Spatio-temporal predictive modelling and burden analysis of Rift Valley Fever and East Coast Fever in response to climate change in Kenya

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Presentation Outline :

- Introduction
- Literature Review
- Objectives
- Justification
- Materials and Methods
- Work plan
- Acknowledgements

1.0 Introduction :

- In Kenya, global circulation models predict that, by the year 2100, Climate Change will increase temperatures by about 4°C. This will result to rainfall irregularity, massive crop failure, reduced availability of forage and water, increase of livestock pests and diseases, livestock mortality and loss of livelihoods.

- Livestock keepers are greatly affected due to higher vulnerability and low adaptive capacity and have developed adaptive measures; traditional early warning systems, use of emergency fodders, multi-species composition of herds and nomadic mobility to reduce their vulnerability.

- However, lack of understanding of the drivers of climate change due to inconsistent weather data remains a major challenge causing unreliable and inaccurate prediction of climate change patterns.

1.1Introduction :

- An improved understanding of indigenous knowledge and practices and the environmental interplay in the risk and transmission dynamics of livestock diseases will contribute to design of efficient adaptation strategies to Climate change.

- This study proposes to compare indigenous adaptation and mitigation strategies in pastoral and mixed-crop indigenous livestock production systems in Kenya and to assess livestock vulnerability in the context of multiple environmental stressors.

- Participatory epidemiology using community based approach, geographical mapping tools and predictive models of livestock infectious disease burden for anticipatory and reactive adaptive preparedness.

- The overall aim is to improve the ability of vulnerable people and their livestock to be more resilient to current climate variability and their decision-making to climate change.

2.0 Literature Review :

- The IPCC climate model projections predict an increase in global average surface temperature of between 1.4 to 5.8 °C by 2100. The direct effects of climate change are higher temperatures and changes in rainfall patterns, translating in increased vector-borne diseases transmission patterns

- Climate change is predicted to significantly increase vulnerability of livestock systems in Kenya on already stressed social and environmental systems. These is exacerbated by rapid population growth, high demand for livestock products, increased conflict over scarce resources and improper land use.

- Kenya's' livestock sector is more vulnerable to the effects of climate change due to a low capacity to adapt, lack of resources and inaccessible veterinary services.

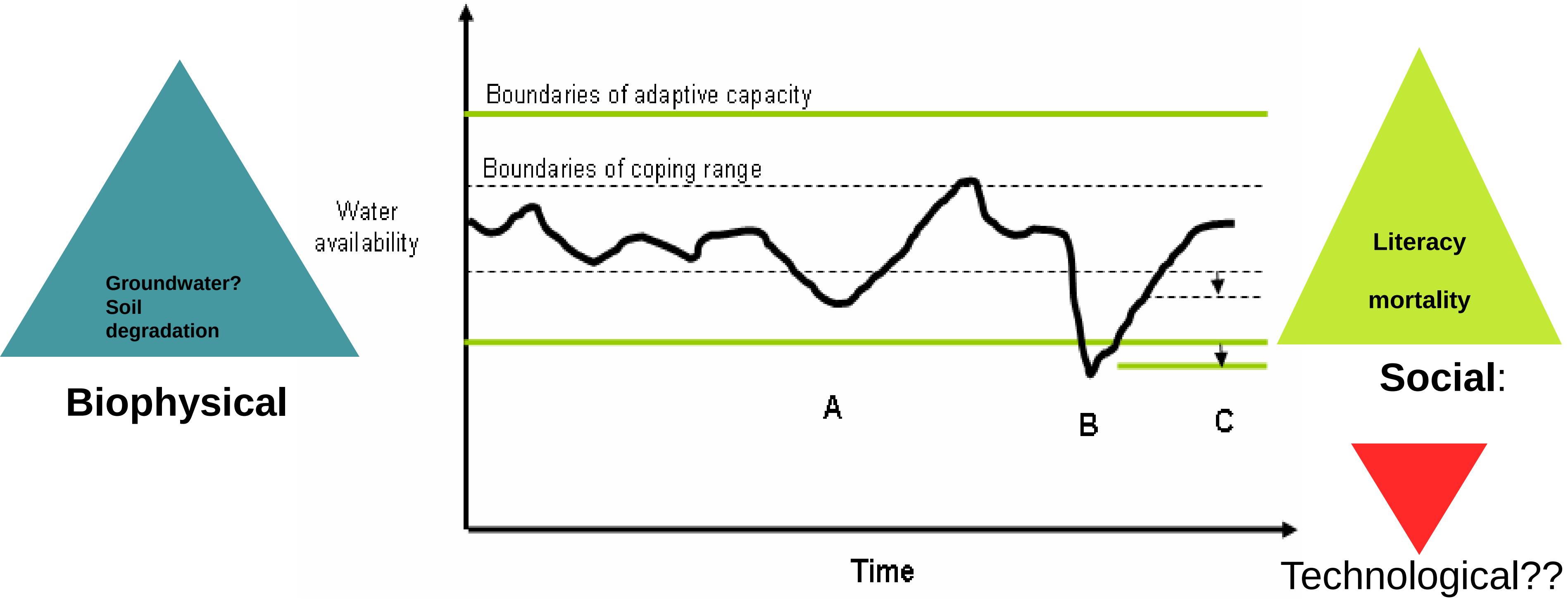
- To respond to this threat it will be necessary to focus on both mitigation and adaptation, to support livestock keepers deal with the impacts. *Adaptation* to reduce sensitivity and *Mitigation* to reduce the magnitude of climate change impact.

IPCC, 2001; Ericksen et al., 2011; IFAD, 2011; Thornton et al., 2010

2.1Vulnerability and Adaptive capacity

1. **Biophysical:** The sensitivity of the natural environment to an exposure to a hazard
2. **Social**: sensitivity of the human environment to the exposure.

Impact is a function of hazard exposure and both types of vulnerability



Climate vulnerability, coping range and adaptive capacity

Vincent (2004)

2.2 Climate change impacts on livestock

2.3 Coping strategies

- Sedentary nature of nomadic pastoralists in search of water and pastures
- Designated community watering points or buffer grazing areas
- Traditional Early Warning Systems
- Use of emergency fodders
- Herd composition, size and diversity management
- Livestock trading as insurance

Indigenous strategies are insufficient to cope with the effects of climate change????

- Impacts will be difficult to model or predict because of the lack of standardised livestock denominator data at the national level on vulnerability to a range of climate-related stressors.

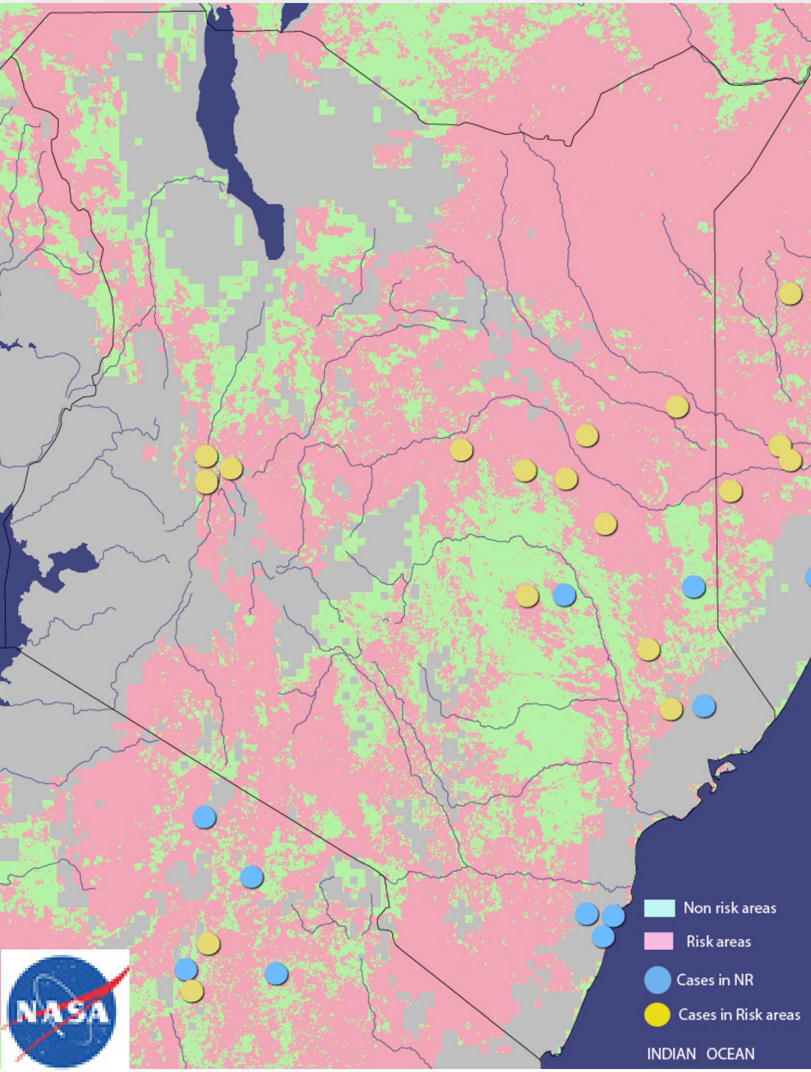
- Need for improving climate risk management ; traditional EWS, Index-based livestock (IBL) insurance and community based risk mitigation through seasonal climate forecasts, contingency planning and training.

Notenbaert *et al.*, 2010; Hellmuth *et al.*, 2009

2.5. Spatial distribution of Vector borne diseases:

Risk Map 2006- 2007

2.5 1. Rift Valley Fever



Viral zoonosis :
Bunyaviridae(F), Phlebovirus(G)
Transmitted by Aedes mosquito

- Economic losses in Garissa and Ijara districts (2007) due to mortality was Ksh 610 million

- Epidemics marked with unexplained abortions (100%) Cattle, small ruminants

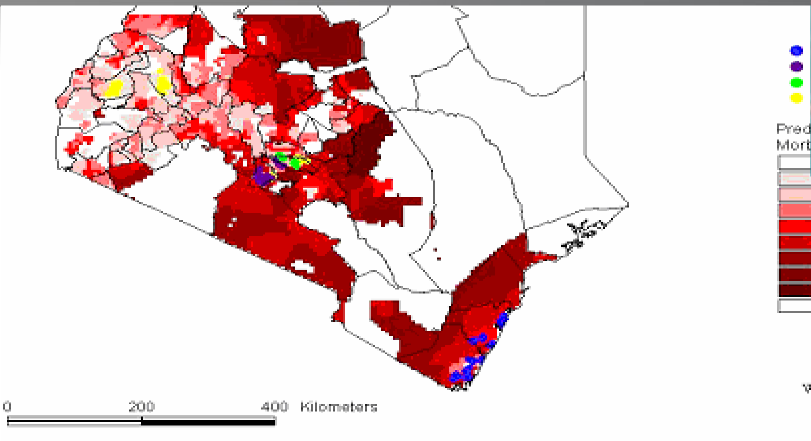
- Potential for epizootics and human epidemics

- Climatic prediction of heavy rainfall associated with an increased risk of outbreaks during the warm phase of the El Niño/Southern Oscillation (ENSO).

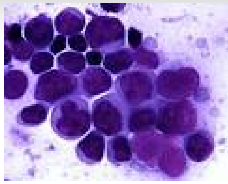
Anyamba *et al*., 2009, PNAS,106 (3), 955-959. & Rich and Wanyoike 2010, *Am. J. Trop. Med. Hyg*., 83(2),

2.5.2 East Coast Fever

Risk Map 2003



Protozoa : *Theileria parva spp*
Vector *: Rhipicephalus appendiculatus*



- **Direct production losses** (Mortality and Morbidity)- weight loss, low milk yields, less draft power **Indirect losses** : Constraint on the use of improved cattle due to susceptibility(*theilerio-intolerance*)

- **Interventional costs**: US$ 10 for a single dose of live vaccines (ECFIM) and cost African farmers in excess of US $168 million in losses

- Disease risk maps for the current and future climatic suitability, establishes vector abundance and TBD distribution is crucial in policy control plans of the ticks and diseases(ECF).

Diaz *et al*., 2003; Olwoch *et al*., 2008

3.0 Objectives

- **Overall Objective**

- Investigate the impacts of climate change on livestock production systems and the livestock owner's mechanisms for adaptation and mitigation.

- **Specific Objectives**

1. Identify climate factors that affect livestock production and livelihood systems and constraints to adaptation and mitigation of vulnerable communities.

2. Estimate the prevalence and disease burden of priority diseases that have climate related risk factors to enhance farmers' preparedness to effects of climate variability in Kenya.

3. Determine the livelihood based economic impacts of climate change on vulnerable communities.

4. Develop predictive spatial and temporal models for early warning systems (EWS) and preparedness for public, institutional and government policy utilisation.

4.0 Justification

- Kenya's' people and livestock industry continue to be ravaged by climate change effects due to inadequate methods and tools for impact and vulnerability assessment.

- This research takes cognizance that coping better with current climate variability is essential for adapting to future climate change and it attempts to utilise indigenous knowledge and local coping strategies as a baseline for adaptation planning.

- This study proposes an integrated climate risk assessment of livestock production, incorporating climate dependent disease models to develop predictive risk maps that will be crucial in current and future control plans of climate related diseases and possibly provide EWS for sustainable and cost effective disease management.

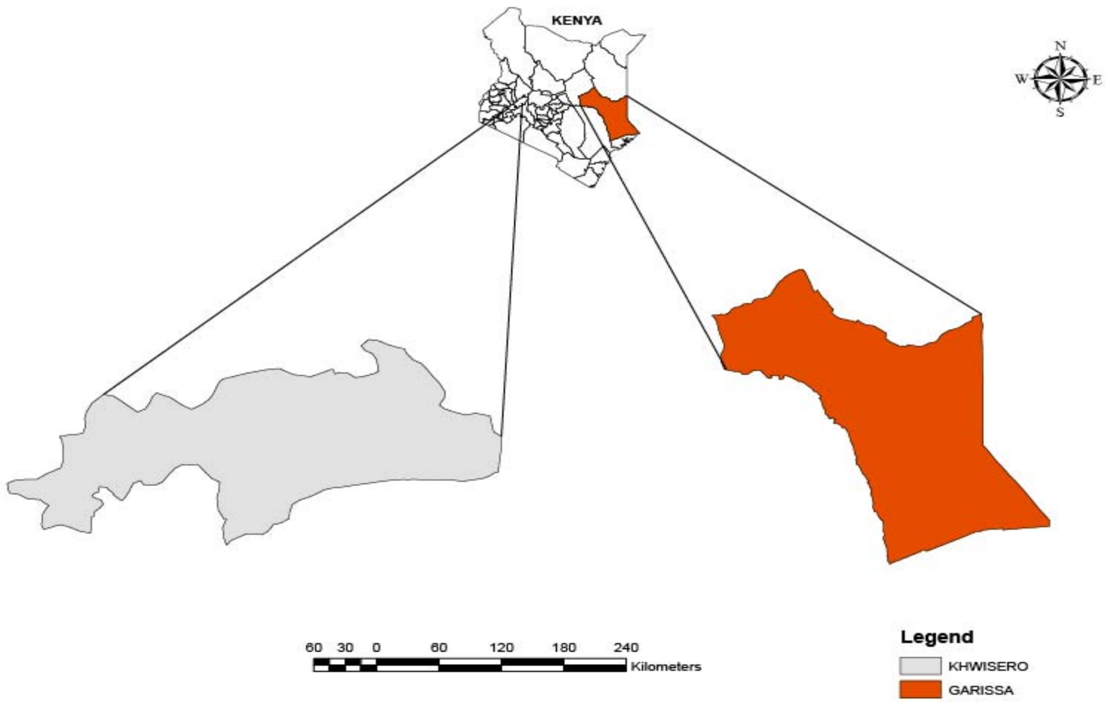
- This is the first case study that attempts to compare the impact of climate change and variability on the mixed (crop/livestock) and pastoral production in Kenya. It aims to provide empirical evidence on the vulnerability of livestock systems to improve livelihood resilience by quantification of the temporal and spatial impact of climate risk.

- The research output should aid individuals and communities to make choices and take actions that lead to sustainable livelihoods in the face of climate change.

5.0 Materials and Methods

❑ Study area

This study will be conducted in selected divisions of Garissa and Khwisero districts in North Eastern and Western Kenya, respectively.



❑ Site selection

Agro-ecological Zoning (AEZ), Garissa (V-VI) and Khwisero (III) represent pastoral and mixed crop/livestock systems respectively

Different cases of previous extent of exposure and vulnerability to climate change (magnitude). .

The comparison of the effects is ideal since indigenous livestock are predominantly reared in both sites

Climate related vector borne diseases (**RVF,ECF**)

5.1 Data collection

- **Study design**
- **Retrospective and Cross-sectional analysis**. Detection, prevalence estimation in different groups within populations, and with investigating the effect of the presence of different determinants on disease prevalence

- **Data collection tools**

- **Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA)**
- A rapid assessment checklist will be developed in consultation with the PE specialists, economists and epidemiologist on (causes, indicators, effects of climate change, adaptations)
- Participatory mapping (sticks, stones)- (homesteads, grazing grounds, livestock routes, watering points and rustling hot spots)
- Focus group discussions on topical issues on effects, adaptations and mitigation
- Disease impact matrix scoring and Proportional piling - Livestock diseases, adaptive strategies

- **Household and community surveys**
- Semi Structured interviews(100 questionnaires) on KAP assessment of disease dynamics, economics of herd sizes, preferred animal species, adaptation/mitigation strategies.

Bryan *et al.,* 2011; Bett et al. 2009

5.2 Participatory Geographical Mapping

- The cluster sampling technique will be used where conveniently accessed livestock and humans will be grouped in random clusters.

- Handheld Global Positioning System (GPS) gadgets will be used to collect point data on the:
    - Geographic locations of livestock markets
    - Distribution of Cattle (livestock diseases -Vector density)
    - Human settlements,
    - Nomadic migratory corridors,
    - Roads networks and veterinary offices.

- This will be entered into a relational database and exported to ArcView GIS (ESRI, Redlands, California) for analysis.

- Participatory involvement of the community will be vital in accuracy and reliability.

Bennett *et al*. 1999; Bett *et al*. 2009

5.3 Sample Size determination

- Garissa–*Bulla* (household unit) a group of villages (N=50) and their livestock living together in temporary settlements, they migrate together in search of pasture. Each “Bulla has approximately 5- 10 humans, who keep 15 cattle, 20-50 shoats and 5-10 camels.

- *Multistage sampling* will be purposively and conveniently employed for the “Bulla” and units (Khwisero), this will be guided by the availability of animals, accessibility and security of the sampling sites. *Cluster sampling* –All animals in a unit will be sampled

- The sample size of animals will be computed according to the method of Dohoo *et al*., (2003) using the following formula:

$$n = \frac{Z_\alpha^2 pq}{L^2}$$

Where n = required sample size, Z_α = is the normal deviate (1.96) at 5% level of significance, *p* is the estimated prevalence and *q* = 1-*p*, and L is the precision of the estimate. Therefore **384** animals will be sampled for both sites. **400** will be ideal after SE estimation.

Dohoo *et al*., 2003

6.0 Statistical Analysis

- The information collected through PRA will be written on flipcharts, compiled and transcribed, coded thematically, entered and analyzed quantitatively. Descriptive analysis of the household and community surveys will be analyzed appropriately.

- **Heckman Probit model :** Two- step process of adaptation to climate change using respective dependent variables, stage 1 (*selection model*) which perceptions to changes in climate change will be evaluated, stage 2 (*outcome model*) is whether the farmer adapted to climate change, conditional stage 1.

- **Multivariate Probit model** will be used to analyse factors that influence decision livestock keepers to adapt to each adaptation strategy.

- **Vulnerability indices** will be done by descriptive statistics of the socio-economic and environmental characteristics that describe the adaptive capacity, sensitivity and exposure to climate change.

Vulnerability = (adaptive capacity) - (sensitivity + exposure)

The analyses will be conducted using appropriate packages in ***STATA, R-Statistics*** Softwares.

6.1 Molecular Analysis

- Systematic sampling of animals for bleeding: every N/nth animal, where **N**(number in herd), **n** (required sample size from the herd).

- Blood samples will be collected by venipuncturing of the jugular vein using 18G vacutainer needles into 10 ml vacutainer tubes.

- All Serum samples will be separated and stored in cryogenic vials at -80°C. serum samples will be coded for ECF and RVF respectively.

- **Khwisero ECF:** Indirect ELISA will be used for antibody detection for *Theileria* pathogens from Khwisero samples (Katende et al., 1998).

- Reverse Transcriptase-Polymerase chain reaction (RT-PCR) will be used for identification of *Theileria* species.

- **Garissa RVF** :ELISA to confirm the presence of specific IgM/G antibodies to the virus and RT-PCR for virus detection.

Katende *et al*., 1998

6.1 Disease Economic modelling

- The epidemiological parameters included; disease incidence rate, affection rate (i.e. morbidity rate, mortality rate and case fatality rate),vaccination coverage, disease surveillance, treatment and impact of affection on productivity.

- Financial burden of diseases and cost-benefit analysis of targeted interventions for their control will be modelled to assess the costs of inaction and intervention.

- For SSA, a bovine ≈0.5, a small ruminant ≈ 0.1 livestock unit (LU). The actual intervention costs will include activities conducted by private and public entities.

- These data will be gathered from secondary sources, published studies and through PE targeting key informants across the AEZ.

- The direct costs of each of these diseases are monetary values of physical losses due to the disease(Declining productivity, distances, dead animals).

Bennett *et al*. 1999 , Mariner *et al*. 2005

6.2 Spatiotemporal Analysis

- **Spatial Cluster analysis** will be performed on the vulnerability indices to group the sites according to their degree of vulnerability using Ward Method of Agglomeration and the pattern mapped in GIS (**Arc View, ESRI, NY**).

- **Spatial regression:** The probability of disease outcomes and exploratory data will be modelled in GIS to determine spatial and temporal autocorrelations of observations and disease aggregations (**R-ArcInfo**).

- The overlays of livestock and human densities/distribution, vegetative cover index (NDVI/EVI), buffer grazing zones, water bodies will be analysed using Generalized Linear Mixed Model (GLMM).

- Existing databases will be vital in data extraction for analyses.

6.3 General Circulation Models/ Global Climate Models(GCM)

- Data set will be the diurnal temperature range, precipitation and average daily temperature on a monthly basis.

- Land surface simulation will be at a resolution of 0.5 degrees latitude and longitude, and cover the period 2012 to 2042

- **HadCM3 and ECHam4 models** will be used to simulate observed rainfall patterns

- Using 10-minute climate normals grid for current conditions, a weather generator *MarkSim* to simulate **30** years of daily weather data for every pixel in study areas.

- The mean and standard deviation of annual rainfall for the pixel will be calculated, and then the coefficient of variation of rainfall(CV) determined.

Engelbrecht *et al*., 2002;

6.4 ECF Modelling

- **ECF Models**
- The study area will be divided into 3000 grids cells of 60_60km resolution as determined by **DARLAM** climate data.

- Each of the 3000 grid cells will be populated with 6 climate variables and a presence or absence record of the tick *R. appendiculatus*.

- A detailed description of this method is available in Olwoch *et al. (2008).* Cattle density data will be added in ArcView GIS (ESRI, Redlands, California) through spatial interpolation.

Olwoch *et al*., 2008;

6.5 Satellite Imagery

- Remote-sensed data from existing databases will be retrieved and used to create Normalized Difference vegetation index (NDVI) maps.

- GIS Ground truthing data will be overlaid on RS data to monitor vector aggregations and RVFV dispersion, thus establishing a correlation between these two parameters.

- Using satellite rainfall estimates, a web-based interface updated every 10 days on The Malaria early warning system (MEWS) will enable to gain a contextual perspective of the current rainfall season by comparing it to previous seasons in both sites

Martin *et al*., 2008; Grover-Kopec *et al*., 2005

7.0 Work Plan

Duration	Year 1(2012)			Year 2(2013)			Year 3(2014)		
Activity / Month	**1-4**	**5-8**	**9-12**	**1-4**	**5-8**	**9-12**	**1-4**	**5-8**	**9-12**
Literature review/Seminar Presentation,	■	■							
Reconnaissance Survey, Collaborative links establishment		■							
Introductory Community Workshop		■							
Household and Community survey data collection on Climate change		■							
Geographical Mapping and Capacity Building		■	■						
Phase 1 Data Entry, cleaning & Storage			■						
Progress report presentation				■					
Data collection on livestock diseases by participatory methods					■				
Biological Samples Collection, Processing						■	■		
Laboratory Analysis (RT-PCR)						■	■		
Phase 2 Data Entry, cleaning and Storage/Preliminary analysis							■		
Midterm Community capacity building and Feedback Workshop							■	■	
Data Analysis							■	■	
Thesis writing, report compilation, submission								■	■

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