HEALTHY FUTURES

Health, environmental change and adaptive capacity; mapping, examining & anticipating future risks of water-related vector-borne diseases in eastern Africa

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Deliverable D4.1

Vulnerability assessment for the eastern African region to identify hotspots

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Short summary	The output of this task identifies vulnerable sub-regions within the five country study area that can serve as the locus of higher resolution analysis and for testing adaptation strategies.		
Keywords	Vulnerability, hotspots, malaria, schistosomiasis, rift valley fever		
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1. Introduction

This report focuses on the impacts of three different vector-borne diseases (VBDs) in the eastern African region: malaria, rift valley fever and schistosomiasis. Malaria has by far the greatest health impact of VBDs: in 2006 alone there were an estimated 0.9 million malaria-related deaths globally, with WHO Africa region accounting for 91% of these (WHO 2008b). RVF is the second vector borne disease that is targeted. Currently RVF occurs throughout sub-Saharan Africa, Egypt and the Arabian Peninsula (Anyamba et al. 2009). Several outbreaks of RVF have occurred in parts of eastern Africa but the disease is as yet unrecorded in Burundi and Rwanda (Chevalier et al. 2004; Gerdes 2004). RVF outbreaks have major economic consequences because they disrupt trade in and markets for meat products (Clements et al. 2006, 2007). The third disease analysed is schistosomiasis. Estimates indicate that each year there are more than 200,000 schistosomiasis-related deaths in Africa (Chitsulo et al. 2000; Steinmann et al. 2006).

The impacts of these vector borne diseases may be direct, in terms of outbreaks of disease among human populations, or indirect, in the form of outbreaks of diseases that affect domesticated animals or plants, and therefore jeopardize food security, agriculture-based economic activities and trade.

The heterogeneous environmental and socio-economic context in Eastern Africa causes differential impact in space, time and population groups. The impacts of these diseases are typically felt most acutely among the poorest members of society as they lack the capacity to treat the disease or cope with the consequences. Some communities or members of the community are more susceptible to get the disease or feel the impacts. Brooker and Bundy (2008) for example found that school-age children and women of childbearing age are the most vulnerable to schistosomiasis infection. In this paper we therefore present vulnerability maps, pointing to this spatial variation. Two approaches are explored within this paper. For the assessment of rift valley fever we combine data on current outbreaks with three basic indicators of exposure, susceptibility and coping capacity and identify current hotspots. In the case of malaria and schistosomiasis we identified different indicators from an expert-based and literature survey approach and mapped social and economic vulnerability for these two diseases following a novel regionalization approach.
The assessments can then provide content for decision-support tools and guidance on critical regions where interventions on the VBDs are most needed.

The report starts with a description of the vulnerability framework used. This framework is thereafter applied to the three different diseases. These results are shown in sections 3 to 5. We end the report with a small discussion and an indication of the next steps we plan to undertake.

2. Conceptual Framework

Vulnerability is one of the key terms in climate change and disaster risk related literature. A wide variety of definitions and frameworks to assess vulnerability of households and ecosystems is used, described and applied throughout the scientific literature (see e.g. Alwang et al. 2001, Heitzmann et al. 2002, Turner et al. 2003, Lim et al. 2004, Thornton et al. 2006, O'Brien et al. 2004, Cutter 1996, Adger 2006, Brooks 2003, IPCC 2001). These different approaches each come with their own specific weaknesses, strengths and fields of application. None of them can be seen as superior, nor is there one that is most widely accepted, especially when it comes to bridge different concepts across different schools of thinking (such as climate change, socio-ecological systems and disaster risk reduction). Their applicability depends on the context in which they are used and the scale at which they are applied. Generally, the definitions and frameworks combine hazard factors with social factors, i.e. they holistically merge external stressors with internal system capacity to resist and/or recover. It is precisely the interaction between these factors that defines the final outcome, impact or overall vulnerability of a system (e.g. Dilley et al. 2005, Lim et al. 2004, Thornton et al. 2006, Alwang et al. 2001). These components can be applied in various ways, depending on the stressors and the systems looked at, the level of uncertainty of the stressors, whether the focus is broad or specific and on the direction and emphasis of the approach used (Notenbaert et al. 2010).

In this study we used a framework that was originally developed within the FP7 research project MOVE (Birkmann et. al, submitted). The framework takes up and integrates different approaches used in disaster risk reduction and establishes a link to climate change adaptation. For the disease and health purpose the framework has been modified and adaptated. Major modifications relate to 'dimensionality' of susceptibility and lack of resilience but also within the wording of definitions for the health context. The framework is shown in Figure1 whereas definitions to the different terms are outlined below.

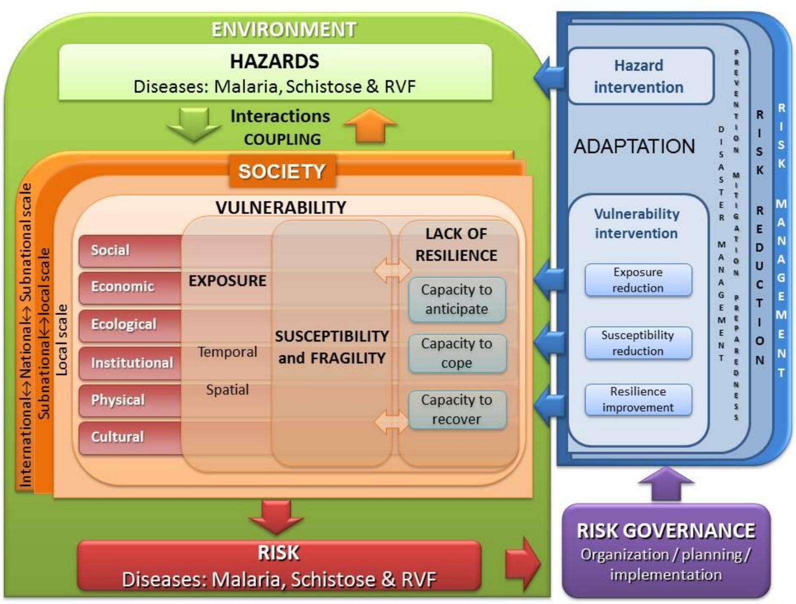


Fig.1: The adapted MOVE framework of risk, vulnerability and its link to adaptation.

Our aim is to conceptualise vulnerability to vector-borne diseases. The main focus thereby is a coupled socio-ecological system (SES) under stress and its ability to respond. As there is not always a linear or direct link between infection rates and societal impacts (e.g. food security), it is important to look beyond the bio-physical dimension. The notion of coupling between environment and society is invoked within the framework to underline the multi-dimensional nature of interactions. Socio-ecological systems are complex systems which co-evolve. The interaction of environment and society leads to the development of diseases and the subsequent risk of being negatively affected by it. In this framework, vulnerability has to be seen as a dynamic process that represents the conditions set by the environments and the choices of the vulnerable populations themselves.

A **hazard** is the potentiality of a disease occurrence that may have a ***negative impact on cultural, economic, environmental, institutional, physical or social assets*** in a given area and over a given period of time. Hazards include latent conditions that represent future threats. A hazard is characterised by its ***location, magnitude, and frequency or probability***.

In our case we are talking about the **spread of vector-borne diseases**. A vector-borne disease is a disease in which the pathogenic microorganism is transmitted from an infected individual to another individual by an arthropod or other agent, sometimes with other animals serving as intermediary hosts. The transmission depends upon the attributes and requirements of different living organisms: the pathologic agent, the vector, the intermediary host and the human host.

Climate affects vector population dynamics and disease transmission, with temperature and humidity considered key variables. Also socio-economic trends, such as population growth and urbanisation drivers, influence the spread of disease. This characterises the strong coupling between the 'hazard' and the vulnerability in this specific context

Example
Malaria: *Probability of an infective bite - EIR (Entomological Inoculation Rate); environmental conditions: Climate and weather, Geographic location (altitude, topography and hydrology); Vector dynamics and systems: Vector species, Anthropophily and endophily, Vectorial system (number of vectors involved in time and space), Vector density in relation to humans*
Schisto: *Number of cercaria larvae penetrating skin per person per unit time*
RVF: *Probability of RVF infection (in humans and animals)*

Vulnerability: Vulnerability rests largely within the condition and dynamics of the coupled socio-ecological system exposed to hazards. In its simplest form, vulnerability towards VBDs can be defined as a function of exposure, susceptibility and the (lack of) resilience. The lack of resilience comprises the ***capacity to anticipate, cope with, resist, respond to, and recover*** from disease events. Vulnerability describes the 'conditions' of a system comprising the key livelihood components.

Exposure: The social context represented by persons, communities and societies that may be affected by a VBD. Exposure varies in time (e.g. between day and night, between seasons, along years) and space. Note: Spatio-temporal aspects of contact with the vectors is only partially dependent on socio-economics.

Example
Malaria*: temporal: affected during the night, spatial: settlements/populations; Numbers of people infected; [Due to the fact that malaria mosquitoes bite mostly at night, this exhibits a clear temporal variation; the spatial variation is –amongst others- resulting from the fact that people are often concentrated in villages or settlements]*
Schisto: *spatial: Proximity to infected sites; temporal: timing and duration of water contact*
RVF: *In the case of RVF, people are also indirectly affected by the infection of their livestock, which*

constitute an important livelihoods asset. It is therefore important to not only look at the number of people infected but also take account of the number of animals. As RVF often occurs in pastoral areas, with (semi-)nomadic people moving around with their herds, a large spatial and temporal variation will be observed.

Susceptibility: ***Predisposition*** of societies to be affected by a VBD. The susceptibility to suffer harm or ***the intrinsic fragility*** of exposed elements, systems or communities that favour loss when affected by disease events. Together with the lack of resilience, it defines the degree to which a system is likely to be affected if exposed to a hazard. Note: Hazard defined above is per-person (ie probability of infection upon contact with infective stage of the parasite). Susceptibility in this context is therefore defined by the individual's ability to not withstand infection

Example
All: *Immunity status and age influence ones susceptibility*
Malaria: *Age, Immunity, Genetic resistance, Pregnancy, Co-infections (e.g. pneumonia), Nutritionalstatus*
RVF: *herding and slaughtering practices influence ones changes of being infected, while the importance of livestock production in a households' income or food security influences to a large extent how badly households will be affected in case of infections of their animals*

Resilience: Adaptive ability of a socio-ecological system ***to cope and absorb negative impacts*** as result of the capacity to anticipate, respond and recover from diseases. The lack of resilience is an important factor of vulnerability.

Comment: Is made up of its 'sub-compartments' anticipation, response and coping capacity. Those who are unable to cope (temporary adjustments in the face of change) or adapt (longer term shifts) are inevitably vulnerable.

Capacity: One can respond to, or manage, hazards in a variety of ways. It involves both ex ante and ex post actions. The available options for response to disease outbreaks are determinedby the combination of all strengths and resources available within a community, system or organisation. Just like ***susceptibility***, this capacity is determined by physical, institutional, environmental, social, cultural and economic means as well as skilled personal or collective attributes such as supportive policies, leadership and management.

Capacity to anticipate: Anticipation entails an ordered and coherent set of strategies, programs and projects carried out ***before*** the hazard takes place. The achievement of appropriate levels of security when faced with a range of hazards, and reduction of the material losses and social consequences associated with VBDs, leads to improvements in the quality of life and sustainability of the population.

Example
Early warning systems and decision support tools that trigger an institutional response. This involves the provision of timely and actionable information, and collaboration that isn't hindered by bureaucratic and legal barriers

Capacity to cope: The ability of people, organizations, systems and/or communities, using available skills and resources to face and ***manage*** adverse conditions, emergencies or disasters.

Example
***All**: Access to diagnosis and treatment and if necessary social networks willing to borrow money for treatment;*
***Schisto**: installation of latrines, installation of safe-water sources*
***RVF:** Herders can migrate with their animals away from RVF zones if they have access to alternative watering points and grazing areas or know family or community members that are willing to include their animals in the herds and migrate*

Capacity to recover: Capacity to ***restore*** adequate and sustainable living conditions in an area or community affected by a VBD. This may be achieved by means of rehabilitation, repair, reconstruction or replacement of destroyed, interrupted or deteriorated infrastructure, goods and services and through the reactivation and promotion of economic and social development in the affected community.

Example
***All:** e.g. access to savings*
***Schisto:** re-stocking of pharmacies with effective drugs; rehabilitation of latrines and safe water-sources*
***RVF:** re-stocking after an RVF outbreak*

Dimensions of vulnerability:

Physical dimension refers to conditions of physical assets - including built-up areas, infrastructure, and open spaces that can be affected by VBDs (probably of less importance to the VBD context). Note: This is tightly linked to the environmental dimension – lack of built infrastructure facilitates parasite transmission.

Environmental dimension: refers to all ecological and bio-physical systems and their different functions. For instance, it entails the natural resource stocks (soil, water, air, genetic resources etc.) and environmental services (hydrological cycle, pollution sinks etc) from which resource flows and services are derived.

Example
***Schisto**: susceptibility: lack of physical infrastructure (e.g. concrete landing stages, built-up river banks etc. favours vegetation growth harbouring snails)*
***RVF: Resilience:** Access to alternative watering points and grazing areas*

Social dimension: the social resources and human welfare upon which people draw, both at an individual and collective level.

Examples
***Malaria: Susceptibility**: Immunity to be considered as a condition; age; Education level*
***Schisto**: **Susceptibility:** socio-cultural issues important; immune-status (dependent on age, infection history), physiological status (e.g. thicker skin preventing penetration of cercariae), ignorance of disease symptoms and/or aetiology, lack of knowledge of available treatment*
***Schisto: Resilience:** school-based learning of transmission routes and disease management*
***RVF: Susceptibility**: household size and dependency ratio, herding/slaughtering practices*
***RVF: Resilience**: social networks willing to borrow money, community members that include animals in their herds and migrate*

Economic dimension: It refers to the productive capacity, the capital base, unemployment and low income conditions

Example
Malaria: Susceptibility: *Incomes and assets, Family size (dependency ratio)*
Malaria: Resilience: *Health seeking behavior (Knowledge, attitude and practice)*
Schisto: Susceptibility: *occupational necessity (e.g. fishermen, animal husbandry), domestic (e.g. bathing, washing clothes)*
Schisto: Resilience: *safe working conditions (e.g. protective clothing), access to diagnosis and treatment (e.g. annual treatment rounds)*
RVF: Susceptibility*: %income generated through livestock*
RVF: Resilience: *Income and savings, resources available, access to diagnosis and treatment*

Cultural dimension is derived from the meanings placed on customs, habitual practices and landscapes.

Example
Schisto*: socio-cultural issues important*

Institutional dimension refers to both - organizational form and function - as well as guiding legal and cultural rules.

Example
How strong/weak are institutional mechanisms in regard to disease prevention etc; Corruption, Laws in place, Collaboration etc, legal and bureaucratic barriers, lack of response planning; For successful coping and adaptation to take place there is need for timely and actionable information.
Malaria: *Budget allocation and policies, Preventative services (Bed nets, Indoor spraying), Distribution of effective drugs for malaria, Accessibility and stability of medical supplies, Epidemic forecasting and intervention strategies, Institutional capacities (personnel), Leadership*

Risk: The potential occurrence of harmful consequences or losses resulting from interactions between VBDs (based on their transmission biology) and vulnerable conditions.

Example: *the probability of Illness, death, economic loss and affected livelihoods*

Adaptation: Adaptation describes ***long-term actions*** undertaken to accommodate the socio-ecological system to known risks. Adaptation entails changing and adapting the ways in which things are currently done (though ideally, building on existing practices and strategies). Adaptation is concerned with learning rather than reactive (reflective rather than reflexive) change. In addition to acting directly on the social components of risk, adaptation can also influence natural aspects of hazard through influences on natural systems and process. While coping capacities and resilience are primarily linked to capacities that help to maintain the current status of the systems under stress, adaptation as a concept implies actions aimed at making more ***profound*** change in socio-ecological relations (see e.g. Pelling, 2010; Birkmann, 2010).
Adaptation (and coping) requires techniques and strategies to be devised that enable society to absorb and deflect the impact of hazards. It is successful if it reduces the risks or the vulnerability without compromising economic, social and environmental sustainability.

Adaptation involves individuals' behaviour as well as communities' behaviour and the interaction between them.

Prevention: Measures and actions taken in the frame of ***prospective*** risk management that attempt to avoid the realisation of a risk into disease outbreaks and emergencies.

> ***Example***
> ***All:*** *Vector-control (nets, spraying, …),vaccination or prophylactic medication, purchase of insurance, building social networks*
> ***Schisto****: snail-control, annual treatment rounds, health education campaigns, latrines, safe-water sources (e.g. borehole)*

Mitigation: The planning and execution of measures designed to ***reduce risk to acceptable levels***. Preparedness activities, including early warning systems, can mitigate risk by reducing the potential for damage or loss when a serious event occurs.

Preparedness: Measures taken to organize and facilitate operations of early warnings, treatment activities and rehabilitation of the population and the economy in case of a serious outbreak of a VBD.

> ***Example:*** *Prediction, Surveillance (cases, vectors, intermediate hosts, weather) and detection (incl. diagnosis), communication, response planning & DSS, capacity building*

3. Malaria

3.1. Data and methodology

As indicated above, to identify Malaria vulnerability hot spots a 'bottom-up' approach was applied. It was aimed to model vulnerability (integrating the domains of susceptibility and lack of resilience) for the social and economic dimension separately. This approach was chosen to be in line with the framework, where clear distinctions between the social and economic dimensions are made. Of further interest, especially when aiming towards the assessment of possible intervention programs is the institutional dimension. However, based on the lack of available data this dimension has been put on hold within the current assessment.

In regard to the methodology chosen, it was envisaged to have an integrated modeling approach which represents homogenous regions of vulnerability, independent from administrative units. This approach has been developed at the Centre for Geoinformatics at the University of Salzburg and has been applied to a series of vulnerability studies in Europe and Africa, in regard to climate change and migration related hot spots and furthermore in the context of landscape analysis.

The following steps have been used to develop the vulnerability hot spot units and are outlined in more detail below:

1. Identification of appropriate indicators (in collaboration with disease experts and based on literature surveys)
2. Identification of suitable datasets for the indicators
3. Agreement on final set of indicators (in collaboration with disease experts)

4. Data collection and processing
5. Regionalization of vulnerability units
6. Visualization

Within a first step an 'ideal' list of indicators has been developed which would best describe the different domains and dimensions of vulnerability and is presented in Table 1 (grey shaded entries). This information was on the one hand gathered from the literature, but additionally experts for the different diseases have been consulted. The exercises were carried out through e-mail communications as well as brainstorming exercises during Healthy Futures workshops.
Following this best-case list of indicators, the availability and suitability of data was assessed. Therefore, data was collected from various data sources and is listed in Table 1. Most of the data derives from global sources and inherits uncertainty when leaving the global scale level towards a more sub-national/sub-district approach. However, suitable data has been found on population distribution, land cover, infrastructure, poverty and child related diseases. Additionally, indicators such as the access to health facilities were modeled, integrating land cover and elevation as differently weighted barriers.

The list with the final indicators was then again discussed with disease experts and used for the regionalization approach. Following that, data was collected and pre-processed to be suitable for the identification of vulnerability hot spots. This step includes the option to weight different indicators according to their importance. At this stage, this has been done only internally, and will be integrated in a next step together with the disease experts from Healthy Futures.
The modeling of homogenous vulnerability regions is based on a concept developed by Lang et al (2008) and an associated methodology developed by Kienberger et al. (2009). In general, geons – in this case the vulnerability units – describe homogenous regions, integrating information from various sub-domains. It is an automated zoning approach for delineating units where similar spatial conditions apply with respect to an aggregated spatial indicator.

Processing steps include the transfer into suitable raster datasets. These datasets and their values are then normalized to a predefined range (e.g. 0 – 255) to allow the comparison of different datasets. Each dataset has to be evaluated in which 'direction it contributes to the vulnerability (such as high value of poverty is high value of vulnerability, low distance to health facilities is low vulnerability, etc…) and prepared accordingly. Having the final normalized set of indicators and possible weights derived from experts (such as through Delphi exercise, scoring, pairwise ranking etc.) the homogenous regions are calculated through multi scale segmentation approaches. In this case the software Definiens Developer was used which integrates such a segmentation method. After deriving the homogenous units (applying standard values for scale, compactness and shape index) for each unit mean values of the underlying indicators are assigned. Using these means, a final, normalized vulnerability index is calculated, which can then be visualized showing for instance a classification into ten vulnerability categories from 0 to 1 (low to high).

Besides the modelling of the vulnerability domain, certain key hazard/disease indicators for Malaria have been mapped. However, as these do not build an inner core of this deliverable, they are attached in the annex.

Dimensions	Domains	Sub-domains	Indicators	Potential proxies	Expected relationship
SOCIAL	**EXPOSURE**		Number of people infected	EIR	+
	SUSCEPTIBILITY		Age	< age of 5 (number per km2)	+
			Education level		
			Poverty Population pressure Conflict Malnutrition Infant mortality *Woman of child bearing age (15-49 years)* *HIV/AIDS* *Genetic resistance?*	Infant mortality Population change (1970-2010) Conflict density % children under five underweight Nr. of stunting children < 5 infant mortality rate *number per km2*	 + +
	LACK OF RESILIENCE	**Capacity to cope**	Health facilities *Social networks* *Education level*	Distance to health facilities *Access to diagnosis* *Access to treatment* *Existence of health facilities* *Type of health facilities* *Quality of health facilities*	+
			Poverty	population < 2 USD per day	+
		Capacity to anticipate	*Education level* *Protection measures* *Early Warning Systems (EWS)/awareness* *Education level*	 *Nets* *Distribution of anti-malarial medicines* *Existence of EWS* *Access to Newspapers* *Ownership of radios/TVs*	
		Capacity to recover	*Access to savings (social, economic)*		
ECONOMIC	**EXPOSURE**		Number of people infected	EIR	EIR

	SUSCEPTIBILITY		Poverty *Source of income*	population < 2 USD per day infant mortality rate (2000) *Fisheries* *Brick-making* *Rice-farming* *Mining* *Other*	+
	LACK OF RESILIENCE	**Capacity to cope**	Conflict	Conflict density	+
		Capacity to anticipate	*Protection measures* *Financial capital*	*Nets* *Distribution of anti-malarial medicines*	

Table1: Present use of indicators for the social and economic vulnerability to Malaria and potential indicators without current access to data (grey, italic)

3.2. Results

Results for the social and economic vulnerability are presented in Fig. 2 and Fig. 5, and its different indicators in Fig. 3 and Fig. 6.

In general, medium to high vulnerability values can be observed in Tanzania, especially in Burundi and Rwanda. Lowest values are observed in Kenya, except the regions close to the Lake Victoria. A similar picture can be observed in Uganda with values in the lower to medium range of vulnerability. Looking at the characteristic of the different hot spots and regions, it can be observed for the social dimension, that the infant mortality is strongly contributing, next to poverty indicators and the distance to hospitals. In certain regions the picture differentiates, whereas conflict strongly contributes to the increase values in Burundi and Rwanda, but also high poverty levels in the cities such as Nairobi or Kampala. The current hot spot maps include unweighted indicators, and the integration of expert knowledge to assign importance to the different indicators is required before finally interpreting the results.

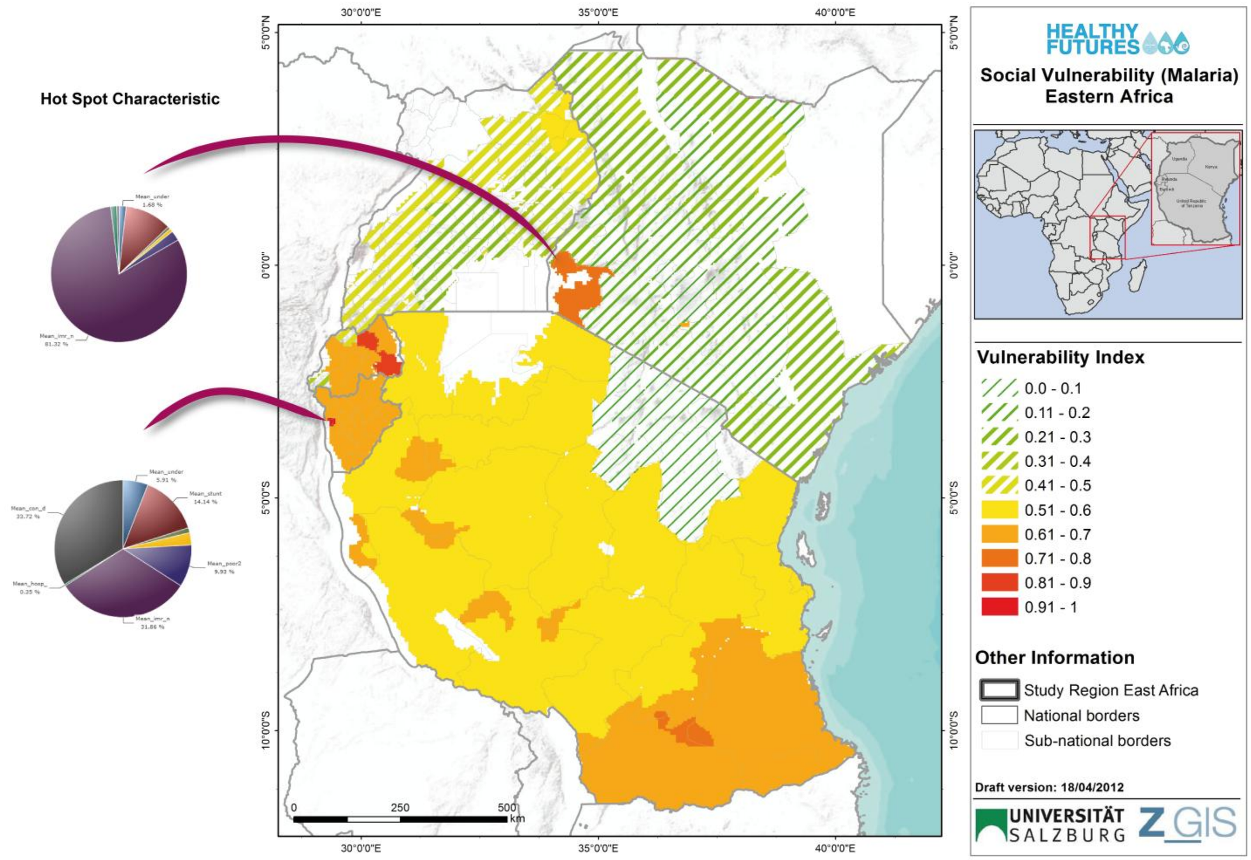


Fig.2: Social Vulnerability to Malaria (equal weighted indicators)

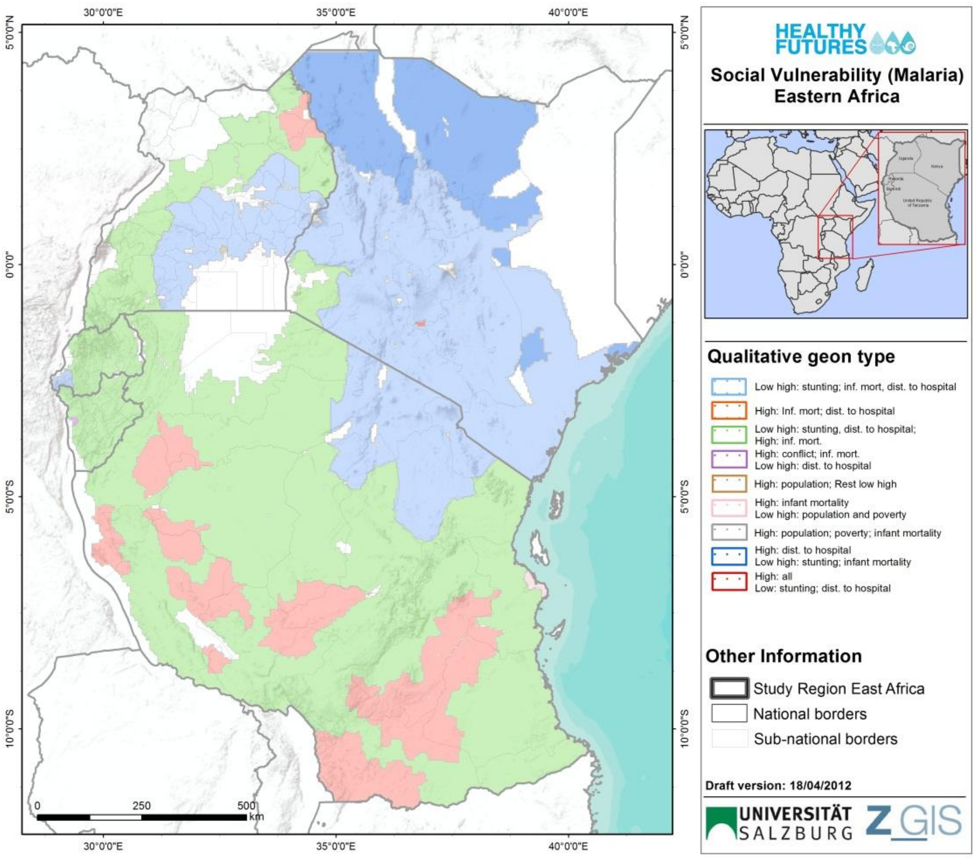
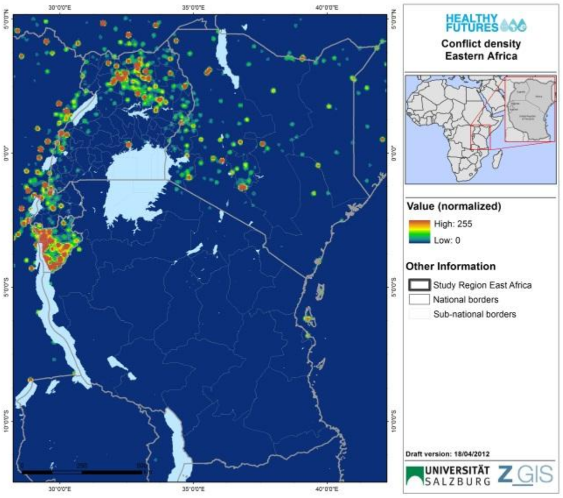
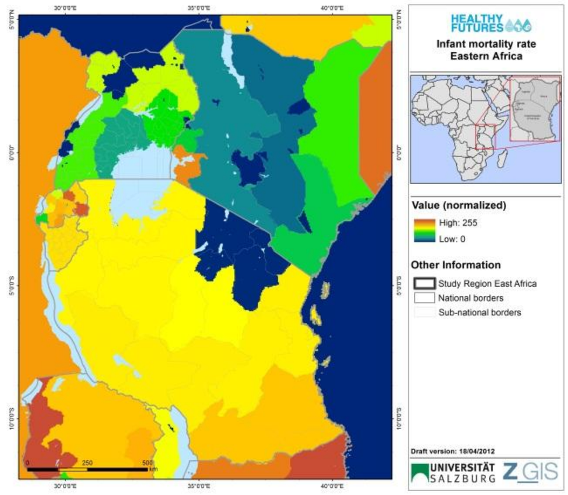


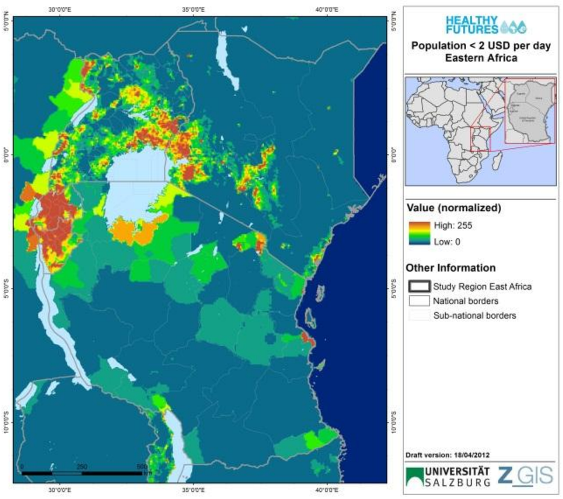
Fig.3: Characteristic of social vulnerability to Malaria. The clustered regions are similar in their qualitative type of vulnerability



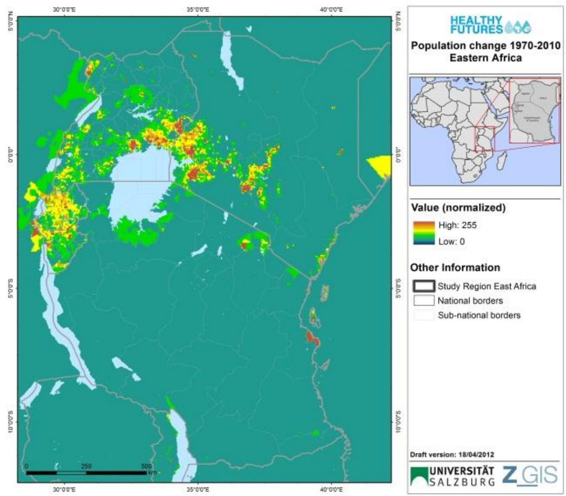
Conflict density



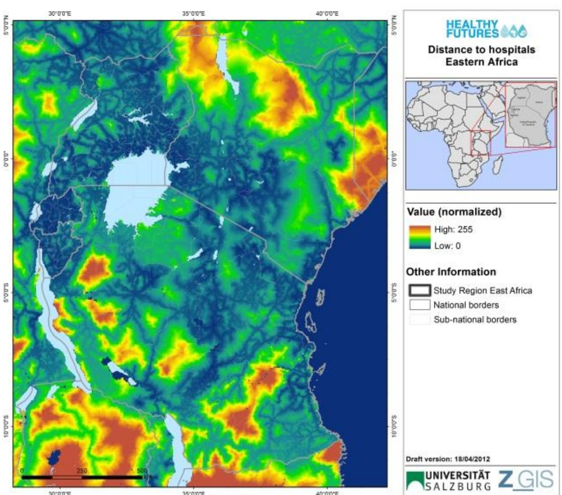
Infant mortality rate



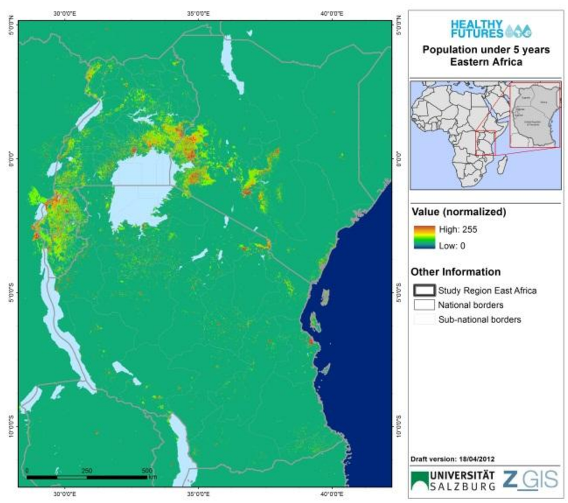
People below 2USD per day



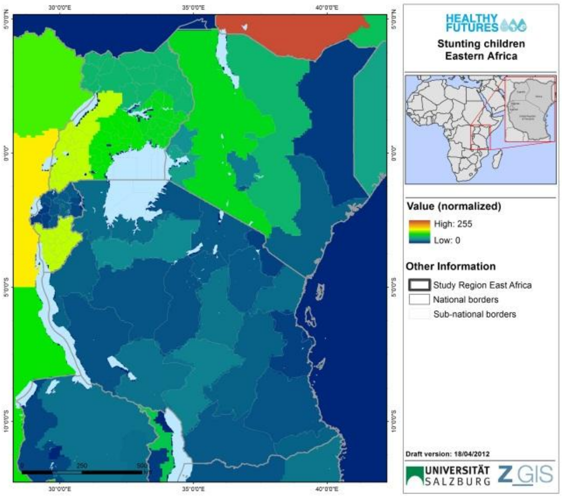
Population change (1970-2010)



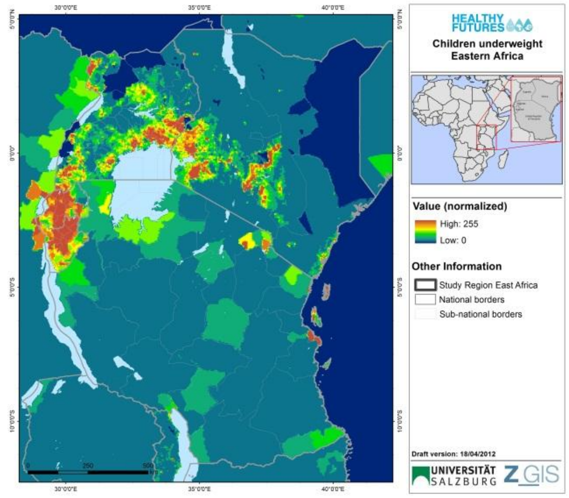
Distance to hospitals



Population under 5 years



Percentage of stunting children



Children under 5 who are underweight

Fig.4: Indicators contributing to the social domain (blue= low values, brown=high values)

Results for the economic vulnerability are characterized by the three indicators such as poverty, conflict density and infant mortality. In this case similar regions as in the social vulnerability show high and low levels, which is also due to the overlap of these indicators. However, more indicators will be integrated in the next steps.

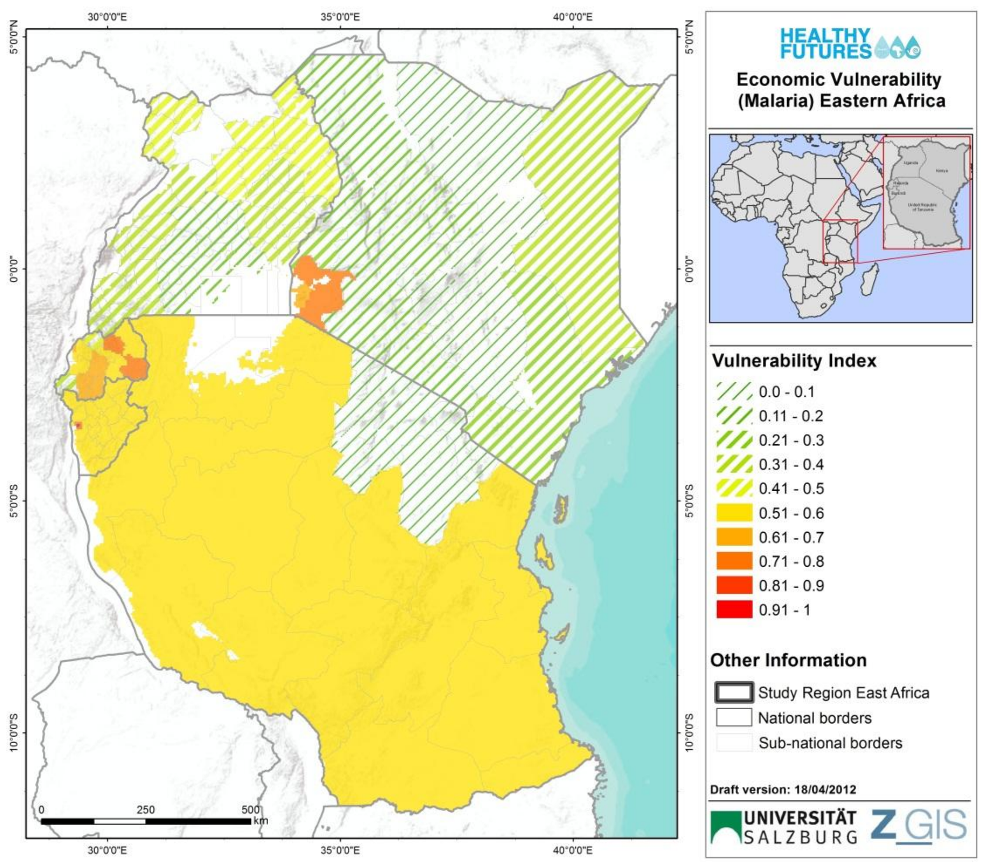
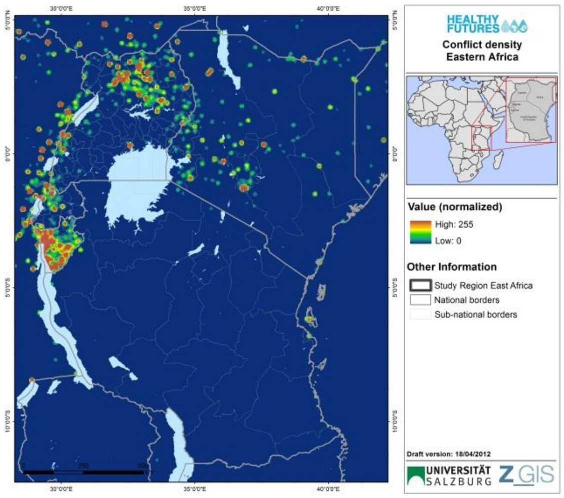
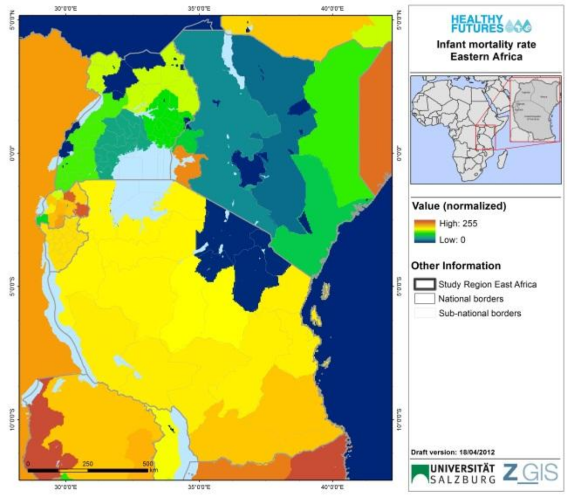


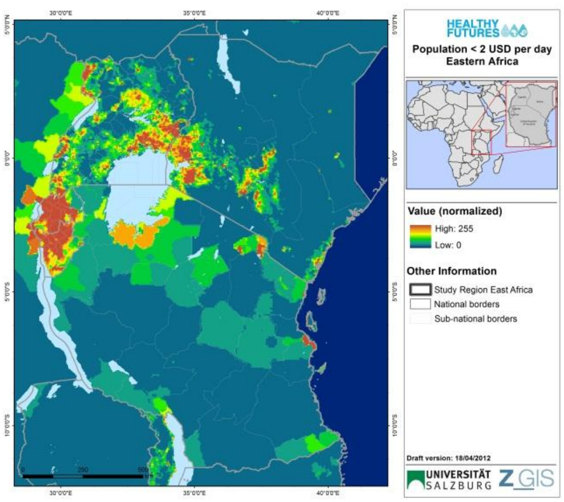
Fig.5: Economic Vulnerability to Malaria (equal weighted indicators)



Conflict density



Infant mortality rate



People below 2USD per day

Fig.6: Indicators contributing to the economic domain (blue= low values, brown=high values)

4. Rift Valley Fever

4.1. Data and methodology

Ideally, a vulnerability assessment should be based ondeterminants ofthe three vulnerability components: exposure, susceptibility and lack of resilience along 6 different dimensions: social, physical, economic, institutional, cultural and ecological. Combining these with an estimation of the probability of RVF infection (the hazard) would then allow us to make an overall RVF risk assessment.

In line with the processes followed for Malaria, a first step consisted therefore of compiling an 'ideal' list of indicators. These indicators were compiled on the basis of literature review and expert consultation (table 2). The last column in table 2 indicates the expected relationship between the indicator and the risk for negative impact from RVF. A positive relationship indicates that higher values of the indicator are expected to be associated with higher risk. For most of these indicators spatial proxies can be found. Maps for the ones indicated in blue are shown in an annex.

A variety of methods exist to compile a risk or vulnerability index on the basis of vulnerability indicators. The most straightforward method is to simply add up the separate indicators. A weighted sum is however more commonly used, with the weight relevant to some level of importance of the different indicators, i.e. the higher the weights assigned to a criterion the higher will its influence to the final results be and vice versa.

$$\text{Index} = \sum \text{weight}_i * \text{indicator}_i$$

Establishing these factor weights is the most complicated -and in a sense also most subjective-aspect of creating an index. Often expert opinion is solicited through participatory processes. Another methods consists of using principal component analysis (PCA) to scale down the original list of criteria to an operational, non-redundant set and weights assigned according to the variance explained before combining the different variables into one map (e.g. Thornton et al., 2006). Another set of approaches starts from known locations of presence and/or absence of risk and uses these to investigate the factors influencing the occurrence. Commonly applied techniques include logistic regressions, Bayesian and neural networks. They allow for an objective establishment of determinants of vulnerability or risk.

In order to make some progress in establishing evidence-based factor weights, we collected historical data on RVF outbreaks in Kenya and explored the association of the listed indicators with these outbreaks through regression analysis. We focused hereby on variables that were thought to influence the occurrence of an RVF outbreak, i.e. the indicators listed under susceptibility. We included only 8 variables in this preliminary analysis due to limited data availability (indicated in red in table 2). We're planning to refine this analysis by including more of the variables as more data is collected and input from a wide scope of stakeholders solicited.

In future, similar analysis should be done on the associations and linkages between negative impact of RVF and indicators of resilience.

Dimensions	Domains	Sub-domains	Indicators	Potential proxies	Expected relationship
SOCIAL	**EXPOSURE**		Number of people infected		+
	SUSCEPTIBILITY		Malnutrition	% children under five stunted	+
				% children under five underweight	+
			Infant mortality	infant mortality rate	+
	LACK OF RESILIENCE	**Capacity to cope**	Gender	% female headed households	+
			Size of households	household size	?
			Social capital	Conflict density	+
				Number of CBOs	-
		Capacity to anticipate	Education level		-
		Capacity to recover			
ECONOMIC	**EXPOSURE**		Number of animals infected		+
	SUSCEPTIBILITY		HH income sources	% population dependent on livestock keeping	+
			Livelihood strategy	Major livelihood strategy	dependent on livelihood zone
			Reliance on markets	% income from livestock keeping	+
			Importance livestock	Percent livestock in GDP	+
			International trade	volume of export	+
			Livestock production system	% area under different systems	dependent on the system
			Meat consumption	kg/capita	+
			Milk consumption	kg/capita	+
	LACK OF RESILIENCE	**Capacity to cope**	Poverty	% population living on less than 1.25US$/day	+
				% population living on less than 2US$/day	+
				Reliance of food ratios	+
		Capacity to anticipate			
		Capacity to recover	HH income sources	Off-farm income	-
				Access to savings	-
				Access to credit facilities	-
ECOLOGICAL	**SUSCEPTIBILITY**		Livestock	Livestock density	+
			Wildlife	Wildlife density	+

			LU/LC	% area under different LC classes % grazing % cropping	dependent on the LC class + -
			Greenness	NDVI	+
			Flooding	Dambo and wetlands density % area under different soil types % area with different soil textures	+ dependent on soil type dependent on texture
			Climate	Temperature Precipitation	+ +
			Elevation	meters above sea level	-
			Vaccination	number of animals vaccinated	-
			Other outbreaks	time since previous outbreak distance to other outbreaks	- -
	LACK OF RESILIENCE	**Capacity to cope**	herd mixes other disease pressures	livestock diversity index HIV / ECF / … prevalence	- +
		Capacity to anticipate			
		Capacity to recover			
INSTITUTIONAL	**SUSCEPTIBILITY**				
	LACK OF RESILIENCE	**Capacity to cope**	Contingency planning	Existence of contingency plans Funding for contingency planning	- -
		Capacity to anticipate	Access to information	Mobile network coverage Surveillance system Investment in research	-
			Early warning systems (EWS)	Existence of EWS	-
		Capacity to recover			
PHYSICAL	**SUSCEPTIBILITY**				
	LACK OF RESILIENCE	**Capacity to cope**	Access to health facilities	distance to health facilities	+
			Access to veterinary services	distance to vet facilities number of CAHWs	+ -
			Market access	travel time to cities/towns	+

		Capacity to anticipate			
		Capacity to recover			
CULTURAL	**SUSCEPTIBILITY**				
	LACK OF RESILIENCE	**Capacity to cope**	Mobility Herding practices	Ethnicities	- dependent on herding practices
		Capacity to anticipate			
		Capacity to recover			

Table 2: Indicators for vulnerability to and risk of Rift Valley Fever.

As there exists a lot of uncertainty about the linkages and interactions between determinants of RVF outbreaks, the outbreak themselves and their associated impacts on livelihoods, we decided to base the first hotspot analysis on a few simple assumptions:

(i) historical outbreaks give a good indication of where future outbreaks might occur (an area that has had an outbreak has a higher chance of experiencing a repeat outbreak because mosquitoes lay infected eggs which are buried in the soils);

(ii) the biggest negative impact of RVF on people is through the loss of their livestock; people more dependent on livestock for their livelihood are likely to be more affected than others;

(iii) poor livestock keepers have less capacity to cope with and recover from their livestock losses than their better-of counterparts.

Therefore three basic vulnerability indicators were selected: (i) population density as a proxy for exposure, (ii) % of population engaged in livestock husbandry as a proxy for sensitivity, and (iii) % of population living on less than 2US$/day as the lack of resilience. Based on these indicators the density of poor livestock keeper was calculated. Historical data on RVF outbreaks was overlaid with the poor livestock keepers' density to identify current RVF hotspots, i.e. those areas where most poor livestock keepers are likely to be hit by RVF outbreaks.

4.2. Results

4.2.1 RVF outbreaks

Figure 7 below shows the divisions that have had RVF outbreaks in Kenya between Jan 1912 and December 2010. About one out of five divisions in Kenya has experienced at least one RVF outbreak in the last 100 years. The majority of the outbreaks have happened in the pastoral and medium potential zones.

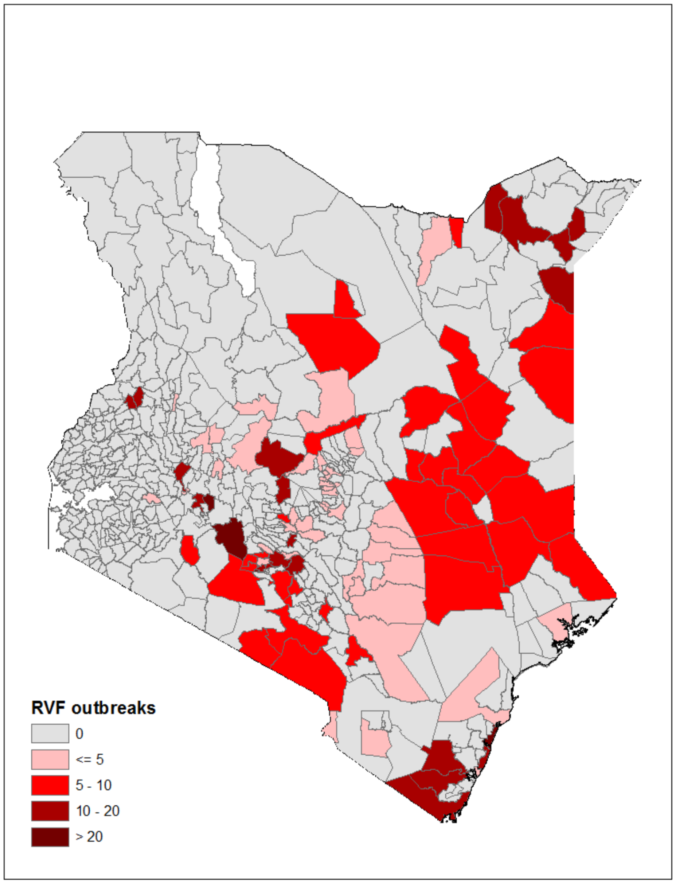


Figure 7: RVF outbreaks in Kenya

Preliminary results of the regression analysis between these outbreaks and the variables from table 2 indicate that land cover, elevation, soil type, livelihood strategy and rainfall are indeed influencing RVF incidence. Predictions from the model indicating the probability of a division experiencing an outbreak are being refined. This can also serve a scheme for ranking divisions based on probability of exposure. The model would also be used to predict future risks based on the climate and other drivers.

4.2.2 Preliminary RVF hotspots

The spatial pattern of poor livestock keepers' density (fig. 8) follows to a large extent the pattern of population density. Relatively high densities can also be found in some the arid and semi-arid regions. This is due to high poverty rates and high percentages of the total population that keeps livestock.

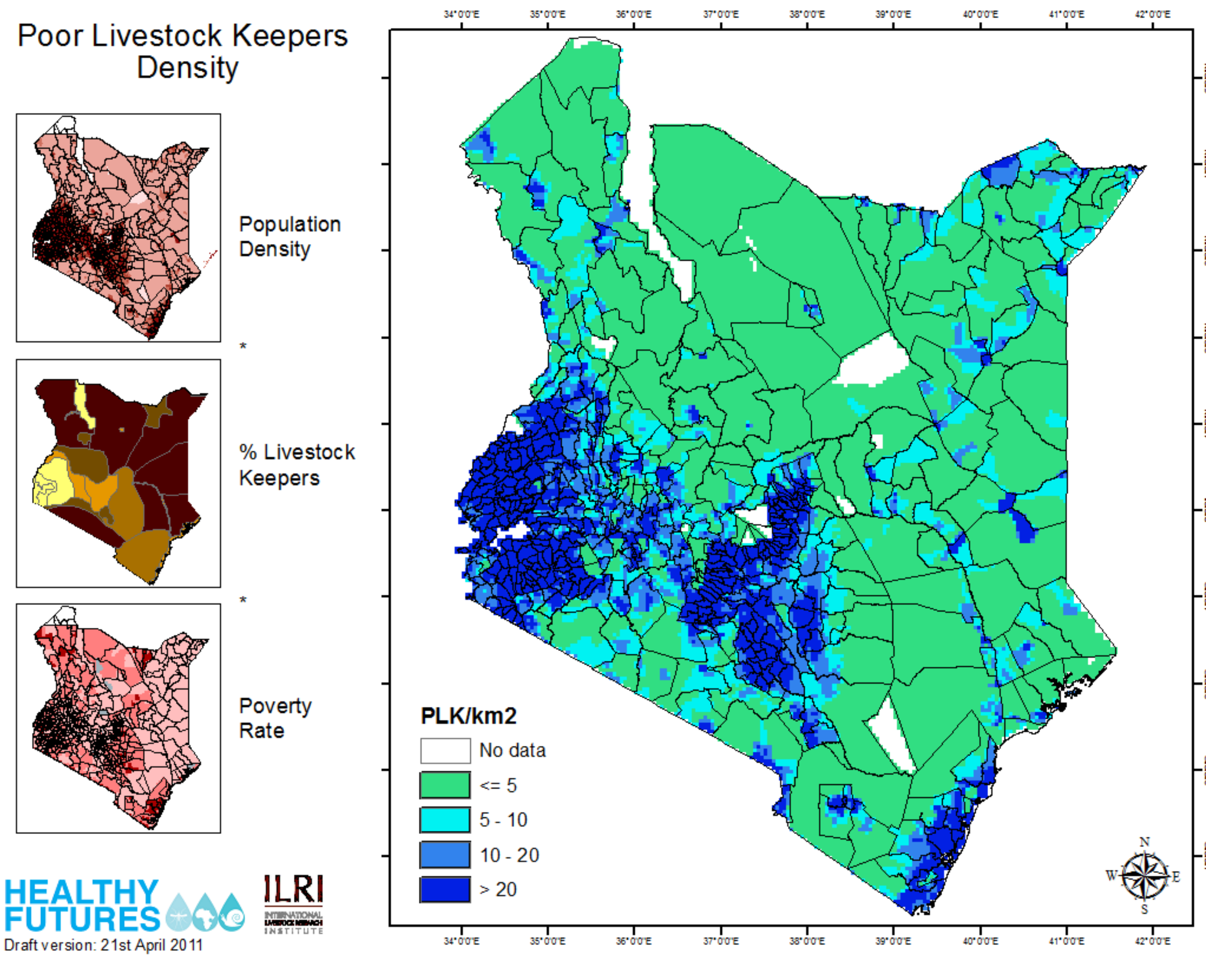


Figure 8: Poor Livestock Keepers' (PLK) Density

A simple multiplication of the poor livestock keepers density with the number of outbreaks that has occurred, gives us a relative value of where most poor livestock keepers are likely to be hit by an RVF outbreak. This value was classified in quantiles with the upper quantiles visualising current RVF hotspots (fig. 9).

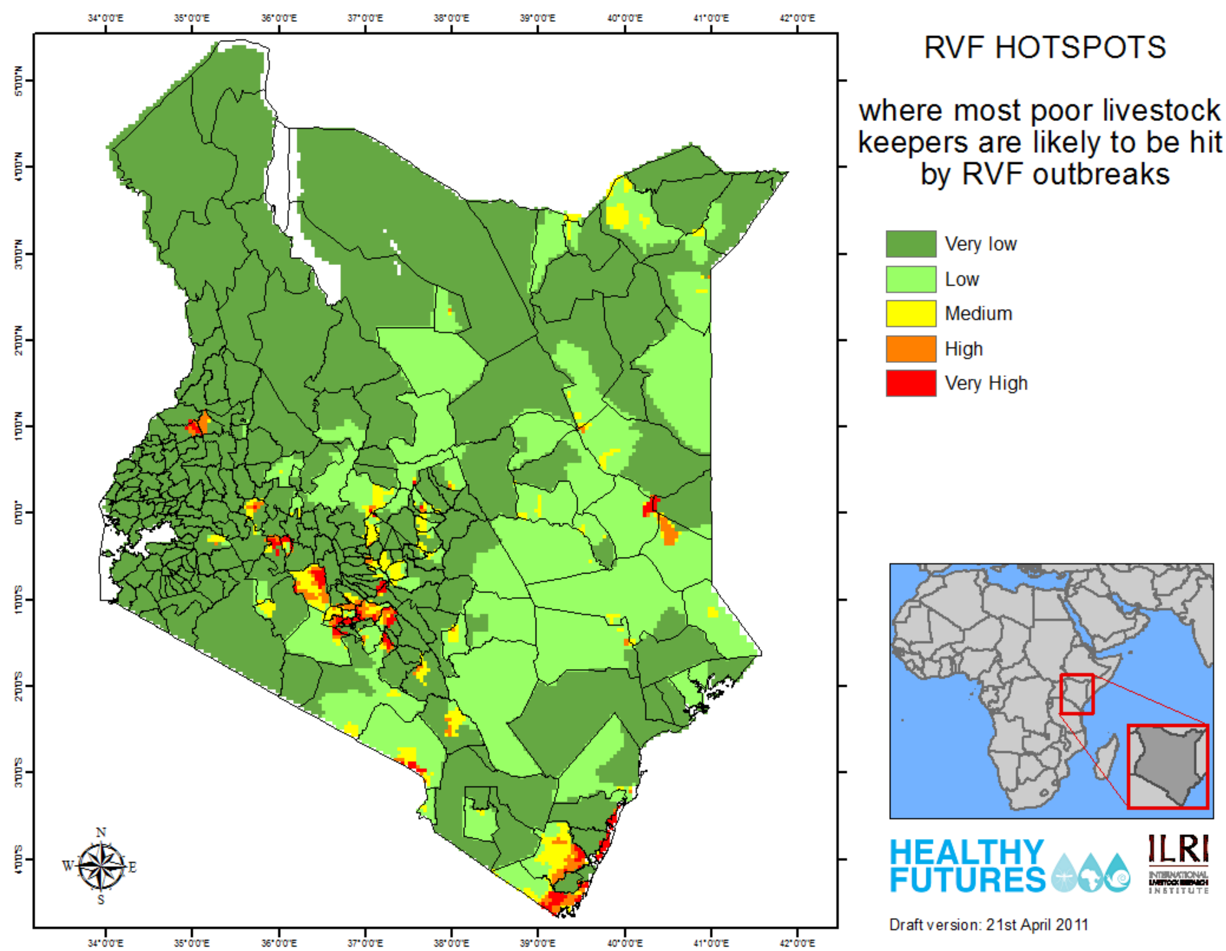


Fig. 9: RVF hotspots

5. Schistosomiasis

5.1. Data and methodology

From a general perspective, the methodology for the assessment of Schistosomiasis for Eastern Africa will be the same as outlined in section 3.1. Certain issues however delayed so far the implementation of the Schistosomiasis part

- in general it seems challenging to model the vulnerability to Schistosomiasis on a regional scale, as the conditions rely strongly on cultural factors (such as washing habits etc.).
- priority was given to the parallel modeling of Malaria, as well as a time delay occurred in corresponding with the different disease experts

The 'best-case indicators' identified so far are shown in Table3

Dimensions	Domains	Sub-domains	Indicators	Potential proxies	Expected relationship
SOCIAL	**EXPOSURE**		*Number of people infected*		
	SUSCEPTIBILITY		*Immunity status* *Sex/gender* *Ethnicity* *Latrines* *Education level*	*# of latrines* *distribution of latrines*	
	LACK OF RESILIENCE	**Capacity to cope**	*Education level* *Latrines*	*# of latrines* *distribution of latrines*	
		Capacity to anticipate	*Poverty* *Health insurance*		
		Capacity to recover	*Poverty*		
ECONOMIC	**EXPOSURE**		*Number of people infected*		
	SUSCEPTIBILITY		*Occupation* *Domestic*	*Fishermen* *Other* *Bathing, washing cloths*	
	LACK OF RESILIENCE	**Capacity to cope**	*Access to health services*		
		Capacity to anticipate	*Poverty* *Safe working conditions*		
		Capacity to recover	*Poverty* *Health insurance*		
INSTITUTIONAL	**EXPOSURE**		*Number of people infected*		
	SUSCEPTIBILITY		*Disease prevention* *Response planning* *Domestic*	*Bathing, washing cloths*	

	LACK OF RESILIENCE	**Capacity to cope**	*Health service availability* *Treatment programme* *Health insurance*	*Coverage, Efficiency*	
		Capacity to anticipate	*Policies, laws, regulations* *Access to safe water supply*		
		Capacity to recover	*Early warning/awareness* *Disease prevention programmes* *Re-stocking of pharmacies* *Rehabilitation of latrines*		
CULTURAL	**EXPOSURE**		*Number of people infected*		
	SUSCEPTIBILITY		*Habits/customs*	*Washing (in fresh water)* *Bathing (in fresh water)*	
	LACK OF RESILIENCE	**Capacity to cope**	*Health treatment seeking behaviour*		
		Capacity to anticipate	*Use of safe water sources*		
		Capacity to recover			

Table 3: 'Best-case indicators' (grey, italic) for the social and economic vulnerability to Schistosomiasis

5.2. Results

No results yet available, see next steps.

6. Discussion

Although the resolution of the maps in this report might be coarse due to the limitations in the input data, there is valuable information coming from the different indicators as well as hotspot maps. The result of the current hotspot mapping effort identifies those where we are likely to find most people negatively affected negatively by the respective VBD. These are therefore the areas where we expect the people to have a great need for coping mechanisms and risk management strategies.

The multi-dimensional approach is a response to the fact that there is not one solution for all problems. This study does not (only) identify regions under high exposure, but also looks at susceptibility and lack of resilience. Clearly, certain interventions have more impact in certain targeted places; particular characteristics ask for particular, context-specific interventions. The identification of major hotspots in combination with information about the underlying drivers could therefore lead to better targeted interventions and thereby providing potentials to embark on interventions/programs/strategies that focus on the causes of vulnerability, not on the symptoms.

As in any modeling work the accuracy of final outputs relies very much on the quality of input data to the analysis. Although there are several initiatives to generate GIS databases, there is still a lot of gaps in GIS data for agriculture and rural development in the Eastern African region. Even where the data exists, you find that some countries have more data while others have very limited or none, it is difficult to get detailed data for the whole region complicating regional level analyses. Availability of high resolution spatial data for the indicators of vulnerability mapping in the region was a major limitation in this study. To our knowledge, we worked with the best datasets available. Nonetheless, we still believe that the accuracy of the maps presented here would have been further enhanced if better data (both in terms of more indicators and higher resolution) was available. Continued effort from the growing number of data providers in the international arena and improved linkages and data sharing between them, however, will enable this type of analysis to be improved further in future.

This mapping work is only a first step towards solving the very important question on “what are the underlying factors determining a person/household/community’s vulnerability?” To get answers to the problem on how best to support people to be prepared for risk/hazard, recover after hazards, and move out of poverty or prevent them from falling into poverty, more detailed case-studies and analytical work will be necessary.

7. Next steps

7.1 Further integration of data

The results of the hot spots mapping have been presented at the Healthy Futures partner meeting in Arusha in May 2012 (The initial version of this deliverable report has been submitted before the meeting and has been revised after the meeting including internal feedback). Feedback provided by the partners is currently being integrated in the final hot spot vulnerability maps, specifically this includes:

- reflection on the appropriateness of indicators

- collection of expert weights and derivation of vulnerability maps based on these weightings
- additional integration of data based on the revised indicator list
- integration of exposure data (specifically for Malaria and Schisto)
- discussion on the use and applicability of key indicators for the hazard domain for Malaria and Schisto
- Integration into future scenario approaches

In parallel with collecting more existing evidence and soliciting further input from experts, we plan to conduct fieldwork in specific disease-prone areas. Household surveys and focus group discussions will be carried out. We will gather more information about the occurrence of the diseases and impact pathways in the areas and establish what would be the most appropriate interventions to suit a particular area and context. Such studies can serve as validation for the accuracy of the mapping work and when carefully designed, more evidence about the actual determinants of vulnerability can be gathered.

Similarly, use of information from other initiatives on vulnerability and poverty mapping in the region to complement information provided by maps from this study will also be useful. These will add more information to this work because they report on the outcomes of vulnerability such as food insecurity, poverty and others. Association between these indicators and mapped hotspots will provide evidence of the need for targeting these areas for interventions on vulnerability.
Additionally an analysis of such multi-scale effects will be carried out and insights will be provided on the applicability of certain (key) indicators for specific sale levels.

7.2 Zooming in

The regional analysis undertaken in this study is limited by issues of scale as well as by the availability and quality of data. Whereas this report has the strength of providing a regional perspective, the lower level of the resolution for the data limits a provision of detailed picture for better sub-district level interventions. In order to derive actionable, context-specific policy interventions aimed at reaching the vulnerable communities within Eastern Africa there is still a need to zoom in from the partly aggregated level of presented maps to access the necessary detail at sub-national levels. This will provide information needed to identify investment options with the greatest potential impact for vulnerable communities.

7.3 Future hotspots

Spatially-referenced datasets about historical disease drivers and occurrence, along with knowledge and models of malaria, schistosomiasis and Rift Valley fever dynamics will be used to produce spatial assessments of the risks of, and vulnerability to, past, present and future disease morbidity and related impacts. These projections will consider a range of possiblefuture climate changes, associated hydrological responses, evolving socio-economic conditions and shifting landuse patterns.

7.4 Putting the results into use

Hotspots maps will have more chances to be of use to policy and decision makers dealing with vulnerability issues if packaged with other additional information on recommended interventions. We will therefore endeavor to provide specific research/policy recommendations together with the maps.

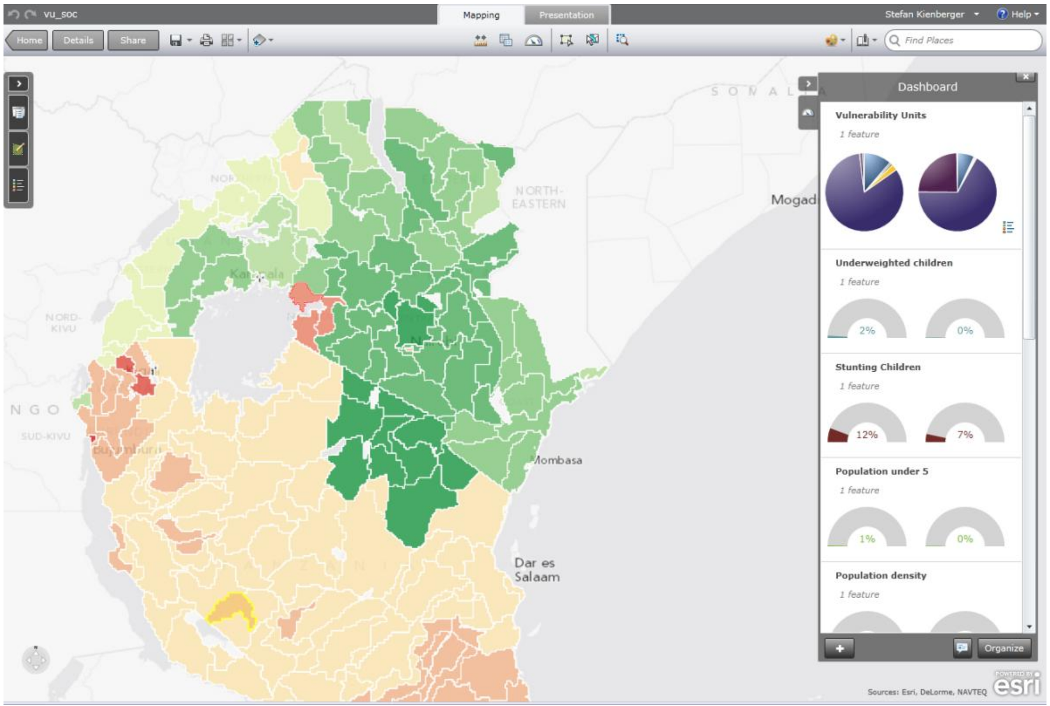


Fig. 10: Prototype of interactive visualisation of vulnerability hot spots, with indicator exploration tool

The vulnerability assessments will inform WP5, by providing content for decision-support tools and guidanceon critical regions where such systems are most needed. In keeping with the overall research design, WP4 will focus on two scales, the regional scale covering the proposed five country region, designed to identify vulnerableregions, and a more local scale focused on critical regions, where actual adaptation strategies will be tested.

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