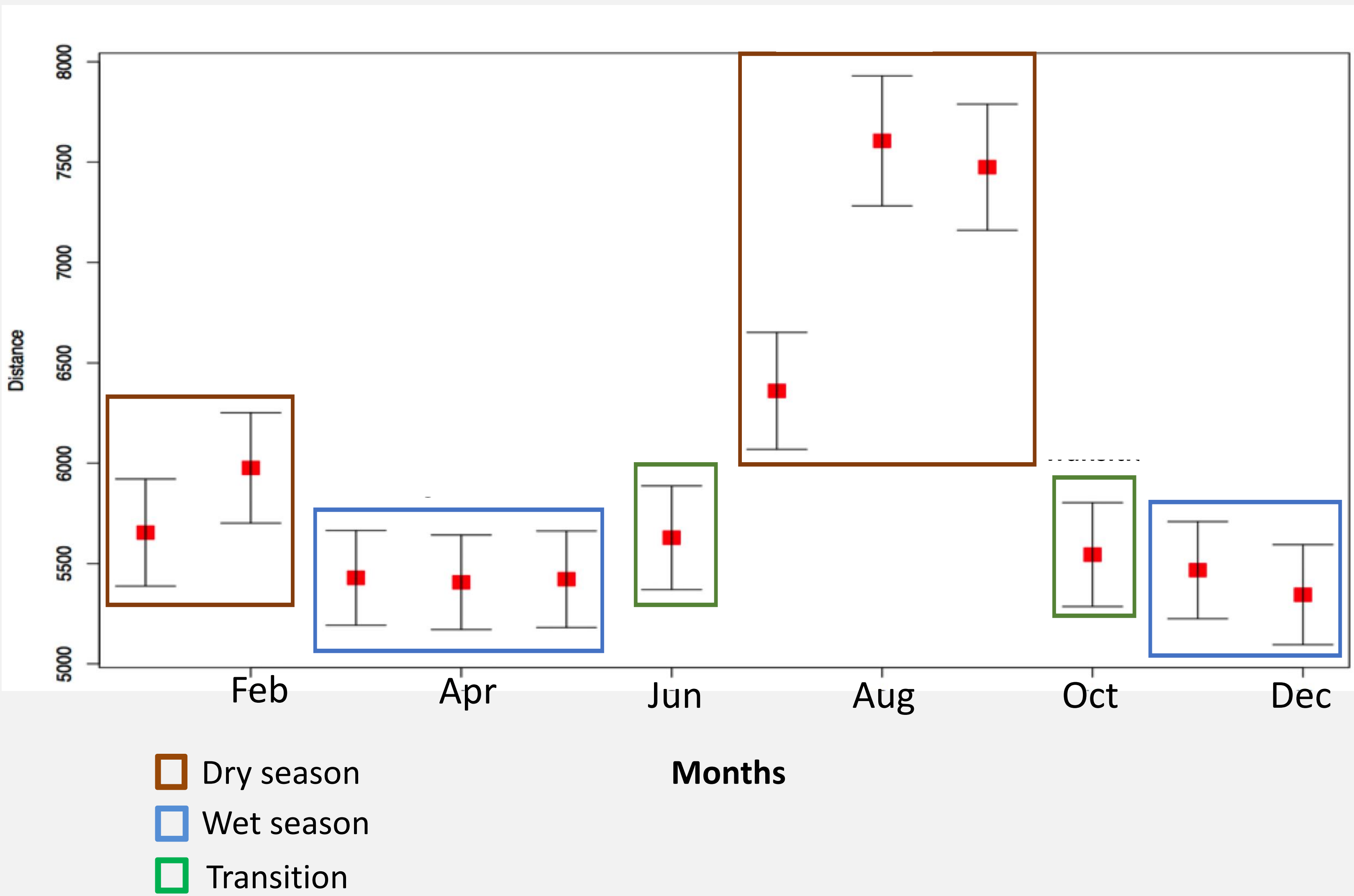
Inter-village connectivity



Seasonality of inter-village connectivity

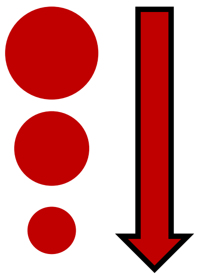


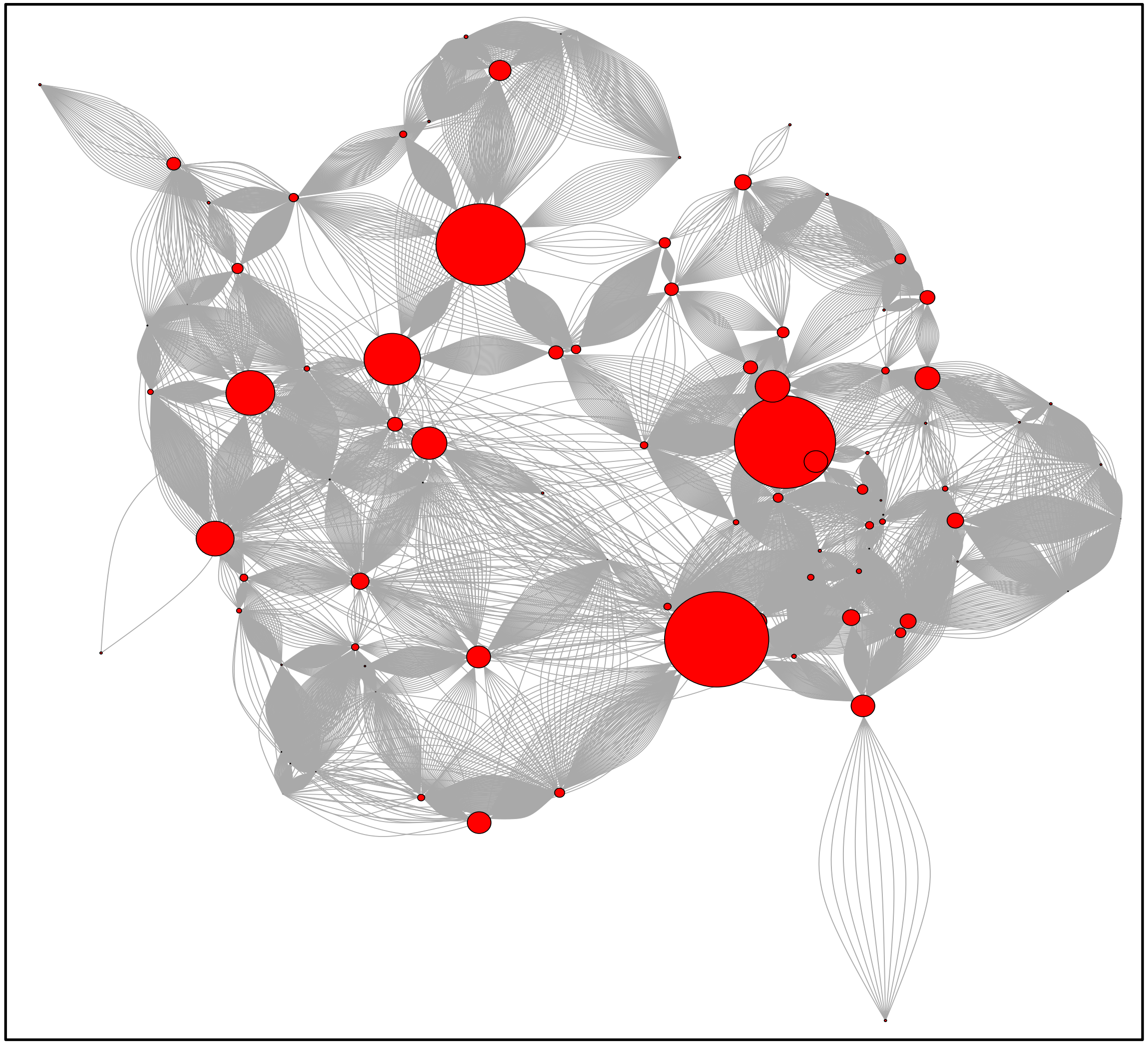
Average distance of villages that are connected across seasons



Identifying most connected nodes

Using centrality measures based on the number of links held by each node to find very connected nodes that could be targeted





Adoption of vaccination in Tanzania

- Vaccination would be culturally and politically acceptable, but…

- …vaccine security and affordability remain an enduring problem

- Socio-economic processes that influence government and household choices towards disease prevention?

Photo credits: K. Bachanek-Bankowska

Photo credits: T. Lembo

What drives vaccination decisions at the household level?

Railey AF, Lembo T, Palmer GH, Shirima GM and Marsh TL (2018). Spatial and temporal risk as drivers for adoption of foot-and-mouth disease vaccination. Vaccine 36 (33): 5077-5083

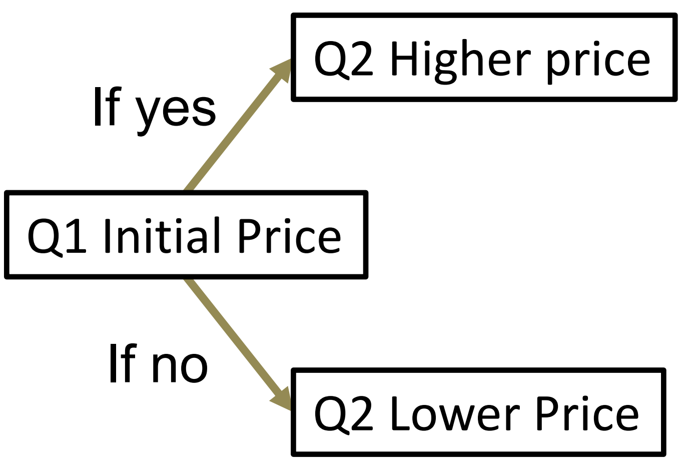
Uncertainties in decision making

- Cost-benefit considerations
  - Individual vs collective risk

- Immediacy and proximity of risk – How proximity of shock affects decisions

- Negative past experience with FMD vaccines in Tanzania

Stated preference willingness to pay – individual preference



n = 432 households

One cow, 6 mths duration

Lower vs higher perceived risk

Routine vaccination

- Biannual, planned application
- Population-level protection
- Lower perceived risk of infection

Emergency vaccination

- Spatial and temporal immediacy
- Individual-focused protection
- Higher perceived risk of infection

Vaccine efficacy: 50 or 100 percent

Outbreak distance: village or neighbour

Higher value on vaccination if immediate threat of disease

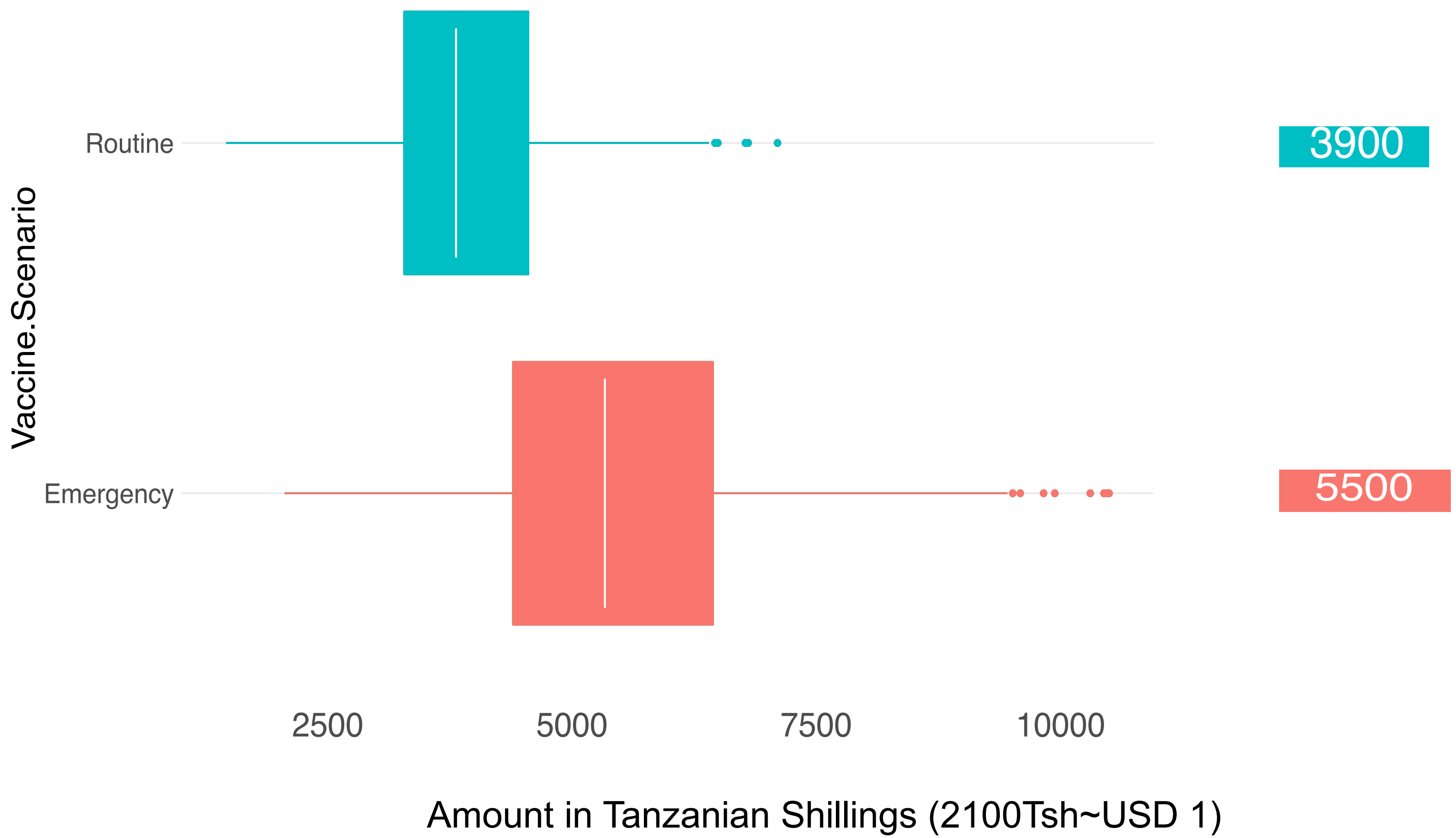


Table 3 Vaccination Determinants

Variable	Routine Marginal Effects (CI 95%)	P value	Emergency Marginal Effects (CI 95%)	P value
Education (0=Formal; 1=No Formal)	681 (-7,1356)	0.096	655 (-369,1679)	0.295
Income				
Off-Farm (≤25,000 Tsh)		Base Case		
Off-Farm (25-100,000)	589 (-34,1213)	0.119	1962 (835,3090)	0.004
Off-Farm (>100,000)	1022 (360,1685)	0.010	1763 (672,2854)	0.007
Crops (≤100,000 Tsh)		Base Case		
Crops (100-500,000)	1635 (806,2465)	0.001	2294 (1034,3554)	0.003
Crops (>500,000)	-445 (-1067,176)	0.237	-403 (-1513,3554)	0.552
Herd Size†	26 (-192,243)	0.846	42 (-348,432)	0.859
Expected Milk Loss (in liters per cow)	306 (-94,707)	0.207	423 (-205,1051)	0.270
Cattle sold in past year	36 (-.33,71)	0.096	11 (-48,71)	0.753
FMD experience in past year (0=No; 1=Yes)	-241 (751,270)	0.439	-283 (-1156,590)	0.595
Vaccinated for any cattle disease in past year (0=No; 1=Yes)	-247 (-795,299)	0.457	216 (-754,1186)	0.715
Use of government vet (0=No; 1=Yes)	-663 (-1113,-214)	0.014	-1817 (-2626,-1008)	0.001
Vaccine efficacy (0=100%; 1=50%)	1573 (370,2778)	0.031	2318 (107,4529)	0.085
Gender (0=Female; 1=Male)	1031 (321,1740)	0.016	857 (-478,2192)	0.292
Gender*efficacy (0=100%; 1=50%)	-1458 (-2740,-174)	0.060	-2737 (-5066,406)	0.053
District (0=Ngorongoro; 1=Serengeti)	-270 (-751,212)	0.358	94 (-779,967)	0.860
Outbreak (0=Village; 1=@Neighbor)			-476 (-1244,293)	0.314
Log Likelihood	-415		-498	
Chi-2 Statistic	39.09		41.87	

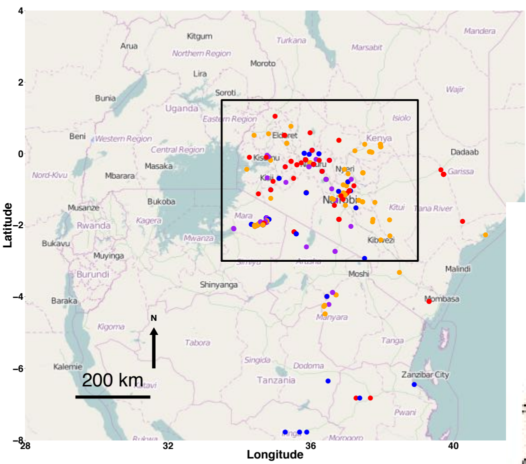
† Log of variable

USD 1.00=2100 Tanzanian shillings

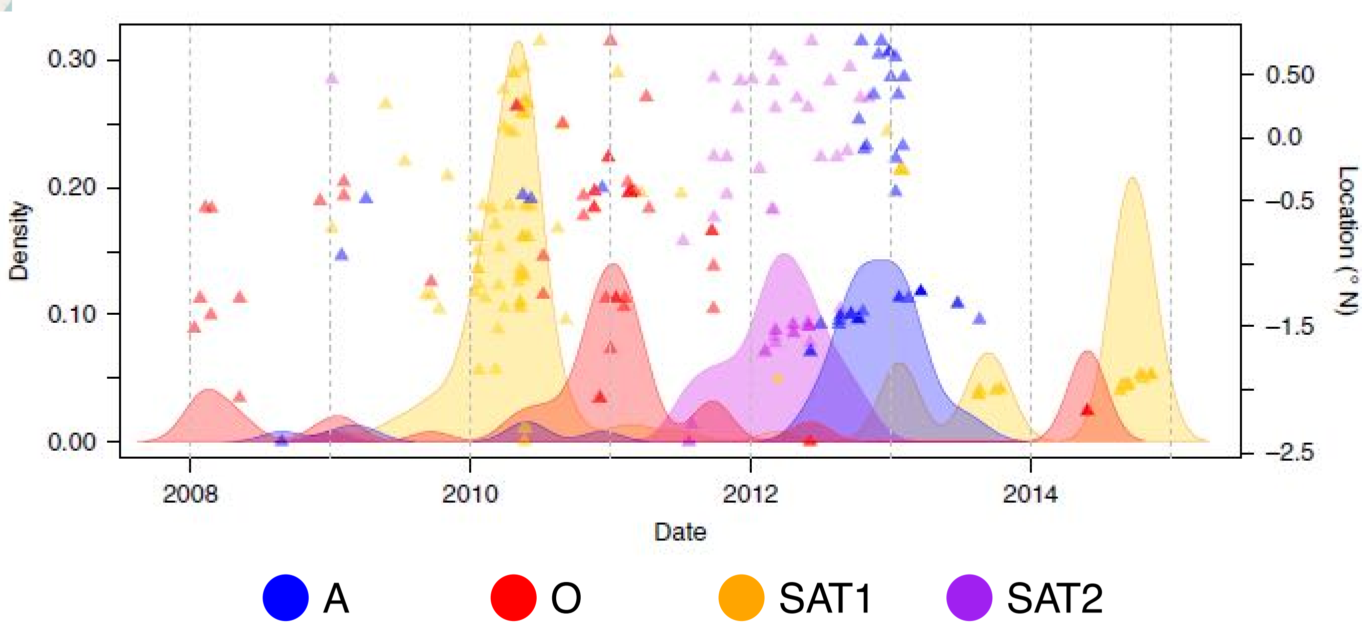
AF Railey, T Lembo, GH Palmer, G Shirima, and TL Marsh (2018). Spatial and temporal risk as drivers for adoption of foot and mouth disease vaccination. Vaccine 36, 5077-5083.

Improved surveillance and viral characterisation frameworks for…

- Can we improve surveillance and viral characterisation platforms across Africa to determine if…
- …the pattern of antigenic dominance in Tanzania is consistent across broader geographical scales?



Virus isolation data Tanzania & Kenya (2008-2015)



…better informed response

- Early typing of outbreak samples (serotype-specific rapid field diagnostics?) critical to:
  a. Inform the choice of vaccine strains
  b. Reduce costs of outbreaks by better informing response
  c. Influence motivations towards sustainable private uptake of diagnostics and vaccination
- Consistency across broader scales would increase market potential of international, high-quality, vaccines

Photo credits: T. Lembo