Statistical modelling-- RVF

Updates on dynamic model

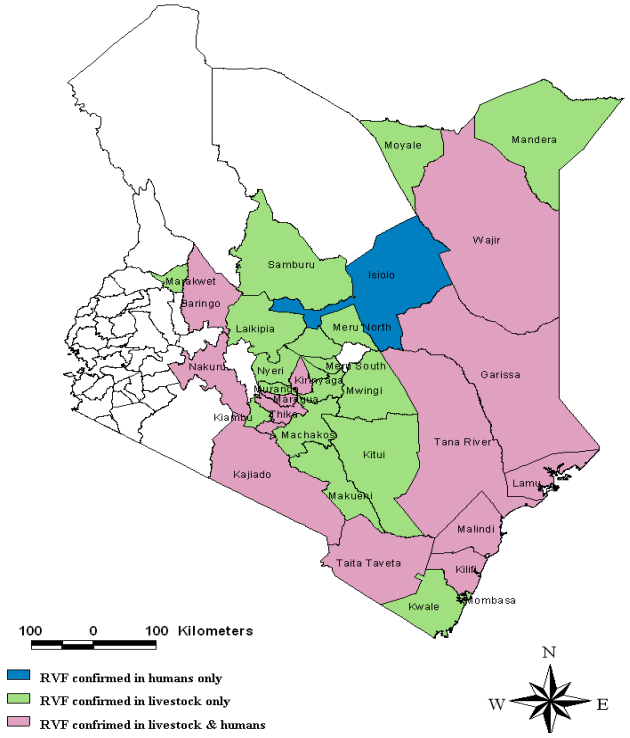
Other RVF projects in ILRI

Geospatial analysis of the risk of Rift Valley Fever in Kenya

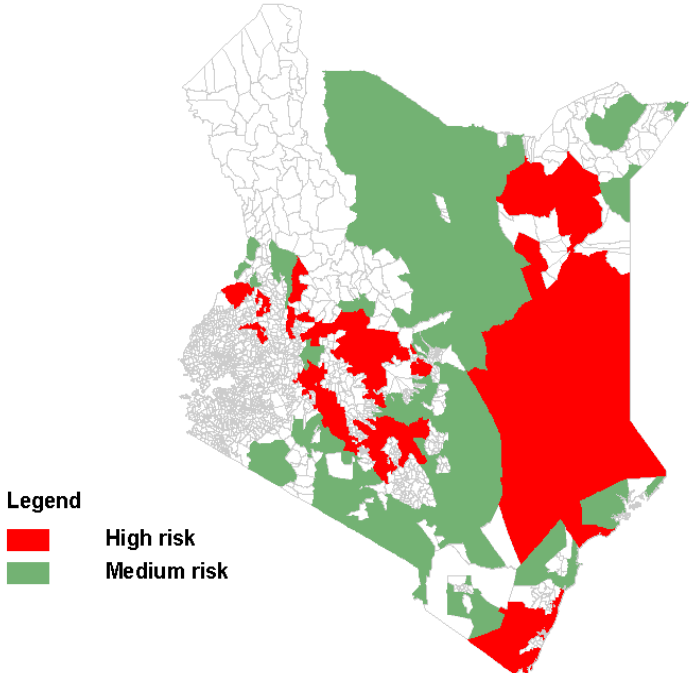
Published work on RVF epizootics in Kenya

- History of epizootics in Kenya (Murithi et al. 2010)
- Risk factors that have been identified (Hightower et al., 2012; Anyamba et al., 2009; Archie et al., 2007)
  - Excessive rainfall (El Nino years, except 1989)
  - NDVI
  - Altitude (areas <1,100 m above sea level)
  - Soil types (solonetz, calcisols, solanchaks, planosols)

On-going work on RVF risk analysis



Source: Department of Veterinary Services



Centers for Disease Control

Current focus: Refine the risk maps and identify factors that influence the incidence of RVF outbreaks verses those that promote persistence

Methodology

- Data on RVF outbreaks
  - Case – laboratory confirmed outbreak of RVF (RT-PCR) by division/month from Vet. Department

- GIS datasets:
  - Land use and land cover maps
  - Precipitation
  - NDVI
  - Human population
  - Elevation
  - Soil types
  - Wet lands
  - Parks

GIS data - predictors

Variable	Source	Description
Livelihood zones	FEWSNET	Livelihood practices as at 2006
Land cover	FAO on-line database	Global land cover data, 2000
Precipitation	ECMWF	Monthly minimum, maximum and average for the period: 1979 - 2010
NDVI	Spot Vegetation	Monthly average, minimum, maximum values from: 1999 - 2010
Human population	Kenya National Bureau of Statistics	Human and household census for 1960, 1970, 1980, 1990, 1999
Elevation	CSI SRTM	
Soil types	FAO	FAO's Harmonized World Soil Database (HWSD), 2009
Wetlands (area as % of total)	ILRI GIS Unit	
Parks/reserves (area as %)	ILRI GIS Unit	

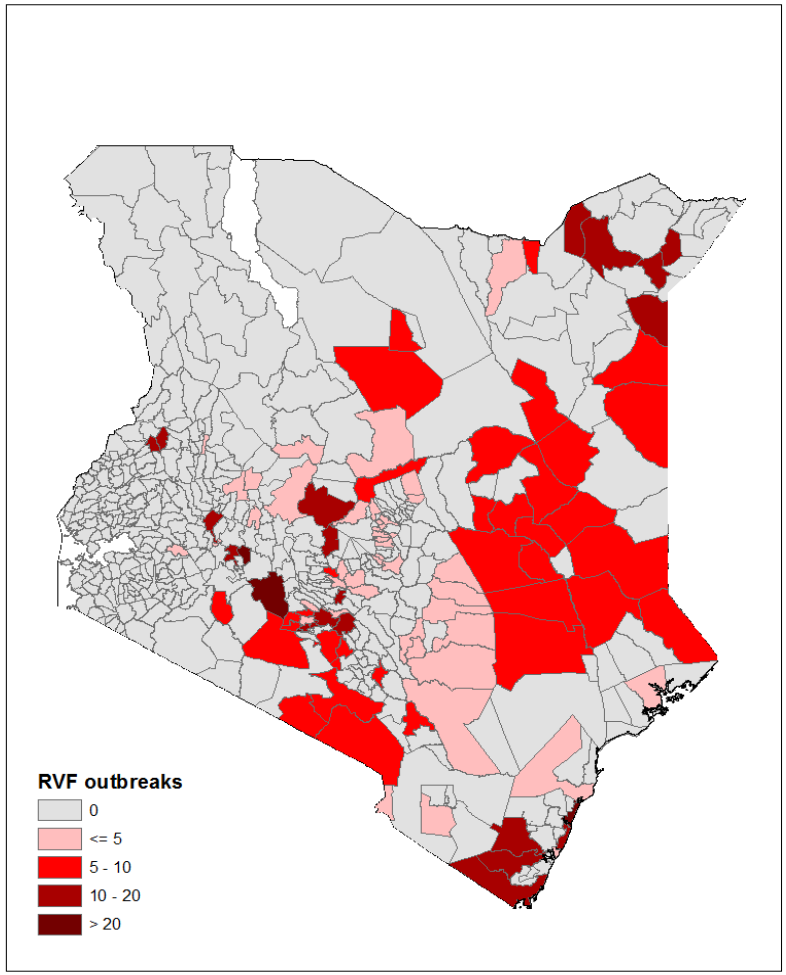
Data analysis

- Descriptive analyses
- Regression models:
  - Generalized Linear Mixed models
    - Poisson model for incidence
    - Logit models for prevalence

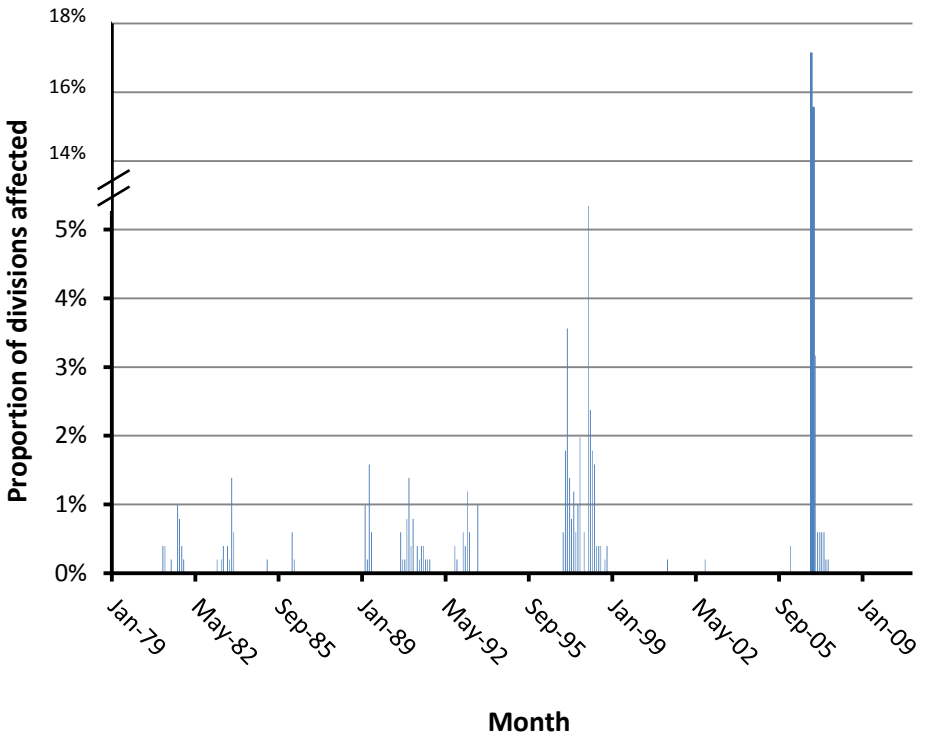
    Restricted iterative generalized least squares estimation
  - MCMC/spatial multiple membership model
    - To account for spatial autocorrelation

Results

Divisions that have had RVF outbreaks in Kenya between Jan 1912 and Dec 2010



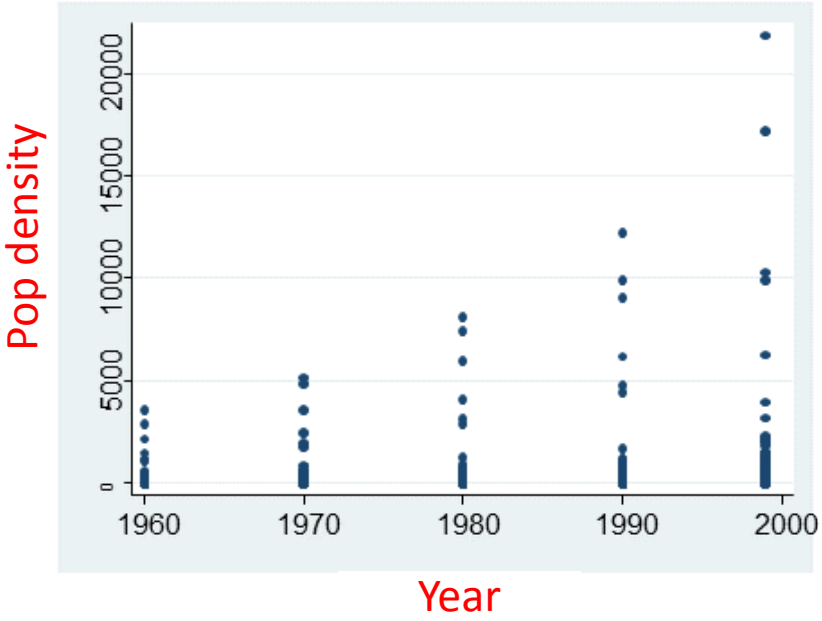
Temporal distribution of RVF outbreaks: 1979 - 2010



- 505 divisions -1999 population census
- 20.2 % (n = 102) of the divisions have had an outbreak at least once
- Mean outbreak interval : 5.4 (4.4 – 6.4) years

Analyzing human population data – predictor?

Human population trends 1960 - 1999

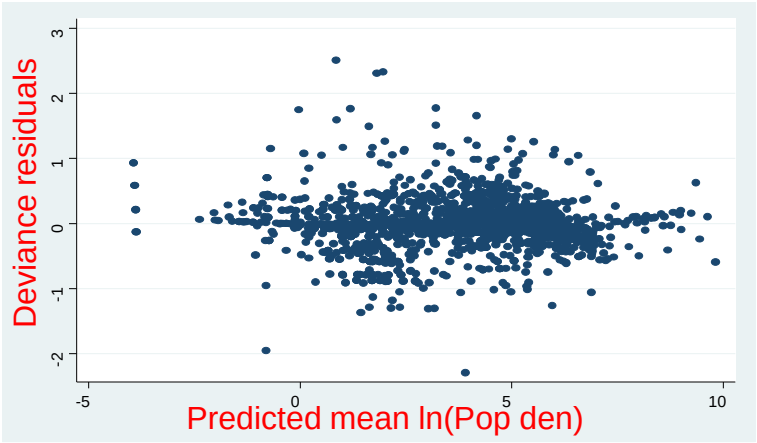


GLM model fitted to the human population data

Variable	Level	β	SE(β)	P>|Z|
Time		0.034	0.001	0.000
Level of growth	Very low	0.280	0.068	0.000
	Low	0.000	-	-
	Medium	0.037	0.022	0.097
	High	0.218	0.063	0.001
Growth x Time	Very low	-0.036	0.006	0.000
	Low	0.000	-	-
	Medium	0.004	0.002	0.033
	High	0.009	0.003	0.002
Ln(starting pop)		1.017	0.013	0.000
Ln(starting pop)_sq		-0.006	0.002	0.013
Constant		0.005	0.016	0.757

Log pseudo-likelihood = -746.67; AIC = 0.62; BIC = -18830.-5

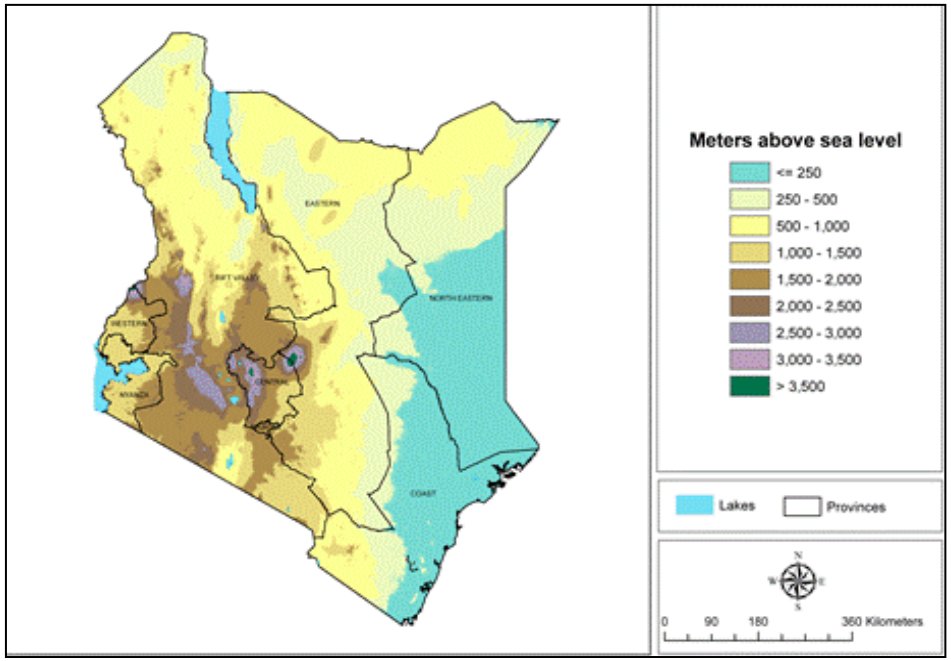
Deviance residuals verses fitted values



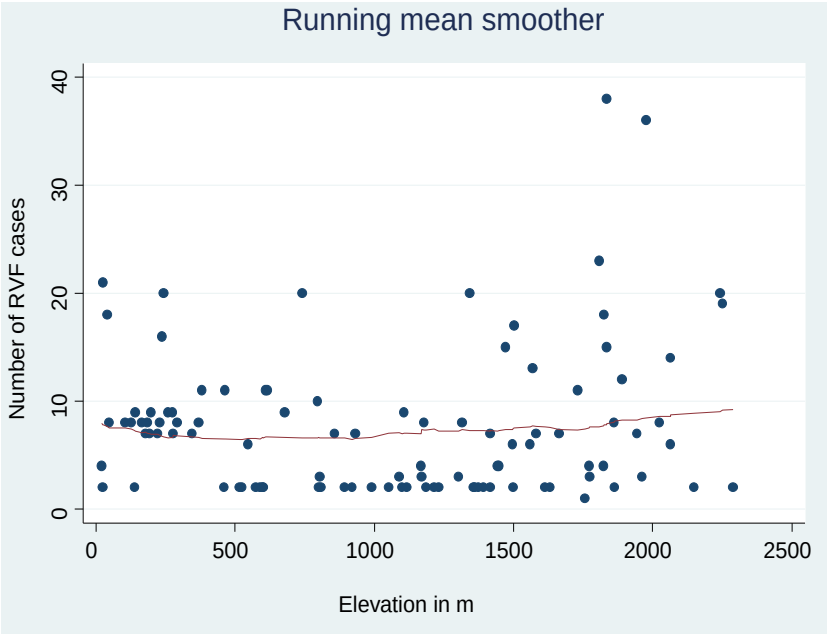
- Gives good prediction for human population
- Outliers – mainly with the 1999 population:
  - 3 divisions in NE Kenya, one with a refugee camp
  - one division near Mau Forest
- Population density is significant in the crude RVF regression model

Association between altitude and RVF occurrence?

Elevation map of Kenya



Scatter plot of the number of RVF cases by altitude

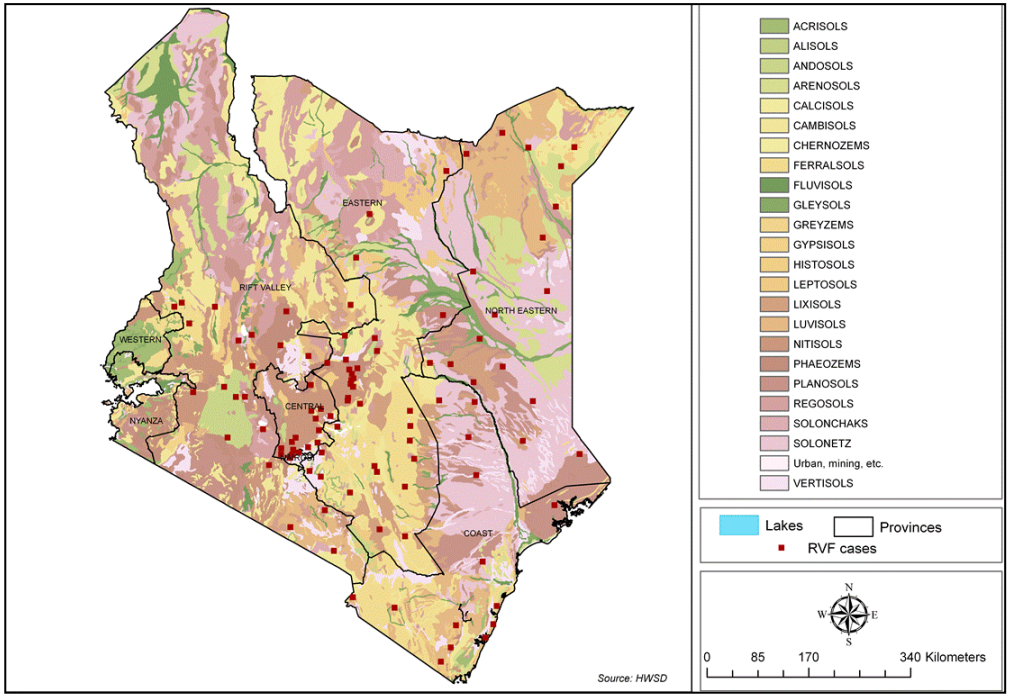


- Altitude is a factor; cases observed up to 2,300 m above sea level
- Similar observations made in Madagascar where RVF occurred in a mountainous region of >1,500m (Chevalier et al., 2011)

Association between soil type and RVF occurrence?

Soil texture	Status	Frequency	Number positive	%	Chi (P)
Clay	Yes	345	80	23.2	5.6 (0.02)
	No	157	22	14.0	
Loamy	Yes	70	11	15.7	1.1 (0.30)
	No	432	91	21.1	
Sandy	Yes	25	2	8.0	2.5 (0.12)
	No	477	100	21.0	
Very clayey	Yes	53	8	15.1	0.1 (0.32)
	No	440	94	20.9	

Relative distribution of soil types and divisions with RVF in Kenya



- Soil types associated with RVF include:
  - Solonetz
  - Luvisols
  - Vertisols
  - Lixisols

Regression model: factors that affect the incidence of RVF with months-at-risk as an offset

		Multi-level Poisson model		MCMC/Bayesian model		Multiple –membership model	
Variable	**Level**	**β**	**SE**	**β**	**SE**	**β**	**SE**
Fixed effects							
Constant		-16.73	0.22	-17.15	0.25	-17.03	0.34
Precipitation		0.30	0.01	0.29	0.02	0.29	0.02
Elevation	< 2300 m	0.000	-	0.00	-	0.00	-
	≥ 2300 m	-0.58	0.54	-0.59	0.49	-0.82	0.52
No. previous infections	0	0.00	-	0.00		0.00	-
	1 - 6	5.86	0.24	5.94	0.21	5.72	0.21
	>6	7.26	0.27	7.37	0.25	6.96	0.24
Random effects							
Livelihood zones		1.72	0.38	0.95	0.27	0.71	0.46
Division		0.00	0.00	0.01	0.01	1.70	0.55
Deviance				4139.29		4140.91	

$$\log(\pi_i) = \text{offs}_i + \beta_{0i}$$

$$\beta_{0i} = \beta_0 + u^{(3)}_{0,live\_zones(i)} + \sum_{j \in neighl(i)} w^{(2)}_{i,j} u^{(2)}_{0j}$$

Models for the persistence of outbreaks

		Multi-level Poisson model		MCMC/Bayesian model	
Variable	**Level**	**β**	**SE**	**β**	**SE**
Fixed effects					
Constant		-3.74	0.69	-6.18	0.92
Precipitation		0.11	0.03	0.16	0.04
NDVI		2.68	0.80	3.29	0.83
Soil types	Solonetz	1.34	0.49	1.64	0.62
	Luvisols	1.24	0.45	1.80	0.59
Elevation	< 2300 m	0.00	-	0.00	-
	≥ 2300 m	-2.99	0.64	-3.79	0.95
Random effects					
Livelihood zones		3.16	0.61	9.37	3.02
Deviance				841.57	

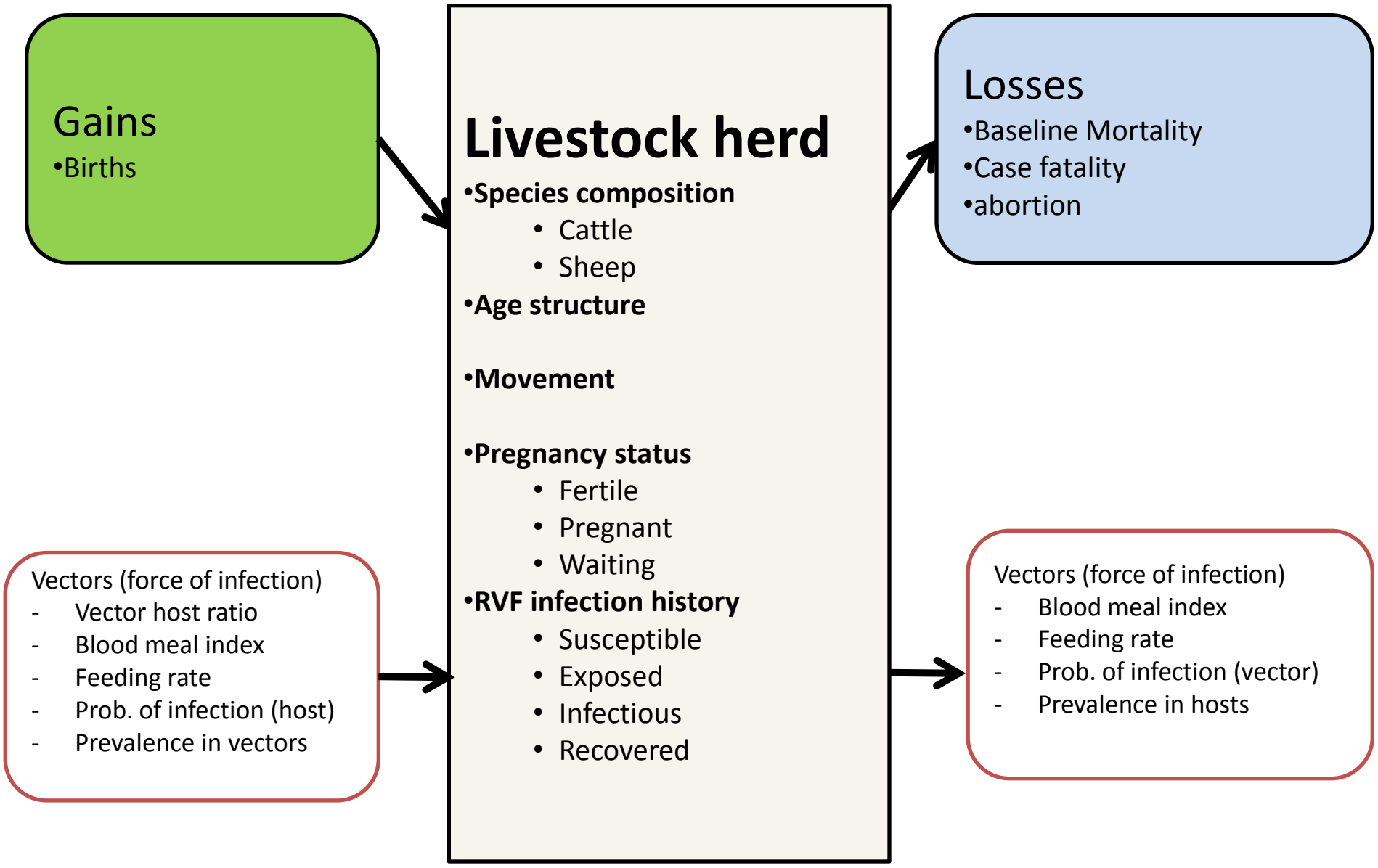
Discussion

- Intense precipitation more important for RVF incidence (3 months cumulative) but soil type (e.g. solonetz and luvisols) supports persistence of outbreaks
- Elevation – consistent with previous findings
- Potential for using these results to map hot spots

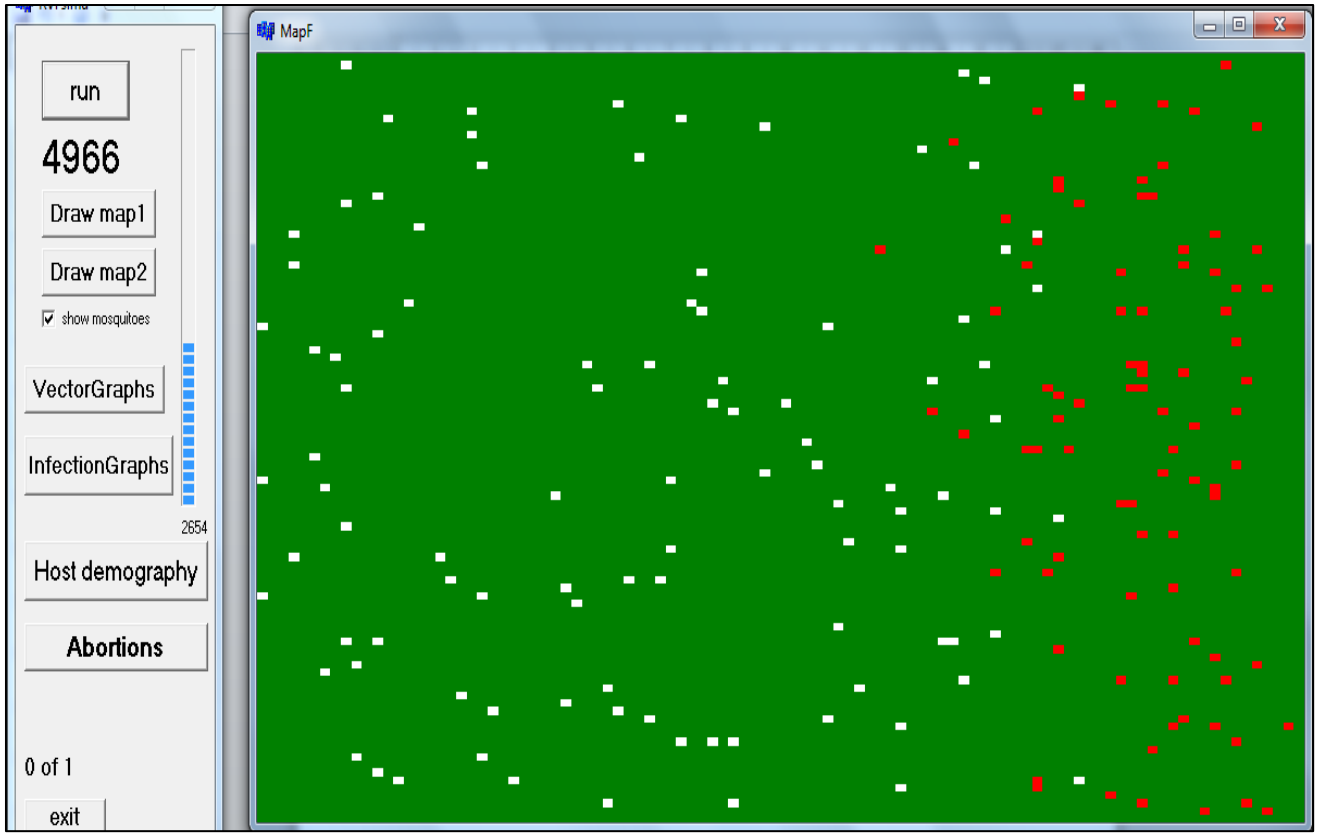
Dynamic model

Basic structure

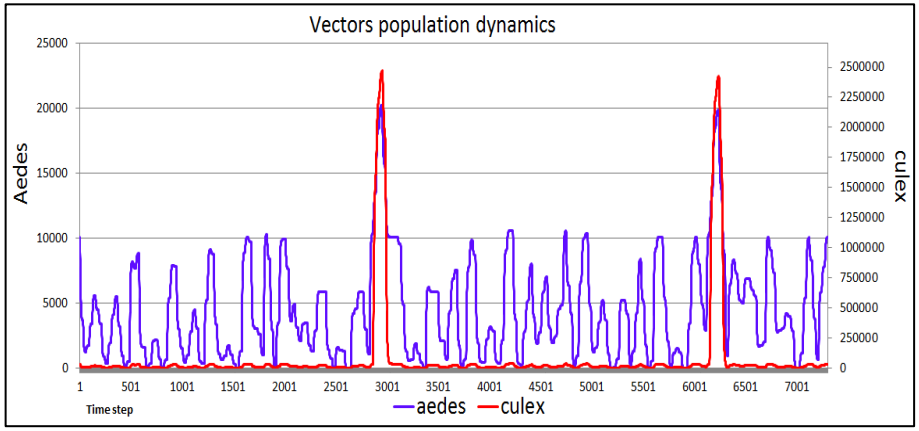
- Grid of 10,000 sq km – 500 x 500 m
- 2 hosts: cattle and goats
- Movement – wet and dry season grazing sites
- Vectors: *Aedes* spp and *Culex* spp


Gains
•Births
Livestock herd
•Species composition
• Cattle
• Sheep
•Age structure
•Movement
•Pregnancy status
• Fertile
• Pregnant
• Waiting
•RVF infection history
• Susceptible
• Exposed
• Infectious
• Recovered
Losses
•Baseline Mortality
•Case fatality
•abortion
Vectors (force of infection)
- Vector host ratio
- Blood meal index
- Feeding rate
- Prob. of infection (host)
- Prevalence in vectors
Vectors (force of infection)
- Blood meal index
- Feeding rate
- Prob. of infection (vector)
- Prevalence in hosts

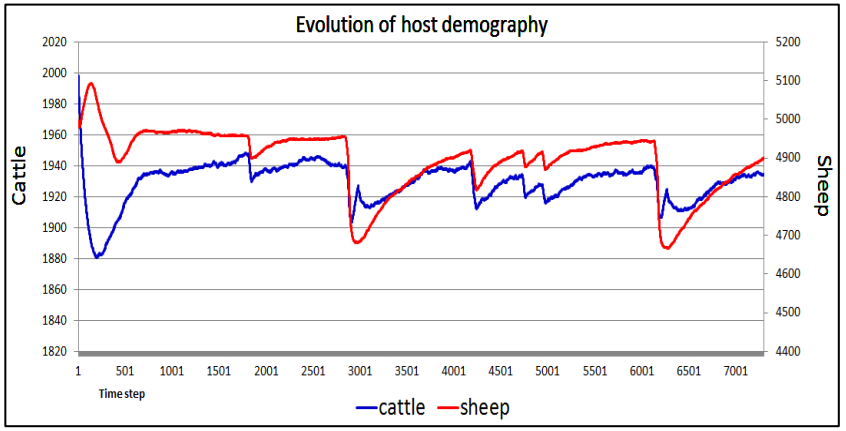
Model interface



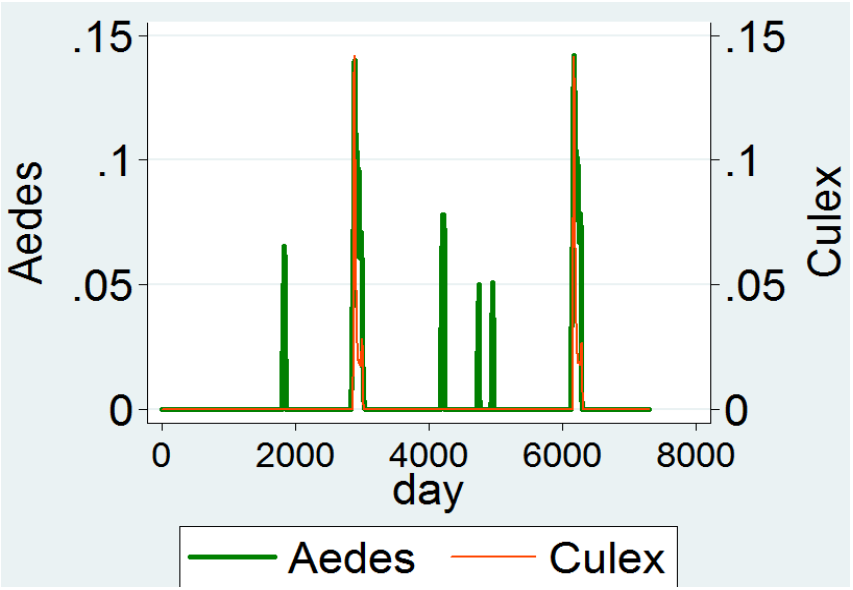
Vector pop dynamics



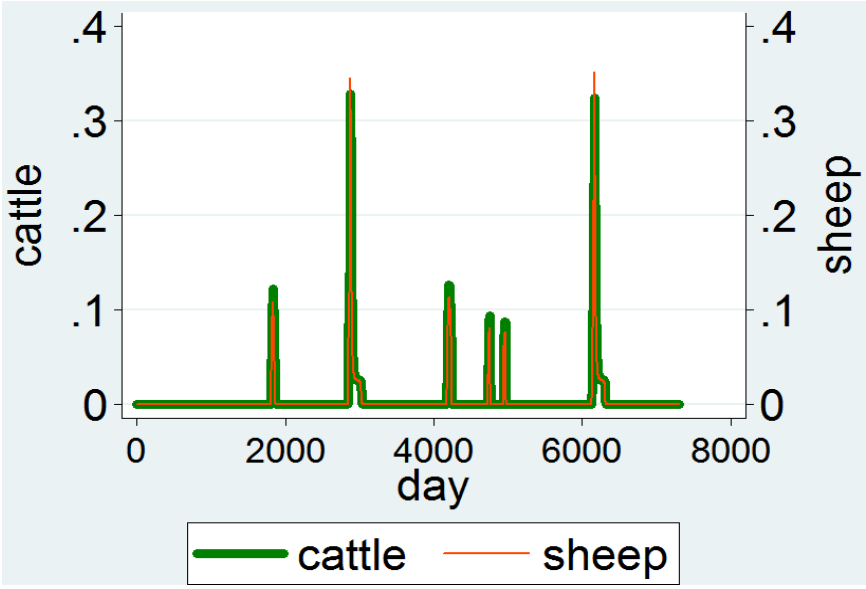
Host pop dynamics



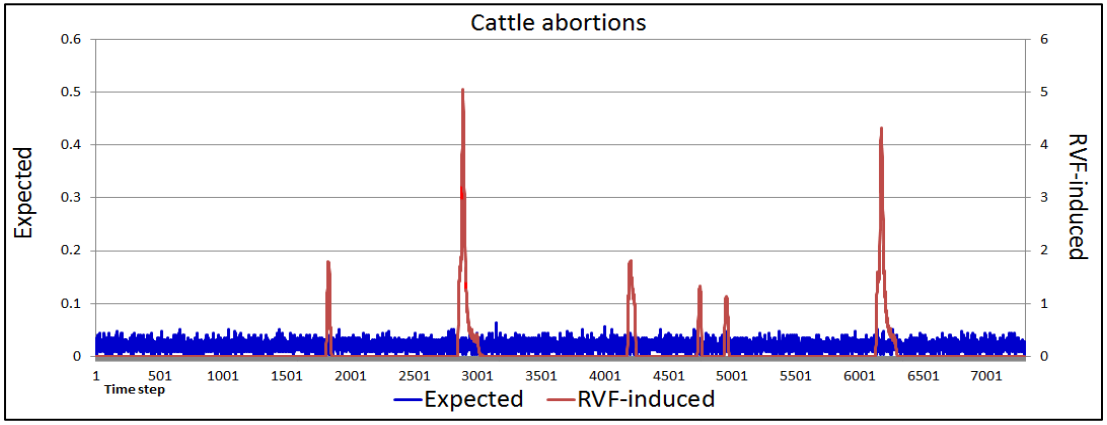
RVF incidence: vectors

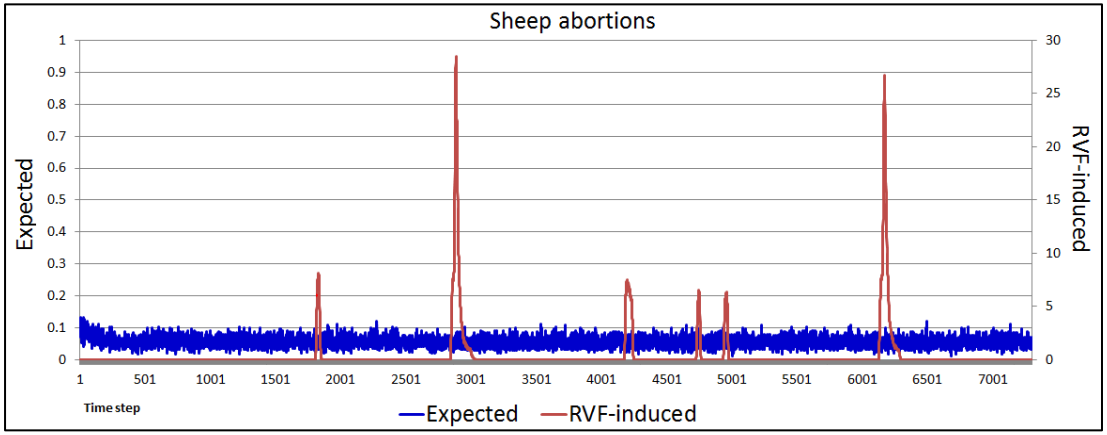


RVF incidence: hosts



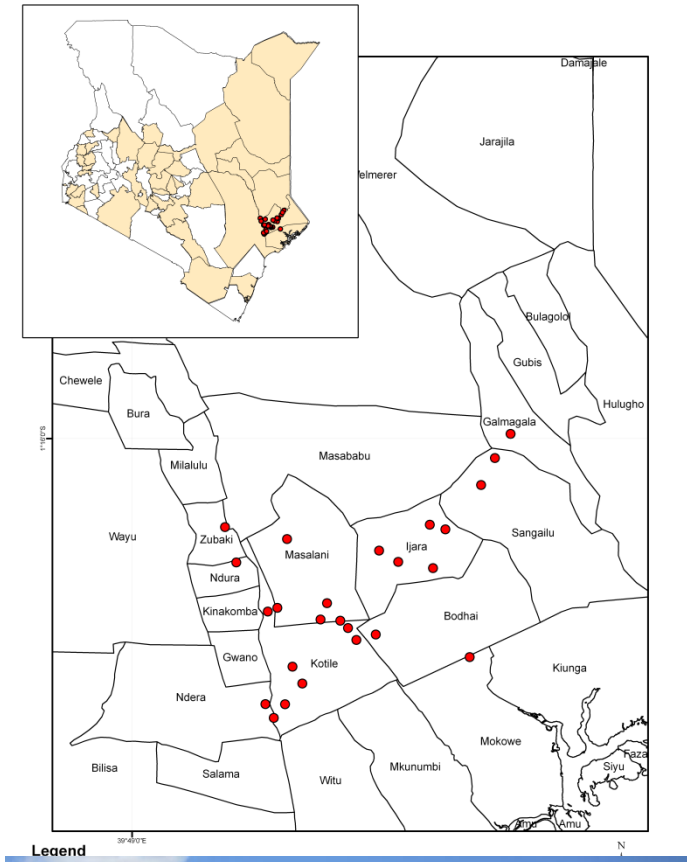
Abortion rates – with and without RVF





Other RVF Projects at ILRI

- Healthy Futures
  - Anticipate future environmental changes and their impacts on water-related VBDs
  - Build capacity of health and veterinary services to respond to early warnings of future outbreaks
- Dynamic Drivers of Disease in Africa
  - the relationships between ecosystems, health and poverty
  - *Hypothesis: disease regulation as an ecosystem service is affected by changes in biodiversity, climate and land use, with differential impacts on people's health and wellbeing*
- AVID
  - Pathogen discovery – RVF



Healthy Futures

WP 2 Disease information and database construction
- Historical outbreaks, socio-economics, migration, settlement, conflicts, climate observations/downscaling
- Meta-database

WP3 Field work, *statistical models* and dynamics models

WP4 Risk and vulnerability mapping of disease and impacts, Socio-economic change scenarios

WP5 Decision Support Tools