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Mapping risk and vulnerability hotspots in the COMESA region: Technical Report

An Notenbaert, Stella Massawe and Mario Herrero

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Sources of pictures for the previous pages

Picture description	Source
Cover PAGE: Man on a camel-	ILRI graphics unit
Next page picture 1: UNEP-WFP food distribution in Narok, Kenya	WFP in http://www.unep.org/PDF/2000_drought_chapter3.pdf
Next page picture 2: ILRI director for partnerships and communication donating a dairy goat on behalf of ILRI to a woman heading a household in Kitengela area in Kenya (this area is prone to frequent droughts making the community very vulnerable)	ILRI: People Livestock and Environment theme

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Key words

Vulnerability Hotspots, mapping, vulnerability mapping, targeted development interventions, vulnerability and poverty, CAADP vulnerability targeting, vulnerability in COMESA, GIS

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1. Introduction

1. 1 Background to the study

The socio-economic condition in most COMESA countries is characterised by persistent high poverty levels and low food security. This is further compounded by the susceptibility of agriculture to climatic variability and other hazards as well as the vulnerability of impoverished and malnourished households to HIV/AIDS, market shocks and prolonged violent conflict. One of the biggest challenges governments in Africa face, with notably few exceptions, is the lack of sufficient financial and human resources to undertake the required action when disaster arises. This starts from the inability to address the underlying causes of disasters, including recurrent poverty that stifles household resilience (NEPAD, 2007).

In recognizing this challenge, the African-led Comprehensive Africa Agricultural Development Programme (CAADP) growth agenda emphasizes the need to ensure that the marginalized are ultimate beneficiaries and are not further marginalized by rapid development. It is therefore crucial that any growth agenda includes a special focus on vulnerable groups who may not be the direct beneficiaries of agricultural growth but who require urgent and immediate assistance to mitigate against chronic hunger and malnutrition. This requires availability of information on where the most vulnerable are located to facilitate the targeting of interventions..

The Strategic Analysis and knowledge Support System (SAKSS) is an initiative with the objective of providing data, information and knowledge to stakeholders in order to improve the formulation, implementation, and monitoring and evaluation of agricultural and rural development strategies in Africa. Regional SAKSS nodes have been established to provide such support to the Regional Economic Co-operations. The Regional SAKSS node for Eastern and Central Africa (ReSAKSS-ECA) is dedicated to support The Common Market for Eastern and Southern Africa (COMESA) in its endeavour to implement the challenging CAADP agenda. Vulnerability hotspots mapping in the COMESA region is one of the activities in the ReSAKSS-ECA analytical agenda.

The ReSAKSS-ECA vulnerability research aims at providing a richer understanding of the sources and consequences of vulnerability, how they differ across space and endowments, and the channels by which they stunt individual welfare and community economic development. The ReSAKSS-ECA vulnerability hotspot mapping and the topic of this report is one of the components in the ReSAKSS-ECA's vulnerability agenda.

The hotspot mapping approach presented in this report builds on the work of Thornton et al., "Mapping climate vulnerability and poverty in Africa" (Thornton et al., 2006), but focuses more rigorously on the risk component of the vulnerability framework. Its main result is the mapping and characterisation of risk hotspots in the COMESA region. This result is based on the analysis of information collected from a myriad of sources thereby addressing two of the main functions of ReSAKSS-ECA, knowledge management and strategic analysis in support of the CAADP agenda.

Risk cannot be avoided while at the same time risks continuously evolve and change. Assuming and managing risk is therefore at the core of any decision-making process. The proper management of risks is one of the biggest challenges that development agents and policy makers face today (O'Brien et al., 2004). The generation of socio-economic profiles of geographical areas and communities, including their risk profile, is very valuable when response measures are considered (NEPAD, 2007). Given the recurrence of certain types of disasters (e.g. floods and droughts) it makes even more sense to generate risk maps of the most prevalent shocks and stresses and their potential impact on communities. Maps and risk assessment reports that show the geographical areas and vulnerable population groups most likely to be affected can serve essential baseline information.

The purpose of this study is therefore twofold. First, it is to provide policy makers with a collation of baseline information on risks and vulnerability (type of shocks and stresses, and geographical areas most affected by them) in the COMESA region, this will form the basis for the monitoring of progress by various interventions. Second, it is to generate information (through maps and the characterised hotspots) that could be used to geographically target future research for increased understanding of the co-evolution of risk profiles, coping strategies and socio-economic development. Hotspots of risk exposure to different types of risks, as well as compounded risks are mapped. The presented maps, tables and graphs can inform policy discussions and eventually how best to target resource allocation. Targeting allows policy-makers to allocate scarce resources effectively and efficiently by directing them to the areas that need them most (GoC and WFP, 2003). This will provide contribution to the CAADP pillar three on increasing food supply, reducing hunger, and improving responses to food emergency crises

1.2 Report Structure

This report is organized as follows. The first section of the report is an introductory one. The conceptual framework of the study is presented in section two of the report. Section three highlights the data that was used, their sources and the methodology followed to identify and characterise risk hotspots in terms of food security and other vulnerability indicators. Section four presents the results of the study. Maps of different risk categories as well as the combined hotspot maps are shown. The section ends with the results of the spatial characterisation. Section five constitutes some discussions, highlighting the policy implications and the suggested way forward.

1.3 Review of similar initiatives on vulnerability mapping and justification for this study

1.3.1 Other initiatives on vulnerability mapping in the region

a) Work by the vulnerability analysis and mapping unit (VAM) of the World Food Program (WFP). This unit monitors the food security situation of populations and assesses their vulnerability to events that could plunge them into the vicious cycle of hunger. It provides information for programming/re-programming of different WFP-supported activities and provides data/information for decision making. The Focus of VAM work is on the aspect of food security (Box 1).

Box 1: What does the Vulnerability Analysis and Mapping Unit (VAM) do?
VAM undertakes in-depth assessments to understand the nature of food insecurity and the risks to livelihoods and monitors emerging food security problems.

VAM's analyses support WFP decision-making in designing and managing emergency and development programmes. The information is crucial for targeting the poorest and most food-insecure people.

VAM uses a wide array of technological sources and analytical methods: satellite imagery and spatial analysis, monitoring of food prices in local markets, exhaustive household surveys and discussions with members of poor and food-insecure households.

VAM works in close collaboration with many partners worldwide. All activities are implemented jointly with governments, UN agencies such as FAO, UNICEF and WHO, local and international NGOs, universities and the private sector. These partnerships ensure a shared understanding of food security and common priorities for action.

b) Food Insecurity and Vulnerability Information and Mapping Systems (FIVIMS)
This is an initiative that promotes cross-sectoral analysis of underlying causes of food insecurity, hunger and malnutrition for improved policy making, programming and action. FIVIMS operates at national, regional and global levels. It helps countries to characterize the food insecure and vulnerable population groups, improving understanding through cross-sectoral analysis of the underlying causes, and using evidence-based information and analysis to advocate for the formulation and implementation of policies and programmes enhancing food security and nutrition. This initiative is supported by six technical divisions at the FAO's headquarters, FAO also support FIVIMS' activities at the country level (**http://www.fivims.org**).

c) Famine Early Warning Systems Network (FEWSNET)
The Famine Early Warning Systems Network (FEWS NET) is a USAID-funded activity that collaborates with international, regional and national partners to provide timely and rigorous early warning and vulnerability information on emerging and evolving food security issues. FEWS NET monitor and analyze relevant data and information in terms of its impacts on livelihoods and markets to identify potential threats to food security.

d) Integrated Food Security and Humanitarian Phase Classification (IPC)
The Integrated Food Security and Humanitarian Phase Classification (IPC) is a system for defining the severity of a situation (from "generally food secure to" famine/humanitarian catastrophe), based upon a wide range of indicators of the impact of a hazard event on human health and welfare (e.g. mortality rate, nutritional status, etc.). It integrates food security,

nutrition and livelihoods information into a clear statement about the severity of a crisis with the aim of eliciting more timely responses that match local needs (RHVP, 2007).

e) Poverty mapping initiatives in the ECA region

Due to the close link between poverty and vulnerability (see section 2.3) we consider poverty mapping initiatives to also be complements to vulnerability mapping. Both poverty and vulnerability mapping yields information useful for targeting interventions for high impacts were there is the highest need. Poverty mapping involves the application of models of household welfare developed from detailed household consumption and expenditure surveys to the extensive, but less detailed data from national censuses (Benson, 2003). Over the past few years a number initiatives to generate high resolution poverty maps have been implemented in Eastern and Central Africa. Such maps help governments and development partners target their projects for greatest benefits to the poor. The maps also provide a guide when decentralizing national resources and support local decision-making. Some of the poverty mapping initiatives in the region include;

- Malawi Poverty maps based on the 1997-98 Malawi Integrated Household Survey and the 1998 Malawi Population and Housing Census (Benson, 2002; Benson, Kanyanda; and Chinula. 2002; Benson, 2003)

- Kenya poverty maps, 2003 developed from a combination of detailed welfare information from the WMSIII (1997 Kenya Welfare Monitoring Survey) with the complete geographical data coverage provided by the 1999 population and housing census. Reliable estimates of well-being for very small geographic areas (divisions and locations as well as provinces and districts) were derived using statistical simulation techniques. This work by collaborative efforts between CBS, ILRI, and The World Bank (Republic of Kenya 2003). Efforts are ongoing to update the maps using recent data from welfare monitoring surveys.

- Uganda poverty book released in year 2005 with 'high-resolution' maps and tables of poverty for Uganda for regions, districts and counties. The maps were developed by the Ugandan Bureau of Statistics (UBOS) in collaboration with the International Livestock Research Institute (ILRI), with technical and financial assistance from the World Bank and World Resources Institute and with financial support from the Rockefeller Foundation and the UK Department for International Development (DFID). The 2005 Uganda poverty book highlights changes in poverty and equality between 1992 and 1999. Analysis combined data on household consumption obtained from a 1992/93 Integrated Household Survey and a 1999/2000 Uganda National Household Survey with complete geographic coverage provided by a 1991 Population and Housing Census. UBOS is in the process of updating these maps using population census data for year 2002. In year 2007 a report titled *"Nature, Distribution and Evolution of Poverty and Inequality in Uganda"* was released by UBOS and ILRI. This report describes and summarizes the trends in poverty and inequality in Uganda over the period 1992-2002. The report presents poverty information using the most recent data from the National Population and Housing Census of 2002 and the National Household Survey of 2002/3 (UBOS and ILRI, 2007).

- Tanzania district level Poverty maps were released in year 2005 in terms of a report titled "Poverty and Human Development Report, 2005" that is the result of the collaboration of members of the Research and Analysis Working Group of the Poverty Monitoring System on behalf of the Government of Tanzania (United Republic of Tanzania, 2005). Analysis for this report was based on data from the Tanzanian Population and Housing Census of 2002, the Household Budget Survey of 2000/01, the Tanzania Demographic and Health Survey of 2004/05, the Tanzania HIV Indicator Survey of 2003/04, basic data tables of the Agricultural Sample Census of 2002/03 and data on primary enrolments by district from the ministry of education (United Republic of Tanzania, 2005)..

1.3.2 Why this study?

There is a high degree of complementarity between the above initiatives and COMESA vulnerability hotspot mapping presented in this report. The need for a COMESA wide analysis as the one in this report comes from the fact that most of the products from the above initiatives provide country specific information and on some few cases regional information such as the horn of Africa. To our knowledge there is no other work than the earlier mentioned Thornton et al. (2006) study on vulnerability to climate change that has analysed vulnerability for the whole of COMESA. While such information is certainly very useful, it becomes hard to get a regional overview of the general vulnerability situation in the whole region. Analysis in this report is done at the COMESA level and hence targeted to regional users. Furthermore, whereas the focus of the above initiatives is on food security and the Thornton study limited to climate change, this work goes further to include other risk factors for vulnerability hence creating an opportunity to provide information that will be useful in decision support to a wider range of stakeholders dealing with rural development in COMESA such as those in public health, animal health, socio economics etc.

2. Conceptual Framework

2.1 Vulnerability

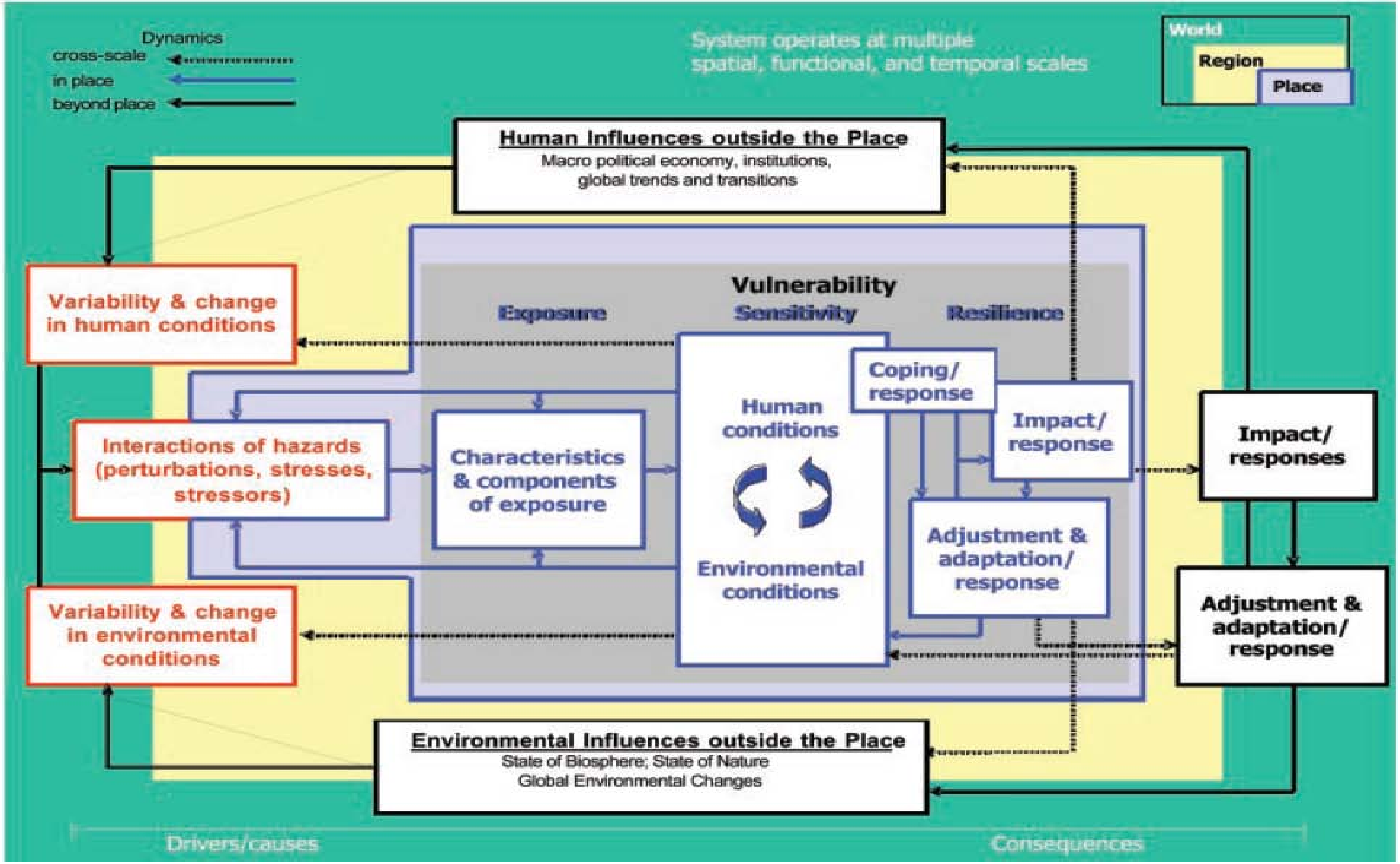
A wide variety of definitions and frameworks to assess vulnerability of households and ecosystems is used, described and applied throughout the scientific literature (see e.g. Alwang et al., 2001; Heitzmann et al, 2002, Turner et al., 2003; Lim et al, 2004, Thornton et al., 2006; TzPPA, 2002; O'Brien et al., 2004). 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. 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 two factors that defines how vulnerable communities can be (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. There is however one point on which arguments of all authors converge: it is essential to start from a clear conceptual base, i.e. explicitly describe which approach is taken, agree on the exact meaning of the terms used and follow this through throughout the whole study, project or program. We opted for a framework that addresses the dual objectives of meeting the needs of the society while at the same time sustaining the life support systems of the planet.

The simple definition we adopted for this study is *"the exposure to risk, mitigated by the ability to cope"*. Vulnerability is thus comprised of risks (or a chain of risky events) that people confront in pursuit of their livelihoods, the risk response or the options that people have for managing these risks and finally the outcomes that describe the loss in well-being. The risk response or available options are in turn determined by livelihood assets, strategies and policy and institutional environments.

Figure 1 shows in more detail the vulnerability framework proposed by Turner et al. (2003) and adopted in this study. The framework provides the broad classes of components and linkages that comprise a coupled human-environment system's vulnerability to hazards. The basic architecture consists of:

(i) linkages to the broader human and biophysical (environmental) conditions and processes;
(ii) perturbations and stressors, i.e. the stress that emerges from these conditions and processes;
(iii) the coupled human–environment system of concern in which vulnerability resides, including exposure and responses (i.e., coping, impacts, adjustments, and adaptations).

The full framework is illustrated in Fig. 1 by way of spatial scale, linking place (blue) to region (yellow) to globe (green). Vulnerability rests largely within the condition and dynamics of the coupled human–environment system exposed to hazards. In this framework, vulnerability has to be seen as a dynamic process that represents the conditions set by the environments they inhabit and the choices of the vulnerable populations themselves.



Source: (from Turner et al., 2003)

Figure 1: Vulnerability framework. Components of vulnerability identified and linked to factors beyond the system of study and operating at various scales.

2.2 Risk and Risk Management

Vulnerability begins with a notion of *risk*. Risk is characterized by a known or unknown probability distribution of the likelihood that a negative event will occur at some point in time. All individuals, households, communities or nations face multiple risks from different sources, whether they are natural (e.g., floods, illness) or man-made (e.g., unemployment, environmental degradation, conflict). These risks cannot be prevented, and if they materialize they can negatively impact individuals, households, communities and/or regions in an unpredictable manner (Heitzmann et al., 2002).

Risks are either idiosyncratic, with one household's experience weakly, if at all, related to neighbouring households'—or covariate, with households suffering similar shocks. Idiosyncratic shocks commonly arise due to crop yield shocks associated with microclimatic variation or local wildlife damage or pest infestation, illness (especially chronic rather than infectious), and one-off events such as property losses due to fire or theft. Such shocks can, in principle, be managed within a locale. Covariate shocks by contrast, commonly arise due to natural disasters, war, price instability and financial crises which virtually everyone in a community experiences. Such shocks are difficult to insure locally and thus require some coordinated external response (Alderman, 2007).

One can respond to, or manage, risks in several ways. Risk management involves ex ante and ex post actions. Ex ante actions involve preparedness and anticipation before a risky event takes place, and ex post management takes place after its realization and is therefore reactive. Ex ante risk reduction can reduce risk (e.g., eradication of malaria-bearing mosquitoes) or lower exposure to risks (e.g., malaria pills, mosquito nets). It is also possible for a household to take ex ante risk mitigation actions that provide for compensation in the case of loss such as purchase of insurance. Risk mitigation includes formal and informal responses to expected losses such as self- insurance (e.g., precautionary savings), building social net works, and formal insurance based on expansion of the risk pool. Ex post risk coping activities are responses that take place after a risky event is realized and involve activities to deal with realized losses such as selling assets, removing children from school, migration of selected family members, seeking temporary employment. Some governments provide formal safety nets, such as public works programs and food aid, that help households cope with risk. It is clear that different types of risk exposure necessitate different risk management measures and responses, and by different actors, e.g. from households themselves as well as from the policy makers.

Table 1 below shows examples of strategies that can be applied at different stages of the risk management cycle. The potential risk management strategies highlighted in this table in addition to broad development interventions, e.g. investments in water management, diversification of livelihood strategies, building up the asset base, increase of productivity, improve market access and integration, can increase the ability of poor households to cope with stress and therefore reduce their vulnerability.

Table 1: Potential risk management Strategies

Arrangements/ Strategies	Informal	Market Based	Public
Risk Reduction			
	• Less risky production • Migration • Proper feeding and weaning practices • Engaging in hygiene and other disease preventing activities	• In-service training • Financial market literacy • Company-based and markert-driven labour standards	• Labour standards • Pre-service training • Labour Reduction Interventions • Disability policies • Good macro economic policies • AIDS and other diseases prevention
Risk Mitigation			
Port-folio	• Multiple jobs • Investment in human, physical and real estates • Investment in social capital (rituals, reciprocal gift-giving)	• Investment in multiple financial assets • Microfinance	• Multi-pillar pension systems • Assets transfers • Protection of property rights (especially for women) • Support for extending financial markets to the poor
Insurance	• Marriage/family • Community arrangements • Share tenancy • Tied labour	• Old-age annuities • Disability, accident and other personal insurance • Crop, fire and other damage insurance	• Mandate/provided insurance for unemployment, old age, disability, survivorship, sickness, etc.
Risk Coping			
	• Selling of real assets • Reduced saving or investment • Borrowing from neighbours • Intra-community transfers/charity • Sending children to work • Dis-saving in human capital • Migration	• Selling of financial assets • Borrowing from banks	• Transfers/ Social assistance • Subsidies • Public works

Source: Holzmann, 2001

2.3 Poverty, Exposure to Risks and Vulnerability

A study on vulnerability in COMESA can not avoid looking at the issue of poverty, clearly, there is a big problem in the region with the majority of the population in the COMESA region (especially those living in the rural areas) being very poor. In addition to that there is a close link between poverty and vulnerability, the poorest bracket of the community are often the most vulnerable ones too. At times it is even misleading to make distinction between poverty and vulnerability as a person who can not provide for the means to appropriately manage risk ought to be considered poor as this means that he does not possess sufficient resources to insure against all the risks whose possible consequences are deemed as socially intolerable (Cafiero and Vakis, 2006).

Over the years, a lot of different poverty and vulnerability measures, ranging from very simple to extremely complex, have been applied. Janin (2007), however, shows there is a high level of correlation between most of them. As opposed to poverty, being a "static" measure, vulnerability is a much more dynamic concept. It includes the notions of moving in and out of poverty, poverty traps and explicitly includes the element of risk. It is therefore an appropriate concept, forcing people to think about protecting and enhancing livelihoods in a context of a consistent threat of risks (Mude, 2007).

Poor households, at any given time, are typically exposed to a wide range of shocks and stresses. The ability of poor and food insecure households to manage this risk largely depends on whether these households can prevent, mitigate or cope with their effects. The latter is greatly influenced by the types of livelihood strategies that households adopt. During food crisis periods, the result of any natural or man-made shock or stress, poor households often do not have access to the necessary resources that would enable them to cope with transitory food shortages while continuing to engage in sustainable economic activities that preserve livelihoods and build household assets. To cope with acute food shortages, households often engage in economic activities focusing on meeting the immediate household food requirements by diversifying food acquisition strategies. Such strategies may include divesting productive assets, stress sale of livestock, pulling children out of school to earn money and migrating to look for jobs in often less productive sectors. Competition for natural resources may trigger conflict and developmental gains achieved may be reversed. Under such circumstances, household vulnerability to future risks increases, trapping these households in poverty and reducing their ability to participate in any sustainable developmental efforts. In the absence of functioning safety nets and rural financial mechanisms to support households during food crises the options that households have are very limited and even a minor shock could have a major impact on the food security status of vulnerable people. Occurrence of disasters or events amongst the poor reduces their resilience and intensifies their food insecurity situation which could have been caused by other underlying factors.

Adverse impact of natural phenomena can be avoided through effective prevention, mitigation and preparedness (Messer, 2003). Indeed, it is clear that well designed strategies of dealing with these adverse events would save significant resources from costly short-term responses. With proper planning, resources could be used for developmental purposes contributing in earnest towards the eradication of hunger and the reduction of vulnerability to food security related crises in Africa. Literature on disaster and risk management e.g. Messer, 2003, WFP,2008, Karugia et al, 200 among others stress the need to insure presence of relevant interventions to deal with disasters. There references highlight the need for the following interventions;

- meeting peoples immediate needs in the aftermath of natural and man-made disasters;
- expanding the scope of livelihood opportunities for poor and food-insecure households, which will enhance their resilience to shocks by strengthening their coping strategies; and
- strengthening capacity to manage the whole disaster management cycle of prevention/mitigation and preparedness (pre-emergency phase), response (emergency

phase) and recovery (post-emergency phase).

One should note that by using the expression “disaster management cycle” it is not inevitable that the cycle repeats itself, following the same response over and over again. Rather, the adverse impact of natural phenomena can be avoided through effective prevention, mitigation and preparedness (Messer, 2003).

It is in the appreciation of the need to address vulnerability related problems in Africa that the African governments have specifically committed to the designing of specific interventions for addressing food insecurity problems in Africa through the CAADP. The third pillar of CAADP aims at increasing food supply, reducing hunger, and improving responses to food emergency crises. CAADP Pillar III is a deliberate attempt to ensure that the agricultural growth agenda targets the chronically poor and vulnerable directly, rather than through indirect and hoped for trickle down effects typical of past development policies and programmes (NEPAD,2009). The CAADPS framework for African food security further states that governments, at all levels, are responsible for the development of a proper disaster risk management policy or plan that clearly stipulates the respective roles and responsibilities of government and non-government actors in case a disaster occurs (NEPAD, 2007; NEPAD,2009) .

3. Data and Methodology

3.1. Introduction

In order to study risk and vulnerability in the COMESA region we collected a wide variety of risk indicators and combined these into five broad risk indices. This combination of indicators into a single measure or index aims to describe the abstract risk concept more comprehensively. The index approach has been applied in a variety of fields. Examples of well-known indices include the consumer price index (CPI) in which the prices of representative goods in a basket are added together, and the Human Development Index (HDI) which combines the life expectancy, education, standard of living and GDP indicators into a single measure of human development. One of the advantages of an indicator framework is that the combined indices can be traced back to the individual contributing factors.

The summary of the methods used to create the indices and hotspots, and thereafter map and characterise them is provided in Figure 2.

In the analysis of risk and vulnerability in the COMESA region, we took five broad categories of risk into consideration:

i) natural disasters,

ii) pests and diseases

iii) human health,

iv) socio-economic,

v) political and governance.

The choice of categories was in the first instance informed by a review of literature (TzPPA, 2002/2003; Republic of Malawi/World Bank, 2006; Freeman et al., 2007; African Development Bank, 2007) and included natural disaster, disease, socio-economic and political risk. Thereafter, we embarked on expert consultation to review these categories. The disease risk category was decomposed into pests and diseases versus human health, while the political risk category was expanded to include governance issues. The resulting five categories were deemed distinct, exhaustive, applicable and measurable by the expert panel. The same experts thereafter identified several risk indicators characterising as much as possible the most important dimensions of each of these categories. The participatory selection of indicators ensured involvement and buy-in of multiple stakeholders. More details about both the categories and the selected indicators within each of these categories are described in paragraph 3.2 below.

For each of the identified risk indicators spatially disaggregated data was collected and a geographical information system (GIS) used to develop probability surfaces. These GIS-based indicators, or criterion maps, were thereafter combined into 5 risk indices (1 for each category). A variety of methods exists for combining indicators into a single index. The most straightforward method is to simply add up the separate indicators. We opted, however, for a weighted sum 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. In our case, two different methods of assigning weights to the risk criteria were applied and thereafter compared to establish their agreement. Firstly, principal component analysis (PCA) was used 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 (Thornton et al., 2006). Secondly, a pair-wise comparison was undertaken by a group of experts on vulnerability related issues in the region. The pairwise comparison method is a very commonly used technique for assigning weight (Sahoo et al., 2007). Both methods yield indices in which higher values relate to higher risk. More details about each of these methods can be found in section 3.2.

Results from the two approaches of assigning weights were put next to each other and their congruence used to establish the likely hotspots of risk and vulnerability I.e. we defined as hotspots those areas where the results of the two methods agreed on them being at very high risk.

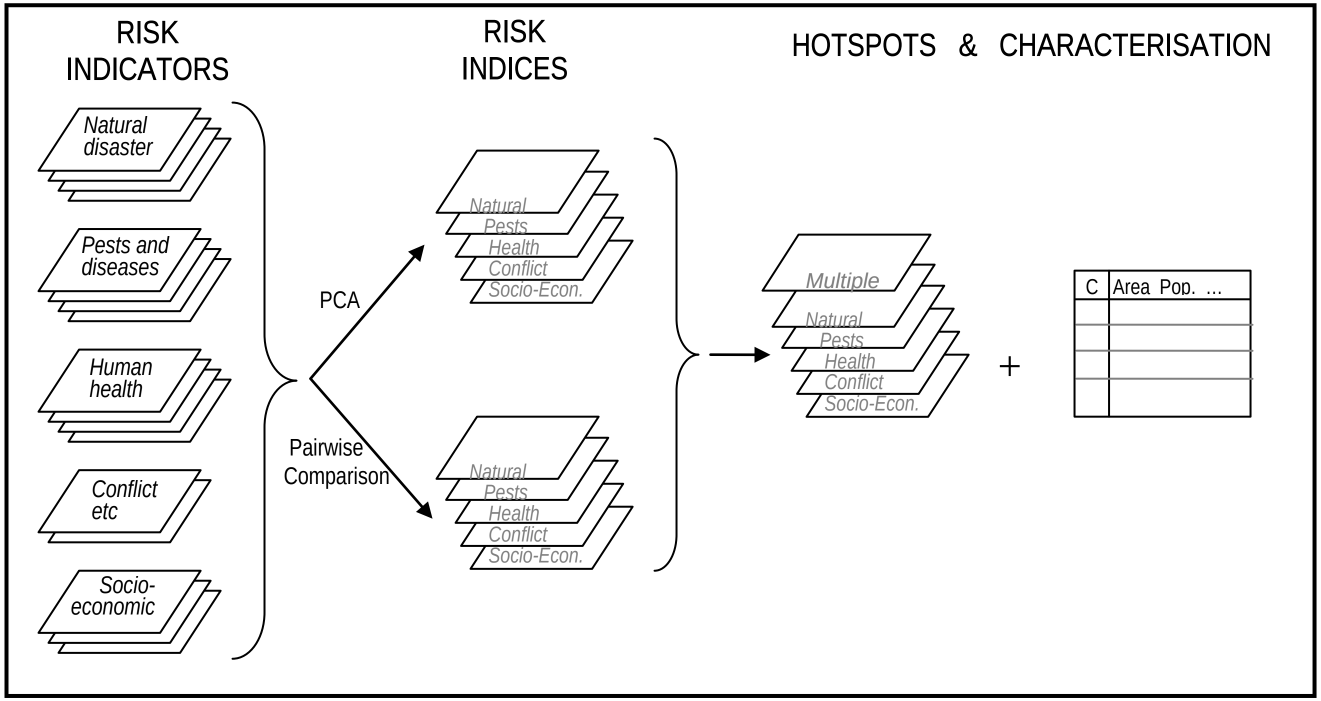


Figure 2: Graphic representation summarizing the methodology followed for the mapping of hotspots in the COMESA region.

The identified hotspots of risk were then further characterised and stratified in terms of farming systems, market access, population density, poverty and malnutrition. This yielded information useful for targeting context-specific interventions. Section 3.4 describes the identification and characterisation of hotpots in more detail.

3.2. Risk Indicators

Five groups of risk indicators were identified: natural disaster risk, human disease risk, crop pest and livestock disease risk, socio-economic risk and political risk. For each of the groups different indicators were chosen (Table 2). Sections 3.1.1 through to 3.1.4 provide more detail about the choice and meaning of the selected indicators. While some of the indicators are really representing actual hazards, shocks or stresses, data constraints forced us to use proxy variables for some of the risks identified. Climate variability for example is a clear stress, influencing the agricultural potential of an environment and therefore people's livelihood strategies. The number of internally displaced people, on the other hand, is not only stressing populations directly, it is mainly a symptom of a (political and/or natural) system under stress. Maps for all the risk indicators can be found in Annex 1.

Table 2: Risk indicators included in the analysis for vulnerability hotspot mapping in COMESA

	Data Source	*Resolution*	*Description*	*Some potential effects*
1. Natural Disaster Risk				
Drought (dryness)	Thornton et al. 2006	1km	Number of days per year with water availability to support crop growth	Loss of crops and livestock, changing terms of trade, less access to water, spreading disease
Floods	CHRR[1] – Dilley et al. (2005)	1º	Counts of extreme flood events	Loss of crops, destroying physical assets, isolating communities, spreading disease
Cyclones	CHRR – Dilley et al. (2005)	30”	Frequency of extreme wind strength	Loss of crops, destroying physical assets, isolating communities
Earthquakes	CHRR – Dilley et al. (2005)	2.5º	Frequency of earthquake hazards exceeding 4.5 on the Richter scale	Loss of crops, destroying physical assets, isolating communities
High CV in the Rainfall	Thornton et al, 2006	18.4 km	Inter-annual coefficient of variation of rainfall	Fluctuation in food production, changing terms of trade
LGP Change 2000 and 2030	Thornton et al, 2006	18.4 km	Percentage change of length of growing period (in days) between 2000 and 2030	Change in suitability of the environment for the current farming systems and practices
Deforestation	AfDB[2], 2007	Country	Annual change of forest cover between 1990 and 2000 (in %)	Soil degradation, declining agricultural productivity
Water Stress	FAO[3], 2004	Sub-basin	Internally renewable water sources plus the natural inflow (in mm)	Conflict, reduced productivity, hygiene and disease
Fire	Modis	0.2 º	frequency of fire occurrence	Loss of crops or pasture
2. Pest & Disease Risk				
Tsetse	FAO, 2006	5.2 km	The maximum suitability for forest, riverine or savannah tsetse (0 to 1).	Loss of Livestock, decreased income and safety nets
ECF	ECFxpert	1:25million	Incidence of East Coast Fever.	Loss of Livestock

Striga	AATF, 2006	Country	Maize area infected by maize (%)	Loss in agricultural production, supply shift
Locust	FAO, 2007	0.05 º	Weighted distance to locust occurrence between 1997 and 2007	Loss of agricultural production
FMD	Wint and Sumption, 2005	0.05 º	Multispecies density weighted Foot and Mouth distribution	Loss of livestock
3. Human Health Risk				
Malaria	MARA/ARMA, 1998	1 km	Suitability for Malaria transmission (0 to 1)	Loss of life, reduced labour force
HIV/AIDS	WRI[4], 2005	Country	Incidence (%)	Loss of life, reduced labour force, increased cost of health care
Diarrhoea	Demographic household surveys (DHS[5]) and multiple indicator cluster surveys (MICS[6])	District	% children under five reported by their mother to have suffered from Diarrhea during the period of two weeks before the survey	Loss of life, increased cost of health care
ARI	Compiled from various Demographic household surveys (DHS) and multiple indicator cluster surveys (MICS)	District	% children under five reported by their mother to have suffered from acute respiratory infection (ARI) during the period of two weeks before the survey	Loss of life, increased cost of health care
4. Socio-Economic Risk				
Population growth	CIESIN[7] - GRUMP, 2005	1 km	Population growth between 1990 and 2000 (%)	Increased pressure on the Natural Resources
Inflation	AfdB, 2007	Country	Inflation in the year 2003 (%)	Reduced income, increased expenses
Unemployme nt	ILO[8] - LABORSTA Labour Statistics Database, 2007	Country	Unemployment rates (%)	Lack of off-farm income
5. Political and Governance Risk				
Refugees	WRI, 2005	Country	Rate of people fleeing the country and applying for refuge outside the	Governance, interruption of agricultural production and

			country (%)	services, lack of good functioning institutions
Internally Displaced	IDMC[9], 2007	District	Number of conflict-induced internally displaced people	Interruption of production, increased competition over resources
Conflict	Variety of country reports[1]	District	Conflict data comprised of civil strife, targeted attack, livestock raids, election violence, clan warfare, water and land disputes, displacement and tribal clashes	Governance, interruption of agricultural production and services, lack of good functioning institutions
Voice and accountability	World bank	Country	The extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media.	Corruption, exclusion, non-efficient socio-economic processes, etc.
Political stability and absence of violence	World bank	Country	The likelihood that the government will be destabilized by unconstitutional or violent means, including terrorism.	Corruption, exclusion, non-efficient socio-economic processes, etc.
Regulatory quality	World bank	Country	The ability of the government to provide sound policies and regulations that enable and promote private sector development	Corruption, exclusion, non-efficient socio-economic processes, etc.

[1] Conflict Arm report on www.ploughshares.ca/libraries; Human Rights Forum Report. 2001; Politically motivated violence in Zimbabwe 2000–2001; UN (United Nations). 2002; Affected Populations in the Greater Horn of Africa Region, 2001; Crisis Group. 2007; Annual crisis report 2007; http://reliefweb.int/rw/fullMaps_Af.nsf/luFullMap/D828CA4BD76B3C53852573990067D669/$File/ hiu_CE_horn071116.pdf?OpenElement;http://allafrica.com/stories/200710231210.html; http://www.ethiopianreview.com/articles/1367; http://www.eastandard.net/news/?id=1143976669&cid=159; http://www.ntz.info/gen/n01510.html; http://www.crisisgroup.org/home/index.cfm?id=1200

Control of corruption	World bank	Country	The extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests	Corruption, exclusion, non-efficient socio-economic processes, etc.
Rule of law	World bank	Country	The extent to which agents have confidence in and abide by the rules of society, including the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence.	Corruption, exclusion, non-efficient socio-economic processes, etc.
Government effectiveness	World bank	Country	The quality of public services, the capacity of the civil service and its independence from political pressures; the quality of policy formulation	Corruption, exclusion, non-efficient socio-economic processes, etc.

1. CHRR: Center for Hazards and Risk Research, Columbia University (http://www.ldeo.columbia.edu/chrr/)
2. AfDB: African Development Bank (http://www.afdb.org/)
3. FAO: Food and Agriculture Organisation of the United Nations (http://www.fao.org)
4. WRI: World Resources Institute (http://www.wri.org)
5. DHS: Demographic and Health Surveys (htpp://www.measuredhs.com/)
6. MICS: Multiple Indicator Cluster Survey (http://www.unicef.org/statistics/index_24302.html)
7. CIESIN: Center for International Earth Science Information Network (http://www.ciesin.org/)
8. ILO: International Labour Organisation (http://www.ilo.org/global/About_the_ILO/lang--en/index.htm)
9. IDMC: Internal Displacement Monitoring Centre (http://www.internal-displacement.org/)

For all the indicators in Table 2, spatial data was collected and stored in a Geographical Information System (GIS). The corresponding datasets were obtained from different sources and came in different GIS formats. Some came as continuous datasets, saved on a cell-by-cell basis, i.e. as raster data, while other data were based on administrative levels, e.g. districts or countries. The layers were all converted to the raster format with a cellsize of 4.6 by 4.6 km. As the criteria are measured at different scales they need to be standardised. This is to convert all maps into the same scale and make them comparable with the same measurement basis before any weights are assigned (Malczewski, 1999, Eastman et al., 1993). These raster layers were thus first of all normalised (by applying log10 and assigning the minimal risk to original zero risk areas) and then standardised in probability surfaces using the simple arithmetic transformation from formula 1 (i.e. linear scale transformation).

Formula 1: $V_i = (X_i - X_{i,\,min}) / (X_{i,\,max} - X_{i,\,min})$

With V_i *= standardised indicator i*
X_i *= the indicator before it is transformed*
$X_{i,\,min}$ *= the minimum score of the indicator i before it is transformed*
$X_{i,\,max}$ *= the maximum score of the indicator i before it is transformed*

This transformed all data into a relative score ranging from 0 to 1. For most variables, the higher the value, the higher the probability of this specific type of risk occurring in that area. The only exceptions in the list of variables is the water stress indicator, where less water means higher pressure and the dryness indicator, where lower number of growing days means higher stress. Therefore, the water indicator was further transformed using the formula $1 - X_i$.

The arrived at values thus no longer provide absolute values. A value of zero for example, doesn't mean there is no risk; it rather refers to the lowest probability of risk in comparison with other locations in the COMESA region. They only provide an 'indication' of much broader and complex social concepts. They are, however, suitable for comparative assessments and therefore also for priority setting and targeting of further research activities and actual interventions.

3.2.1. Natural Disaster Risk

Over 60% of the population in the COMESA region depends on agriculture for their livelihoods and employment (FAOSTAT, 2006); they almost entirely depend on direct utilisation and/or transformation of local natural capital. Disasters have a significant impact on agricultural production and represent a major source of risk for the poor and wipe out development gains and accumulated wealth in developing countries (Dilley et al, 2005). In addition to that, African farmers face formidable ecological constraints, including old and weathered soils, and limited irrigation potential due to the hydrology of African river systems (Bloom and Sachs, 1998).

The risk indicators included in this category are very relevant to CAADP Pillar 1, "*Extending the area Under Sustainable Land Management and Reliable Water Control Systems*", which aims to revert fertility loss and resource degradation, to ensure broad-based and rapid adoption of sustainable land and forestry management practices and to improve management of water resources while expanding access to irrigation.

a. Climatic Shocks

Floods, droughts, earthquakes and cyclones disrupt productive activities. The result is loss of crops and livestock, changing terms of trade, reduced access to water, spreading disease, destroyed physical assets, isolated communities, etc. The Global Natural Disaster Risk Hotspots Project generated global flood, earthquake and cyclone data. This data was downloaded and integrated in the Spatial Risk Database.

For drought risk, the palmer drought severity index was used. Monthly indices from January 1973 up to 2003 by NCAR, (2006) were downloaded from the IRI/LDEO Climate Data

Library[b] . The percentage of months with severe or extreme droughts was used as a drought risk indicator.

b. Climate Variability

Climate variability, especially as regards to precipitation, can have huge impacts. Rainfall variability continues to be the principal source of fluctuations in global food production, particularly in developing countries (Reynolds et al., 1998).

Climate change may affect food systems in several ways ranging from direct effects on crop production (e.g. changes in rainfall leading to drought or flooding, or warmer or cooler temperatures leading to changes in the length of growing season), to changes in markets, food prices and supply chain infrastructure (Gregory et al., 2005).

The coefficient of variation for rainfall was calculated by Jones and Thornton in the framework of the Mapping Climate Vulnerability and Poverty study (Thornton et al. 2006). The same study also provides data for change in length of growing period (LGP) between the year 2000 and 2030. The areas where a gain in LGP was projected were set to zero and then the rest of the data was normalised and standardised as described above.

c. Natural Resource degradation

As most rural livelihoods directly depend on natural resources, declining natural resources mean declining returns from livelihood activities. In contrast to the above droughts, floods and cyclones, the natural resource degradation is not a sudden shock but rather a slow and continuous stress on the livelihoods assets of the poor.

Natural resource degradation takes many forms, soil erosion being one of the most prominent ones. Data limitations, however, drove us to the selection of deforestation as a proxy for natural resource degradation.

Deforestation

A high rate of deforestation contributes significantly to soil degradation, making the latter one of the most serious problems facing Africa today (African Development Bank, 2007). The African Development Bank provides country-level figures of forest cover change in the 1980's and 1990s. It is the data for the 1990's that was normalised, standardised and converted to GIS format for further analysis.

d. Water Stress

The increasing scarcity of clean water is becoming an issue of serious concern in Africa. There is a fear that future regional conflicts may result from competition over water use. Partly owing to long spells of drought, Africa has less water today than in the 1970s (UNEP/OAU, 1991). Associated with falling water supplies is the issue of water pollution. In rural areas, the population draws water from unprotected sources, such as wells and rivers. Many of these sources have been exposed to serious pollutants from industry, the infiltration of agricultural chemicals and fertilizers, and raw sewage. The African Development bank (2007) estimated that in most of Africa sewage is discharged untreated into surface waters.

[b] http://iridl.ldeo.columbia.edu/SOURCES/.NCAR/.CGD/.CAS/.Indices/

These are often sources of drinking water for downstream communities, making populations vulnerable to 'environmental' diseases like cholera, typhoid, diarrhea and dysentery. The limited access to health services further compounds the vulnerability of these communities (African Development Bank, 2007).

For water availability, river basin values from the FAO Atlas of Water Resources and Irrigation in Africa were used. The values for Internally Renewable Water Resource (IRWR) and Natural Inflow (NI) were added up and combined into a “Discretionary Surface Water” raster dataset. This dataset was normalised, standardised and used for further analysis.

IRWR represents the sub-basins contribution to the overall runoff of the major basin and is actually the "surplus" rainfall that either infiltrates to recharge aquifers or runs off into rivers. It is calculated using a model that amongst others takes into account precipitation, reference evapo-transpiration, and soil moisture storage capacity. This so-called “surplus” was then routed through the river basins and natural inflow calculated.

e. Fire

A last indicator that was added to this risk category is fire risk. The fire hazard was calculated on the basis of the historical archived active fire data (NASA, 2003). The processing involved several steps and included sub setting of data from Global MODIS data followed by calculation of point density surfaces for the different years. In calculating the density, a neighbourhood radius of <100km was used to estimate the maximum distance of cluster. The resulting density maps per year were then used to obtain a weighted sum surface to establish hotspots.

3.2.2. Crop and Livestock disease risk

Livestock diseases and crop pests directly reduce yields, agricultural productivity and food security. Diseases of crops and livestock are widespread in the COMESA region. In addition, agricultural intensification generally leads to even higher pest pressure (ReSAKSS, 2007).

a. Livestock Pest and Diseases

While exposed to a wide array of risks related to animal disease, the poor have little capacity to cope. Existing close to the survival threshold, the poor tend to be more risk- averse, and so less likely to ‘take a chance’ on preventive disease technologies. Livestock disease is particularly damaging since it threatens one of the few assets that the poor keep on hand for dealing with other shocks (Perry et al., 2002). Due to data limitation we only included data on three major livestock diseases in this analysis, namely: East Coast Fever (ECF), animal trypanosomiasis, and Foot and Mouth Disease (FMD). However, because these are quite prevalent and have been shown to have significant effects on livestock production systems in the region (see Perry et. Al, 2002; stakeholder consultations January 2008), we are quite confident they represent well the risks associated with livestock diseases.

According to a study from Perry et al. (2002), for example, ECF actually has the greatest impact on the poor people in the East and Central African region. ECF is indeed a major economic threat, putting at risk the lives of about 25 million cattle in Burundi, Kenya, Malawi, Mozambique, Rwanda, Sudan, Tanzania, Uganda, Zaire, Zambia, and Zimbabwe.

The disease has been reported to be the cause of half a million deaths in cattle per year in East Africa. In Kenya alone, it has been estimated that 50-80% of the national cattle population, currently around 10 million animals, are exposed to the tick, and of these animals 1% die of ECF each year. (ECFxpert, 2007).

Another major livestock disease in the COMESA region is Trypanosomiasis. This disease severely limits livestock rearing, animal traction and mixed cropping in the tropical zones (Bloom and Sachs, 1998; Sachs, 2001; Masters and McMillan, 2001). Tsetse-transmitted trypanosomiasis occurs in 36 sub-Saharan countries, covering some 10 million square kilometers of Africa. Animal trypanosomiasis causes the death of about 3 million cattle annually and, each year, African livestock owners administer about 35 million doses of trypanocides to prevent or treat the disease. The annual economic losses resulting from the disease are estimated as being about US$3-5 billion per year (NRI, 2007). The economic loss due to East Coast Fever has been estimated at US4 168 million (Torr et al., 2005). A third livestock disease causing havoc in the COMESA region that was included in the analysis is FMD.

The areas under threat of Trypanosomosis were sourced from the data generated by the Programme Against African Trypanosomiasis (PAATS) and was accessed from the FAO website (FAO, 2006). The maximum probability of occurrence of any of the tsetse species was used as a proxy. ECF occurrence was digitized from a map in Perry et al. (1989). The Multispecies density weighted Foot and Mouth distribution was sourced from Wint and Sumption (2005).

b. Crop Pest and Diseases

Epidemics of diseases, infestations of insect pests and colonization by weeds result in significant losses in agricultural production worldwide. These yield losses occur despite the application of pesticides valued at $30 billion annually and the use of improved varieties with varying levels of resistance to specific pests. As a result of crop improvement programmes to incorporate resistance to pests, devastating epidemics and infestations are now the exception and not the rule; nevertheless, pests continue to exact a heavy toll in terms of yield losses (Oerke E-C, 2005).

The most recent global estimate of yield losses for eight major crops was published by Oerke et al. (1994). According to their data, developing countries had higher losses than industrial countries. Africa had the highest percentage losses at 49% (equivalent to $13 billion annually). By crop, the highest absolute annual value and percentage loss was reported for rice at $113 billion/51% loss, followed by wheat at $39 billion/37% and maize at $28 billion/38%. Of these three “top crops” maize is the most important staple crop in COMESA. De Groote (2007) estimates that in the whole of SSA 250 to 500 million US$ is lost due to Striga infestation. Data on the areas infested with Striga in East- and Southern Africa were obtained from a publication by AATF (AATF, 2006) and digitized for inclusion into this analysis.

Desert locusts inflict heavy crop damage that's devastating for subsistence farmers, many of whom must flee land that can no longer support their families (Handwerk, 2005). FAO point data on locust infestation was digitized. The source of this data was from various reports (desert locust bulletins for the period between 1997 to 2004) developed by the FAO

Emergency Centre for Locust Operations (www.fao.org/ag/locusts/common). The point data was converted in a distance weighted risk measure for further inclusion in the analysis.

Cassava mosaic disease (CMD) is undoubtedly the most important constraint to the production of cassava in Africa, a key staple in much of this region. During the 1990s, a major regional pandemic of an unusually severe form of CMD expanded to affect parts of at least five countries, causing massive economic losses and destabilising food security (Legg et all, 2000). The epidemic of severe CMD that spread to affect most of Uganda devastated the country's cassava production, causing losses valued in excess of USD 60 million annually between 1992 and 1997 (Otim-Nape et al., 1997). Farmers literally abandoned the crop in large parts of the country, and in eastern districts widespread food shortages led to some famine-related deaths (Thresh and Otim-Nape, 1994). During the second half of the 1990s, the epidemic spread to the neighboring countries of Sudan, Kenya, Tanzania and eastern Democratic Republic of Congo (DRC), with a similar impact on cassava cultivation (Legg, 1999).

Banana xanthomonas wilt (BXW) previously restricted to Ethiopia has recently spread to East Africa. Since it was first observed in Uganda in 2001, BXW has spread to neighbouring countries. Apart from 32 of Uganda's 54 districts at the time, BXW has been observed in Tanzania, Rwanda and DRC. The spread of the disease threatens the livelihoods of millions of people who depend on banana as a food and income source in the Great Lakes Region – an area that boasts the highest per capita consumption of banana in the world (INIBAP website, 2007).

Data on the incidence of CMD and BXW in the Great Lakes region was provided by the C3P project. The Crop Crisis Control Project (C3P) is a regional activity supported by the USAID Famine Fund to intensify and bring coordination to the fight against Cassava Mosaic Virus disease (CMD) and Banana Xanthomonas Wilt (BXW) in six countries of Central and East Africa – Burundi, Democratic Republic of Congo (DRC), Kenya, Rwanda, Tanzania, and Uganda. Due to many missing data values for most of the COMESA region, data on CMD and BXM were however left out in the subsequent hotspot analysis.

3.2.3. Human Health Risk

Illnesses and injuries in a family simultaneously reduce income due to lost time working and increased curative health treatment expenditures (Alderman, 2007). Human diseases undermine the capacity of those who are ill as well as their caretakers to pursue livelihoods. It significantly reduces labor productivity and often results in the sale of productive assets in order to pay for treatment.

HIV and AIDS are having a devastating effect on agriculture, education and the private sector. Many farmers have died and many others are debilitated by illness, leading to reduced food production. Low food production and accessibility in turn contribute to food and nutrition insecurity.

In the short and medium term, the epidemic impoverishes households through:

- loss of labour in agriculture and other livelihood activities;
- increased cost of health care and funerals;
- diminished capacity to care for children and other vulnerable individuals; and

• erosion of the asset base.

In the longer term, HIV and AIDS have impacts on social and economic systems and institutions in hard-hit countries. AIDS forces children, particularly girls, to withdraw from school in order to work or care for ill parents. It reduces the inter-generational transfer of skills and knowledge of agriculture, and erodes the human resource base of institutions required to address the sectoral and cross-sectoral impacts of the epidemic. HIV and AIDS reduces the availability of labor and knowledge that in turn affect household level access to food (Panagides et al., 2007).Country level HIV/AIDS incidence for the year 2003 was sourced from World Resource 2005[c].

More than 70 per cent of almost 11 million child deaths every year are attributable to six causes: diarrhoea, malaria, neonatal infection, pneumonia, preterm delivery, or lack of oxygen at birth (UNICEF, 2008). District level data on diarrhea and acute respiratory infection was compiled for the COMESA countries from demographic household surveys and multiple indicator cluster surveys.

According to MARA/ARMA (1998), in SSA, *malaria* is the single most important disease, being responsible for nearly one million deaths and 300-500 million clinical cases every year. SSA caries the highest per capita burden of disease in the world. This situation results both from the particular epidemiological situation in Africa and the nearly total absence of systematic control activities during the past decades. As a result, the burden of the disease on societies and economies is tremendous (MARA/ARMA, 1998). The probability layers developed by MARA/ARMA were added to the spatial database and used in the subsequent analyses.

3.2.4 Socio-Economic Risk

The socio-economic risk indicators included in our analysis are population growth, price fluctuations and unemployment. These were identified by stakeholders as having a high impact on the vulnerability of communities in the COMESA region. It is important to note that other socio-economic indicators, as for example poverty and food security are not included as risk factors. They are considered to be the outcome or result of communities being exposed to a variety of risks and therefore proxies for measuring vulnerability. We however use the outcome indicators in the characterization of the risk hotspots (refer to section 3.4).

a. Population growth

Africa's population is one of the fastest growing in the world. Over the past 40 years, the African population has grown at 2.7% per year, compared to 2% in developing Asia and 2.2% in Latin America (FAOSTAT). High population growth exerts further pressure on the limited land, leading to increasing encroachment on forests and other natural resources, that in turn leads to soil degradation, deforestation and subsequent loss of productivity (African Development Bank, 2007). Given Africa’s high population growth rates, it will face the

[c] For the countries without data, the average incidence of the other “similar” COMESA countries was taken. Similarity was identified by constructing country clusters based on human poverty and development indices and GDP/capita.

largest food supply challenge of any developing region until its demographic transition is complete.

CIESIN's spatial population layers (GRUMP) for the year 1990 and 2000 were used to calculate the percentage population increase between these two years.

b. Price fluctuations

Economic shocks reduce revenues just as they necessitate an increase of expenditures (Alderman, 2007. Inflation figures for the year 2003 were obtained from the African Development Bank[d] and used as a proxy.

c. Unemployment

The latest unemployment figures were obtained from the International Labour Organisation for Egypt, Ethiopia, Madagascar, Mauritius, Uganda, Tanzania, Zambia and Zimbabwe[e].

3.1.4 Political and Governance Risk

Conflicts disrupt people's lives and their livelihoods. The lack of security in civil wars for example often prevents people generating income or food or drives them from their lands completely, leaving them stranded in foreign lands, without access to productive assets or in refugee camps, largely dependent on emergency relief provided by the UN agencies, international civil society and donors. Food crises due to civil war can be long-term and beyond the scope of national coping capacity (NEPAD, 2007).

Proxies used were the number of people fleeing the country and the number of internally displaced people (IDP). The number of refugees was sourced from WRI. While information for IDPs in 9 countries in the COMESA region was downloaded from the Internal Displacement Monitoring Centre (IDMC): Burundi, DRC, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Uganda and Zimbabwe.

In addition to that, a conflict risk layer was compiled on the basis of a variety of country reports. Conflict data comprised of civil strife, targeted attack, livestock raids, election violence, clan warfare, water and land disputes, displacement and tribal clashes. A distance weighted risk measure for conflicts was created for further inclusion in the analysis.

Lastly, six different country-level governance indicators were included: Voice and Accountability, Political Stability and Absence of Violence/Terrorism, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption. Kaufmann, Kraay and Zoido-Lobatón (1999) came to the conclusion that governance quality, measured

[d] For the countries without data, the average incidence of the other "similar" COMESA countries was taken. Similarity was identified by constructing country clusters based on human poverty and development indices and GDP/capita..

[e] Again, for the countries without data, the average incidence of the other "similar" COMESA countries was taken. Similarity was identified by constructing country clusters based on human poverty and development indices and GDP/capita.

across six dimensions,1 had important predictive power in respect of various development indicators, such as per capita income, infant mortality and adult literacy. The idea is that countries that score better on the governance dimensions perform better on the development indicators. The latest aggregate indicators are based on hundreds of specific and disaggregated individual variables measuring various dimensions of governance, taken from 35 data sources provided by 32 different organizations. The data reflect the views on governance of public sector, private sector and NGO experts, as well as thousands of citizen and firm survey respondents worldwide. This data was extracted from the worldbank website[f].

3.3 Composite Risk Indices

In order to come up with composite index maps, multi-criteria evaluation (MCE) was used. MCE is a process for combining spatial data according to their importance in making a given decision (Carver, 1991). This is a well-established optimisation method used extensively in land use resource allocation and decision support (Wood and Dragicevic, 2007). MCE has been widely applied in suitability analysis and targeting studies (Jankowiski and Richard, 1994; Malczewski, 1999a and b, 2000; Sharifi et al, 2002; Jankowiski, Andrienko and Andrienko, 2001; Robinson, 2002).

There are various methods that can be used to aggregate criteria maps to generate a final suitability/ priority map. These aggregating methods are also known as "Decision rule". These are primarily concerned with how to combine the information from several criteria or indicators to form a single index of evaluation. In case of Boolean criteria (constraints), the solution usually lies in the union (logical OR) or intersection (logical AND) of conditions. However, for continuous factors, a weighted linear combination is a usual technique used to aggregate the criteria maps and generate the priority map (Malczewiski, 2000 and Malczewiski and Jackson, 2000). This method aggregates the maps using the following formula:

Formula 2:

$$\text{Priority/ suitability map} = (C_1W_1 + C_2W_2 + C_3W_3 \ldots\ldots C_nW_n)$$

Where:

C = Criterion/ criterion map

W= Weight/ relative importance of the criterion

We applied two alternative weighing schemes for the hotspot analysis. One set of weights was derived using Principal component analysis, the second set came from the input of set of stakeholders through pairwise comparison. The areas of congruence were then used to identify the most likely locations of risk hotspots.

[f] http://info.worldbank.org/governance/wgi/mc_countries.asp

3.3.1 Principal Components Analysis

In order to distil the 30 indicators from Table 2 down to a smaller number of indicators, we subjected the data to a Principal Component Analysis (PCA). PCA was performed per risk category and on all the pixels that had valid data for all indicators in that category. PCA is an example of a factor analysis, a class of statistical methods that attempts to reduce the complexity of multivariate datasets by producing a set of new factors or components that are orthogonal, thereby avoiding the problems of correlation among indicators. The main reasons to transform the data in a principal component analysis are to "compress" data by eliminating redundancy, to emphasize the variance within the grids of a stack, and to make the data more interpretable. The PCA was done with a Varimax orthogonal rotation and new factors were selected that had an eigenvalue greater than unity (Solano et al. 2003).

The result of the PCA is a set of uncorrelated principal components, with the first principal component explaining the highest proportion of the variance, the second one showing the second highest variance not described by the first, and so forth. The normalised and standardised indicators from Table 2 were reduced to 5 non-redundant sets of orthogonal factors or principal components (PC), each set representing one of the risk groups mentioned above. PCA scores were saved for each pixel in the dataset and standardised between 0 and 1. They were then used to derive a vulnerability index as follows. The sets of principal components per risk category were used to construct a "categorical" risk index. This combined index is the weighted sum of the standardised PCA scores for each pixel. Although small in effect, the PCA scores were weighted by the variance explained by each PCA as in Thornton et al (2006).

3.3.2. Pair-wise comparison by experts

The above described maps of individual indicators as well as combined indices based on the PCA analysis were presented in a meeting of policy-makers and donors in the region (see annex 2 for the list of participants). During this meeting all the individual data layers were validated. The combined indices based on the results from the PCA were shown, in order to explain the concept of combining indicators into an index and giving the rationale for establishing weights.

Then, we embarked on a pairwise comparison exercise. This method enables the generation of weights by comparing criteria using a nine-point continuous scale (Figure. 3). The resulting weights assigned to different layers represent the estimated significance for causing higher vulnerability.

9	7	5	3	1	1/3	1/5	1/7	1/9
extremely	Very strongly	strongly	moderately	equally	moderately	strongly	very strongly	extremely
More important					Less important			

Figure 3: Nine- point scale for pairwise comparison weight assigning method

Pairwise comparison method is based on an approach called Analytical Hierarchical Structure (AHP) designed by Saaty (1980). It involves the comparison of the criteria and allows the comparison of only two criteria at once. Pair wise comparison method is a more robust method of assigning weights than e.g. the direct weight method as it enables the stakeholders to brainstorm and consistently evaluate the criteria. In this way the decision on the importance of a criterion is made through a process and not just by sheer chance as it is the

case with the direct method. In applying AHP, the weights are generated by a means of the principal eigenvector of the pair wise comparison matrix. The criteria comparison matrix takes the pairwise comparisons as an input and produces the relative weights as output, and the AHP provides a mathematical method of translating this matrix into a vector of relative weights for the criteria (Malczewski, 1996). The weights for all the criteria sum up to 1. During this process the consistency of the comparison is also calculated and a consistency ratio provided. A consistency ratio below 0.1 indicates that the comparison was fairly consistency and thus the weights are reasonably correctly calculated while a consistency above 0.1 means that the comparison was inconsistent and hence the need for re-evaluation. A total of 10 consistent responses were received from workshop participants.
The resulting weights of these respondents were averaged and then fed into formula 2 to construct 5 risk indices, 1 per category.

3.4 Identification and Characterisation of Hotspots for vulnerability

Both methods for establishing weights (PCA and pairwise ranking) resulted in 5 weighted risk indices (intermediary risk maps), one for each of the categories (i.e. Natural disaster, human health, pests and diseases, political, and socio-economic). The categorical risk indices from the two methods were classified in four quantiles and mapped. The top quantile was labelled to be at very high risk, the second one at high risk, the third one as low risk, the last one as very low risk. The results of these two weighing schemes were compared by identifying omission and commission errors and estimating the overall accuracy according to the methods outlined by Jensen (1996). Table 3 below summarises the variables looked at. In addition, we also compared the agreement of the top quantile only. We compared -cell by cell- the inclusion in this very high risk quantile and calculated percentages of agreement (and non-agreement).

Table 3: Accuracy of individual classes

Omission: indicates the probability of the risk class according to PCA being the same as the risk class according to the pairwise ranking method Commission: indicates the probability of the risk class according to the pairwise ranking being the same as the risk class according to the PCA method
Overall Accuracy: fraction of the total number or cells that are in agreement
KAPPA statistic: an index comparing the agreement against that which might be expected by chance.

We assume that areas where both methods coincide in classifying the area to be under very high risk have indeed a maximum likelihood of being hotspots of risks. We therefore defined as hotspots the intersection of the top quantiles resulting from the PCA weighing scheme and those resulting from the pairwise ranking weighing scheme.

In addition to the categorical hotspot maps, a combined map was produced. It indicates to how many high risks a certain area is exposed.

In the characterisation we considered 3 different types of factors; the population at risk, the environment they're living in and the outcome indicators. We provide country-level information for each of these characteristics in the different hotspot categories. Such information is vital in informing the effort in intervention on addressing vulnerability.

As this study considers vulnerable communities as the main element at risk, human population number was one of the factors looked at in spatial characterisation. We calculated the actual number of people living within the hotspots; this indicates potential impact of strategic interventions. The population data we used comes from the global rural urban mapping project (GRUMP) developed by CIESIN in cooperation with IFPRI.

Secondly, in looking at the environment in which people live, we identified the major farming system found within the hotspots as well as the average travel time to settlement with more than 250,000 inhabitants. These factors were included because they influence the choice of potential intervention strategies. Clearly, interventions required in remote pastoral areas are very different from strategies applicable in accessible mixed farming areas.

Farming systems are defined as groups of farms which have a similar structure and function and can be expected to produce on similar production functions. A major component of any impact assessment and targeting exercise is information on the location of these systems. Given the fact that livestock forms a critical part of the livelihood strategies of most rural households, it is essential we also understand how livestock fits in the system. The spatial layer we used for farming systems is therefore the livestock production systems, created by ILRI (Kruska, 2006). This layer is based on the work of Seré and Steinfeld (1996). Livestock systems fall into four categories: landless systems, livestock only/rangeland-based systems (areas with minimal cropping), mixed rainfed systems (mostly rainfed cropping combined with livestock) and mixed irrigated systems (a significant proportion of cropping uses irrigation and is interspersed with livestock). All but the landless systems were further disaggregated by agro-ecological potential as defined by the length of growing period. This gives 11 categories in all. For the purpose of this study, we aggregated these systems into 4 classes: Rangelands, mixed crop-livestock farming (rainfed and irrigated) and other (coastal systems, forest, urban areas, etc).

JRC (2006) recently developed a global urban access layer. This layer actually refers to physical (or infrastructural) access to markets, whereas other, and more difficult to model, factors might have an equally important or even greater influence on a smallholder's accessibility to markets, e.g. information about prices, cold chain equipment, … Unfortunately, GIS layers representing these were not available and we decided to use the physical market access as a proxy.

Lastly, for each of the hotspot categories, the average percentage of malnourished children below 5 years was established. This gives an indication of how well the population within the hotspots is dealing with the risk they're exposed too. Other potential outcome indicators, such as poverty, food security status, etc. could have been included as well. Sub-country level data on these is not available for the whole COMESA region. Therefore we limited our analysis to malnutrition only.

The indicator used for malnutrition indicator is percentage of children under 5 that are stunted. Stunting or height-for-age is a measure of linear growth. Stunting is a condition that reflects failure to receive adequate food intake over a long period and is also affected by repeated episodes of illness. Height-for-age thus represents a measure of long-term effects of under nutrition in a population and does not vary appreciably according to recent diet. In a population in which children are healthy and well nourished, approximately 2 percent of children are expected to be stunted. It is, however, very important to keep in mind that the malnutrition data, in terms of percentage of the children under five stunted, is not very up-to-date. Stunting was sourced from the FAO hunger map. The data for this map is based on the latest survey conducted in the period 1987 and 2002. In Uganda this happened for example in 2001, while the data for Mozambique in based on a survey from 1995. Caution needs therefore be taken when comparing across countries.

4. Results and Discussions

4.1 The risk indicators

Annex 1 contains maps of all the risk indicators as listed in Table 2. Each of the pages contains two maps. The map on the left hand side, shows the raw risk indicator, while the right pane of each page shows the normalised and standardised probability surfaces. In these right-hand maps, the 0 to 1 values have been classified in 5 quantiles, representing 5 classes – from very low to very high risk.

4.2 Composite indices based on PCA

The results of the PCA in terms of factor loadings and the percentage of variance explained by each component are shown in tables 4 to 8. The interpretation of the values in these tables provide an insight in the main contributing factors to the composite indices that are mapped in figures 1 to 5 in annex 2.

As an aid to interpret the results of the analyses, all tables show the factor loadings for each variable. The higher the loading, the more the variable contributes to explaining the variance in that PCA. For example, in table 4, the first principal component (PC1) was dominated by variables all related to water stress (rainfall variation, fires, dryness, change in LGP and water stress). All these variables are somewhat related and they represent aspects of the same phenomena, therefore the analysis clusters them together in a single new variable (PC1) which can be described as ‘Access to water’. The loadings can be positive or negative, which shows some of the relationships between the variables composing the new principal component. The relationships between the signs of the variables are sometimes very clear, but this needs to be interpreted with caution, especially when using spatial data at different resolutions.

In general terms, the three natural disaster factors explain more than 65% (sum of the total variance) of the variance of the original dataset. The water-related factor is by far the most important one, explaining more than 42% of the variance. PC2 seems dominated by the floods and deforestation and adds 13% to explaining the variance in the dataset. PC3, finally, is completely dominated by the earthquakes and cyclones. The final natural disaster hotspots are therefore a combination of the 9 natural disaster indicators, with the water-related factor given most weight, followed by the flood/deforestation and earthquakes/cyclones factors.

Table 4: PCA results for Natural Disaster Risk

	PC1 "Access to water"	PC2 "Floods and deforestation"	PC3 "Earth quakes and cyclones"
Rainfall Variation	-.884	-.172	.065
Cyclones	-.155	.082	-.625
Deforestation	-.346	.556	-.161
Earth Quakes	-.104	.063	.779
Fires	-.880	.057	-.030
Floods	-.007	.901	.085
Dryness	.858	-.140	-.013
LGP Change	-.942	.098	-.015
Water Stress	.720	-.092	.079
%variance explained	42.792	13.355	11.573

Table 5: PCA results for pest and disease risk

	PC1 "Crop pests and ECF"	**PC2 "Livestock diseases"**
ECF	.524	.597
FMD	-.226	.796
Locust infestation	-.784	-.309
Striga	.779	-.216
Trypanosomiasis	.797	-.110
%variance explained	**43.609**	**22.900**

The five pests and disease indicators were combined into 2 principal components, together explaining 63% of the variance in the original dataset. It seems that principal component 1, which is most influential in the final pest and disease composite index (due to the 43.6% of variance explained by it), has to do with all indicators but the foot and mouth disease, whereas component 2 is heavily loaded on foot and mouth disease and ECF, which is not surprising as these diseases are frequently observed in the same places. Data for tsetse was missing for Libya, Egypt and Comoros. For these countries the pest and disease risk index was not created.

The Human Health composite index (Table 6) is a combination of two principal components, together explaining 72% of the variance in the original dataset. The most important contributor, PC1, is -not surprisingly- dominated by HIV/AIDS and Malaria risk. Due to its heavy load in PC2, acute respiratory infection (ARI) is also strongly represented.

Table 6: PCA results for human health risk

	PC1 "HIV/AIDS and Malaria"	PC2 "ARI"
ARI	.068	.928
Diarrhea	.486	-.483
HIV/AIDS	.900	.065
Malaria	.850	-.098
%variance	**44.341**	**27.723**

Within the socio-economic risks (Table 7), the first PC combines mainly un-employment and inflation, whereas the second one is completely dominated by population growth. The combination of these 2 factors represents the original dataset very well, with almost 80% of the variance explained by it.

Table 7: PCA results for socio-economic risks

	PC1 "Unemployment and inflation"	PC2 "Population growth"
Inflation	.769	.384
Population growth	-.013	.932
Unemployment	.825	-.294
%variance	**42.391**	**36.729**

The PCA reduced the 9 political risk indicators (Table 8) into 2 principal components, together explaining more than 75% of the variance of the original dataset. The first PC is a combination of mainly highly correlated country-level data (corruption, effective governance, refugees, regulatory quality, rule of law and voice and accountability). The only country-level indicator with much less weight here is the political stability. This political stability gets relatively a lot of weight in PC2, and is highly correlated to the sub-country level data for conflict and IDPs (internally displaced people). Due to the much lower variance explained by the second principal component, these sub-country level indicators do not outweigh the country-level indicators. However, within the countries with high risk indicators important in PC1 (e.g. effectiveness of government and regulatory quality), those areas with high conflict risk and high numbers of IDPs, show up as the hotspot areas.

Table 8: PCA results for political and governance risk

	PC1 "Country performance"	PC2 "Stability"
Conflict	-.134	.854
Corruption	.838	.370
Effective gov	.949	.067
IDPs	.254	.568
Refugees	.848	.366
Regulatory Quality	.928	.154
Rule of law	.812	.407
Stability	.317	.774
Voice and accountability	.814	-.073
%variance	**52.073**	**23.564**

The five categorical risk indices were classified in four quantiles and mapped. The top quantile was labelled to be at very high risk, the second one at high risk, the third one as low risk, the last one as very low risk. The maps are presented in Annex 3.

4.3 Composite indices based on pair wise ranking by stakeholders

The respondent's rankings per risk category yielded weights for each of the indicators. The average scorings together with the minimum and maximum value and the standard deviation are listed in tables 9 to 13. The average weights were used to construct categorical risk maps. These, together with the composite indices based on the PCA can be found in annex 3.

Table 9: Pair wise comparison results for natural disaster risk

	Average	min	max	st-dev
Rainfall Variation	0.15	0.11	0.20	0.04
Cyclones	0.03	0.02	0.06	0.02
Deforestation	0.12	0.05	0.16	0.04
Drought	0.25	0.19	0.29	0.04
Earth Quakes	0.03	0.02	0.04	0.01
Fires	0.05	0.02	0.09	0.02
Floods	0.14	0.07	0.22	0.05
LGP Change	0.07	0.05	0.11	0.02
Water Stress	0.17	0.12	0.20	0.03

For the natural disaster risk indicators there was a lot of agreement between the assessments of the different consulted experts. The standard deviation is low. The factor that was indicated to be of most influence on the vulnerability of people in the COMESA region, is droughts, followed by water stress, floods and rainfall variation. It is interesting that similar factors come out of the PCA. The only factor that gets much more weight in the PCA analysis than through the pairwise comparison is the long term climate change, proxied by the projected LGP change. This is not surprising as is a relatively vague and intangible factor as it is a projection in the future, which is not really observable on the ground. It therefore did not get high rankings from the stakeholders.

Table 10: Pair wise comparison results for pest and disease risk

	Average	min	Max	st-dev
Tsetse	0.18	0.08	0.29	0.11
ECF	0.36	0.21	0.46	0.13
FMD	0.11	0.04	0.21	0.09
Striga	0.27	0.04	0.39	0.20
Locusts	0.09	0.07	0.12	0.03

The crop pests seem to be considered to be contributing more to the vulnerability of people in the COMESA region than livestock diseases. This is in agreement with the PCA analyses in the sense that striga had a high factor loading. However, locust infestation was ranked the lowest, which is in sharp contrast with the results from the PCA. This is probably due to the fact that locust is not very widespread in the region. It is therefore not intuitive for the consulted experts to give it high importance in contributing to vulnerability. However, if it strikes, it can have devastating effects.

Table 11: Pair wise comparison results for human health risk

	Average	min	max	st-dev
Malaria	0.36	0.13	0.59	0.21
HIV/Aids	0.37	0.16	0.61	0.17
Diarrhoea	0.11	0.05	0.22	0.07
Acute Resp. Infection	0.16	0.05	0.48	0.18

Completely in parallel with the PCA, Malaria and HIV/AIDS are considered to be of very high influence on the vulnerability. ARI is ranked third, but the respondents had quite different ideas about that, this is therefore resulting in a very high standard deviation for this indicator and caution in the interpretation of the overall index.

Table 12: Pair wise comparison results for socio-economic risks

	Average	Min	max	st-dev
population growth	0.23	0.09	0.43	0.13
Inflation	0.31	0.14	0.57	0.18
unemployment	0.46	0.14	0.70	0.21

There was relatively good agreement between the respondents. Unemployment was ranked most important. Population growth is getting only half the weight of the unemployment factor. This is much less than it gets in PCA. The two most important indicators being country-level data, the resulting hotspots are including whole countries without further differentiation. It is obvious that this category would benefit tremendously from higher-resolution input data.

Table 13: Pair wise comparison results for political and governance risk

	Average	min	Max	st-dev
Refugees	0.05	0.03	0.06	0.02
Internally Displace People	0.07	0.02	0.15	0.06
Voice and accountability	0.09	0.04	0.13	0.04
Pol. stability and absence of violence	0.12	0.07	0.15	0.03
Regulatory quality	0.09	0.04	0.12	0.03
Rule of law	0.17	0.11	0.23	0.06
Control of corruption	0.12	0.06	0.20	0.06
Government effectiveness	0.17	0.09	0.34	0.11
Number of conflict incidents	0.13	0.05	0.21	0.07

From the eight political and governance risk indicators, the ones relating to the rule of law and government effectiveness are considered to be contributing most to the vulnerability of people in the COMESA region. Again, there was relatively high agreement about this amongst respondents. This analysis was in line with the PCA results.

Again, the five categorical risk indices were classified in four quantiles and mapped (annex 3).

4.4 The risk and vulnerability hotspots

While PCA in principle provides the most objective factor loadings to be used in the construction of the indices, this procedure is likely to overlook specific locally important issues. The weights established through the pairwise ranking by local stakeholders include this local knowledge while they are at the same time ensuring stakeholder buy-in and increasing the likelihood that the results of the study will be accepted and used.

Visual inspection of the risk indices in the maps resulting from the two alternative weighing schemes suggests that both are yielding broadly the same risk patterns (see annex 3). In order to quantify agreement between the two methods, the top quantile (very high risk) of the pairwise comparison method was cross-tabulated against the PCA top quantile. Table 14 below tabulates the percentages of agreement/non-agreement for the five categorical risk indices.

Table 14. Percentages of agreement for the five categorical risk indices of the PCA and pairwise comparison methods

	Natural disaster	Pest and diseases	Human Health	Socio-economic	Political and governance
Agreement: at high very high risk	17%	23%	15%	17%	22%
Agreement: not at very high risk	67%	74%	76%	71%	76%
Total agreement:	***84%***	***97%***	***91%***	***88%***	***98%***
At very high risk according to pairwise comparison only	8%	2%	0%	5%	0%

At very high risk according to PCA only	8%	1%	9%	7%	2%
Total disagreement:	***16%***	***3%***	***9%***	***12%***	***2%***

The political and governance risk as well as pest and disease risk indices show very good agreement, with respectively only 2 and 3% of the cells where there is no agreement between the different methods. The two methods differ most in the natural disaster index, with a total of 16% of the area being classified as a very high risk area according to only one of the two methods. The overall accuracy assessments (see annex 3) show the same pattern. With an exception of the natural disaster risk indices, which show a general agreement of about 55%, the indices show an fair to good agreement (from 62% to 87%).

Figures 3 and 4 contain the maps of the five categorical risk hotspots, which were constructed on the basis of the maps in Annex 3. These can be used by decision makers interested with targeting specific types of risk (Natural disasters, human health, crop and livestock pests and diseases, human health risk hotspots, socio- economic). Figure 5 indicates multiple hazard risks which is made by combining the hotspot maps for the above five risk indicators. Risk profiles in the different countries are quite varied. Twelve out of the sixteen countries for which data was available face multiple risks. Zambia, Zimbabwe, Burundi, Sudan and Kenya are highly vulnerable as they are hotspots of more than three types of risks occurring at the same time in the same locations. Parts of Rwanda, Uganda and DRC are also to a big extent vulnerable, they are exposed to at least two risk categories.

Table 15 summarises for the different hotspot categories per country the total area, total population, major farming system, malnutrition level and average travel time (in hours) to the nearest town with a population of more than 250,000 inhabitants. It should be noted that Mauritius and Seychelles are missing from this table; this can be traced back to the quality of the secondary data that was used in the analysis. There was a lot of missing data for these islands; therefore they were not included in the analysis. It would, however, be wrong to assume they don't face any risks. The same remark counts for other than natural disaster risks in Madagascar and human health risk in Comoros.

Focusing on each of the five risk categories analyzed in this study we find that political and Governance Risk hotspots are affecting the largest area in COMESA, i.e. almost a quarter of the land area. Political and governance risk hotspots are clustered in 5 countries: DRC, Burundi, Eritrea, Sudan and Zimbabwe. More than 60% of the population in Zimbabwe, DRC, and Sudan are living in political/governance hotspot areas. Eritrea has at least a quarter of its population living in such areas (Table 15).

Natural disaster risk hotspots are mostly found in the North and East of the COMESA region. The rangelands seem to be more under pressure. Although a huge land area within COMESA is exposed to very high natural disaster risk, in terms of population impinged upon natural disaster risks score much lower. This can be explained by the fact that those areas subject to recurrent natural disasters often very low population densities. Still, in some countries, i.e. Djibouti and Malawi, the percentage of the total population struck by high natural disaster risk is about 70%.

Socio-economic risk affects close to a third (27%) of the COMESA population indicating the significance of this risk category to the people within the region. The level of malnutrition in the hotspots is 4 to 6% higher than the average in the COMESA region (Table 15). This, however, varies from country to country. The average malnutrition level in the natural disaster hotspots is the big exception here. This might be explained by the fact that more than half of the natural disaster hotspots are located in Egypt and Libya, which are countries malnutrition levels that are only half of the COMESA average.

Of interest is also that most of the hotspots are mainly found in the rangelands. The only exception to this is the pest and disease hotspots.

The risk profiles within the different countries are quite varied. In thirteen out of the seventeen countries listed there are areas where people face multiple risks. For some close to or even more than 50% of the population faces multiple risks e.g. Malawi (68%), Uganda (49%), Zambia (61%) and Zimbabwe (71%) (Table 15). It is not surprising that in most of these countries the malnutrition level is more than 10% above the COMESA average. Malawi and Zimbabwe are big exceptions here.

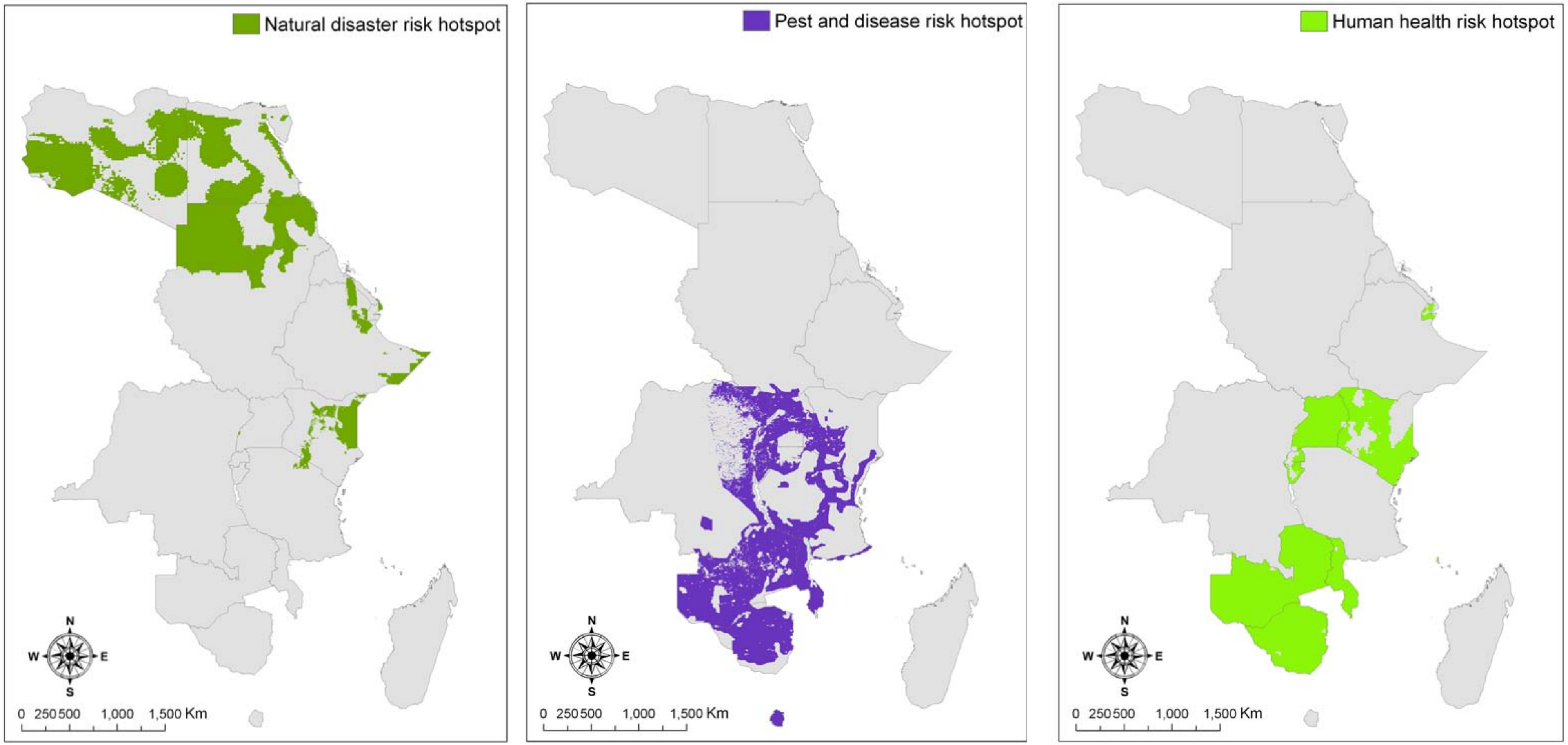
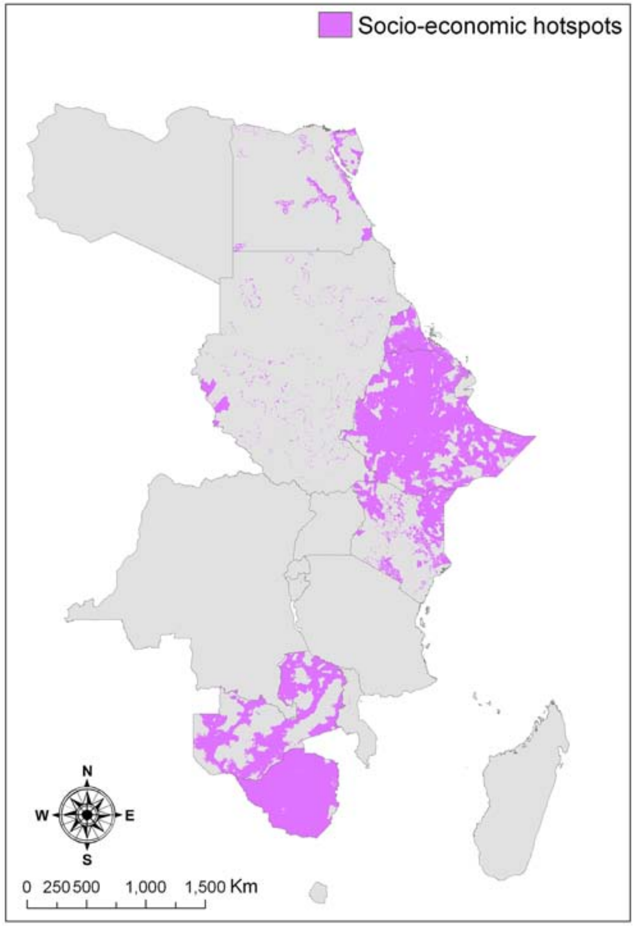


Figure 3: Hotspots for Natural disaster, crop and livestock pests and diseases and human health risks in the COMESA region



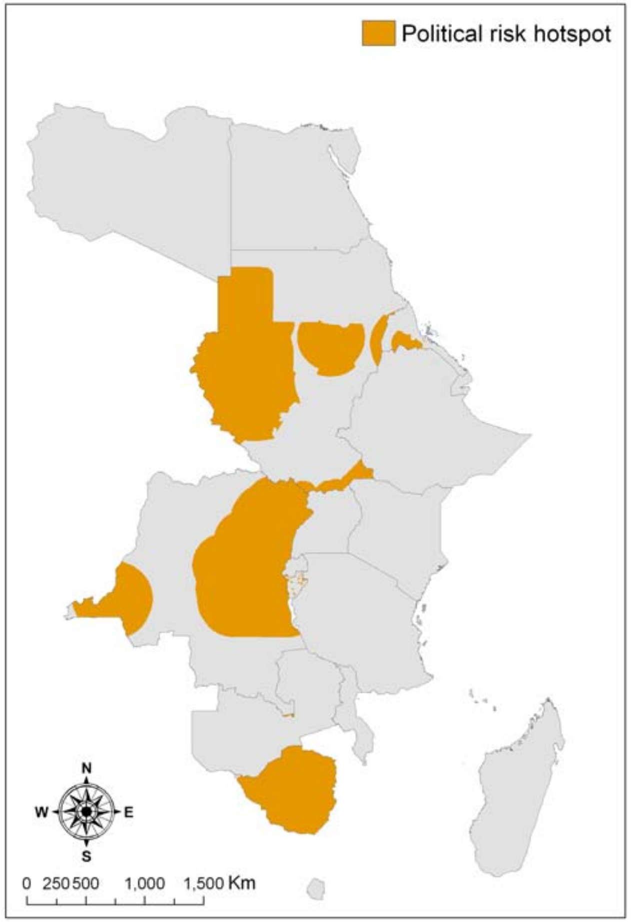


Figure 4: Hotspots for socio-economic and political risks in the COMESA region

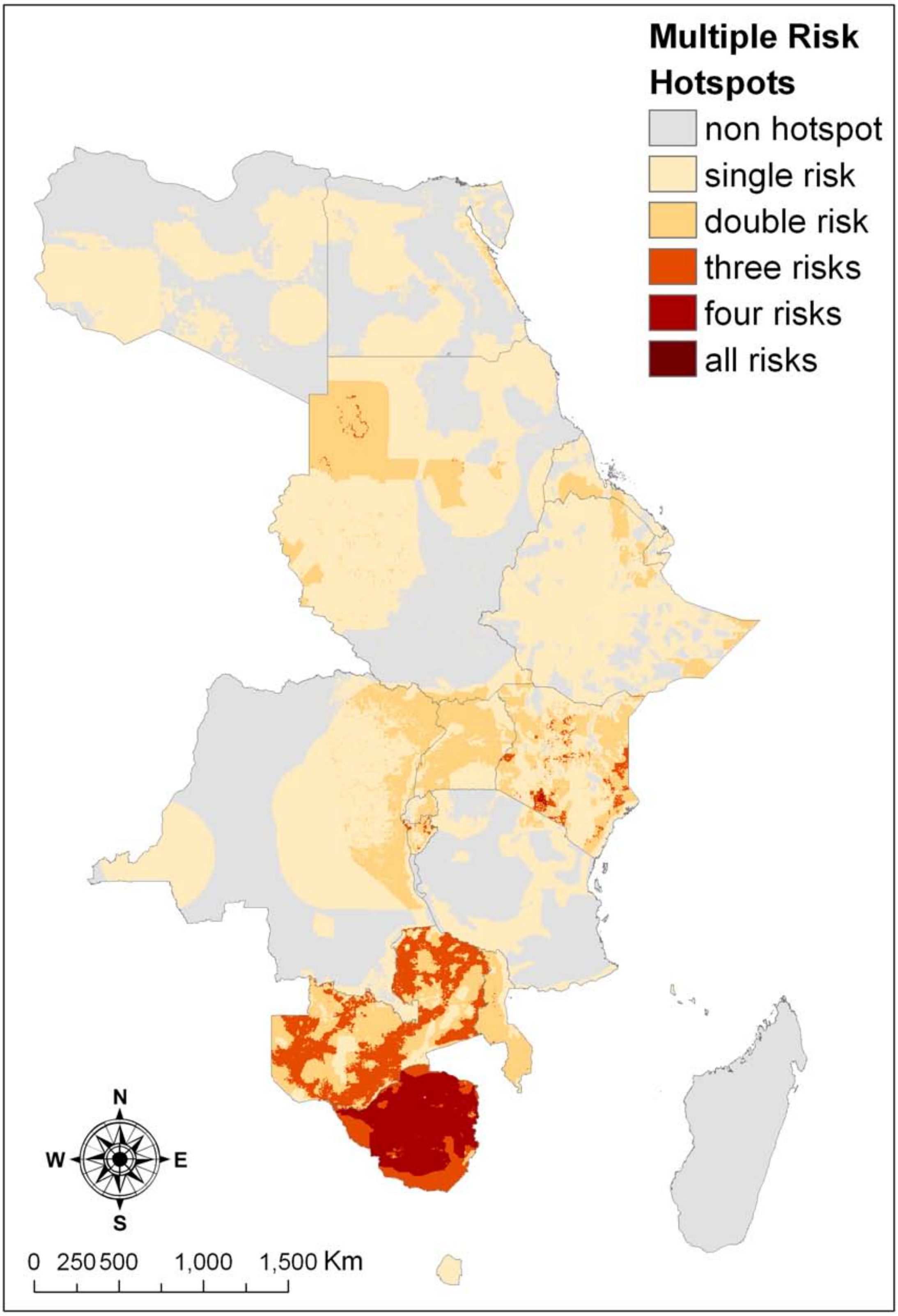


Figure 5: Composite Vulnerability hotspots map for COMESA

Table 15: Characterization of the Hotspots based on various parameters

	Area ('000 km2)	%	Population ('000)	%	Major Farming System	Travel time to town > 250,000 (hours)	% children under five stunted
Burundi							
Pest & Disease Risk	14	52	3,613	59	Mixed Rainfed	6.9	56.6
Human Health Risk	19	73	4,328	70	Mixed Rainfed	6.5	56.7
Pol. and Governance Risk	5.2	20	926	15	Mixed Rainfed	6.5	56.7
Socio-Economic Risk	0.2	1	66	1	Mixed Rainfed	5.6	56.4
Multiple Risk	9.2	35	2,397	39	Mixed Rainfed	7.0	56.7
Total Country	27		6,159		Mixed Rainfed	6.7	56.7
Comoros							
Human Health Risk	0.7	37	198	27	Other	No data	42.1
Total Country	1.9		734		Other	No data	41.7
DRC							
Natural Disaster Risk	0.1	0	18	0	Other	23.7	46.5
Pest & Disease Risk	238	10	8,274	17	Other	13.0	40.8
Human Health Risk	0.2	0	8.5	0	Rangeland	6.0	45.9
Pol. and Governance Risk	1,133	49	31,441	63	Other	10.1	40.0
Socio-Economic Risk	0.1	0	0.8	0	Rangeland	4.2	46.6
Multiple Risk	166	7	6,884	14	Other	13.3	41.6
Total Country	2,324		49,607		Other	10.9	39.6
Djibouti							
Natural Disaster Risk	5.5	26	331	71	Rangeland	11.3	46.8

Human Health Risk	14	*64*	124	*26*	Rangeland	7.9	44.9
Socio-Economic Risk	0.3	*1*	0.8	*0*	1	13.0	42.3
Multiple Risk	0.1	*0*	0.5	*0*	Rangeland	12.0	47.6
Total Country	21		469		Rangeland	8.9	43.7
Egypt							
Natural Disaster Risk	388	*40*	453	*1*	Rangeland	17.0	17.1
Socio-Economic Risk	66	*7*	13,090	*19*	1	6.5	17.7
Total Country	981		68,257		Rangeland	14.7	17.4
Eritrea							
Natural Disaster Risk	4.6	*4*	53.1	*2*	Rangeland	11.3	40.4
Pol. and Governance Risk	26	*22*	1,500	*43*	Mixed Rainfed	6.7	43.0
Socio-Economic Risk	92	*78*	3,126	*89*	Rangeland	11.9	41.5
Multiple Risk	20	*17*	1,101	*31*	Mixed Rainfed	7.1	42.7
Total Country	118		3,500		Rangeland	13.2	41.5
Ethiopia							
Natural Disaster Risk	88	*8*	1,257	*2*	Rangeland	12.9	46.9
Human Health Risk	0.0	*0*	0.4	*0*	Rangeland	8.1	46.4
Socio-Economic Risk	906	*80*	60,818	*97*	Mixed Rainfed	17.8	49.6
Pol. and Governance Risk	0.5	*0*	20	*0*	Mixed Rainfed	10.1	48.5
Multiple Risk	49	*4*	795	*1*	Rangeland	12.8	46.8
Total Country	1,130		62,663		Rangeland	18.4	49.1
Kenya							
Natural Disaster Risk	141	*24*	1,371	*5*	Rangeland	12.5	37.1
Pest & Disease Risk	99	*17*	13,411	*46*	Mixed Rainfed	9.1	36.2
Human Health Risk	389	*67*	18,895	*65*	Rangeland	11.0	38.1
Socio-Economic Risk	185	*32*	5,214	*18*	Rangeland	12.6	36.4
Pol. and Governance Risk	0.5	*0*	0.3	*0*	Rangeland	20.3	36.8
Multiple Risk	182	*31*	9,756	*33*	Rangeland	11.2	37.0
Total Country	581		29,202		Rangeland	11.5	37.5
Libya							

Natural Disaster Risk	705	*44*	213	*5*	Rangeland	21.4	15.1
Total Country	1,612		4,737		Rangeland	18.2	15.1
Malawi							
Pest & Disease Risk	67	*57*	7,801	*68*	Mixed Rainfed	7.9	47.4
Human Health Risk	116	*99*	11,413	*100*	Mixed Rainfed	7.7	47.0
Socio-Economic Risk	1.3	*1*	10	*0*	Rangeland	13.8	50.0
Multiple Risk	66	*56*	7,791	*68*	Mixed Rainfed	7.6	47.5
Total Country	117		11,432		Mixed Rainfed	7.9	46.9
Rwanda							
Pest & Disease Risk	13	*54*	4,270	*57*	Mixed Rainfed	6.7	63.7
Human Health Risk	14	*54*	3,358	*45*	Mixed Rainfed	5.3	61.4
Pol. and Governance Risk	0.2	*1*	16	*0*	Mixed Rainfed	12.1	44.5
Multiple Risk	7.6	*30*	1,953	*26*	Mixed Rainfed	5.4	63.6
Total Country	25		7,535		Mixed Rainfed	7.0	61.7
Sudan							
Natural Disaster Risk	730	*29*	1,729	*6*	Rangeland	16.5	39.5
Pest & Disease Risk	19	*1*	164	*1*	Rangeland	15.9	38.9
Pol. and Governance Risk	1,177	*47*	19,626	*65*	Rangeland	10.3	45.4
Socio-Economic Risk	66	*3*	599	*2*	Rangeland	10.9	45.9
Multiple Risk	259	*10*	1,143	*4*	Rangeland	14.8	43.3
Total Country	2,502		30,028		Rangeland	13.0	42.4
Swaziland							
Pest & Disease Risk	11	*65*	583	*64*	Other	9.3	29.8
Total Country	17		909		Other	9.3	29.7
Tanzania, United Rep of							
Natural Disaster Risk	10	*1*	120	*0*	Rangeland	15.6	42.6
Pest & Disease Risk	214	*23*	9,653	*28*	Mixed	10.7	47.5

Human Health Risk	0.8	*0*	76	*0*	Rainfed Mixed Rainfed	10.6	44.4
Socio-Economic Risk	0.1	*0*	5.4	*0*	Rangeland	11.8	45.5
Multiple Risk	5.3	*1*	77	*0*	Rangeland	16.5	43.3
Total Country	933		33,890		Mixed Rainfed	11.7	44.5
Uganda							
Natural Disaster Risk	0	*0*	25	*0*	Other	43.2	47.8
Pest & Disease Risk	109	*45*	12,595	*54*	Mixed Rainfed	8.1	40.1
Human Health Risk	235	*97*	21,669	*94*	Mixed Rainfed	8.1	40.0
Pol. and Governance Risk	1.0	*0*	36	*0*	Mixed Rainfed	16.0	42.5
Socio-Economic Risk	0.0	*0*	0.7	*0*	Rangeland	15.6	36.8
Multiple Risk	97	*40*	11,384	*49*	Mixed Rainfed	7.8	40.4
Total Country	242		23,124		Mixed Rainfed	8.4	40.2
Zambia							
Pest & Disease Risk	439	*59*	6,166	*62*	Rangeland	14.6	47.6
Human Health Risk	746	*99*	9,681	*97*	Rangeland	14.9	47.5
Socio-Economic Risk	380	*51*	6,162	*62*	Rangeland	11.8	48.2
Pol. and Governance Risk	0.3	*0*	10	*0*	Other	20.3	40.5
Multiple Risk	454	*61*	6,065	*61*	Rangeland	14.6	47.7
Total Country	750		9,989		Rangeland	14.8	47.4
Zimbabwe							
Pest & Disease Risk	204	*52*	6,728	*54*	Mixed Rainfed	6.0	27.3
Human Health Risk	388	*99*	12,483	*100*	Mixed Rainfed	6.5	27.4
Socio-Economic Risk	383	*98*	12,201	*97*	Mixed Rainfed	6.4	27.3
Pol. and Governance Risk	388	*99*	12,512	*100*	Mixed Rainfed	6.4	27.4

Multiple Risk	263	*67*	8,910	*71*	Mixed Rainfed	6.4	27.3
Total Country	390		12,518		Mixed Rainfed	6.5	27.4
Total							
Natural Disaster Risk	2,073	*17*	5,571	*2*	Rangeland	17.9	26.7
Pest & Disease Risk	1,428	*12*	73,259	*20*	Mixed Rainfed	11.1	42.2
Human Health Risk	1,922	*16*	82,275	*22*	Rangeland	10.9	40.7
Socio-Economic Risk	2,080	*17*	101,294	*27*	Rangeland	13.2	42.4
Pol. and Governance Risk	2,731	*22*	66,087	*18*	Rangeland	9.6	40.3
Multiple Risk	1,579	*13*	58,255	*16*	Rangeland	11.8	41.2
Total Countries	12,361		370,505		Rangeland	13.5	36.0

** The farming system classification used, is an aggregated version of Kruska et al. (2002). Differentiation was made between Rangelands, Crop-Livestock Mixed Irrigated, Crop-Livestock Mixed Rainfed and Other (including urban, coastal, forestry, etc).*

5. Conclusions and way forward

5.1 Conclusions

5.1.1 Conclusions on the results

The result of the current hotspot mapping effort identifies those areas that are most likely to be affected by hazards that contribute to people's vulnerability. These are therefore the areas where we expect the people to have a great need for coping mechanisms and risk management strategies. In some of these areas the risk management strategies in place are more effective than in other ones, i.e. the coping capacity (of the coupled human-environment system) differs across space.

Although the resolution of these maps might be coarse due to the limitations in the input data, there is however very valuable information coming from the different indicator (categories of risk) as well as the combined hotspots maps. There is no one-fits-all solution to reducing vulnerability. Clearly, certain interventions have more impact in certain targeted places; particular risks ask for particular, context-specific interventions, this is the value of the maps focusing on different risk categories provided here. The identification of major threats and some of the characterisation information 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.

5.1.2 Strengths of the COMESA hotspot mapping

This report provides information on where various risk factors occur in COMESA based on a uniform analysis for the whole of the region, this will allow cross-country comparisons be made. Multi-dimensional approach of assessing exposure to risk is also a strength of this analysis, It is clear that it is impossible to have one solution for all problems, this study categorises risk factors into five groups and for each group an aggregate risk map is generated based on a number of indicators. This way it will be possible for actors interested with specific interventions to visualise vulnerability based on a particular perspective e.g. the human disease risk map might be of use to stakeholders responsible for public health related interventions, while that of crop and livestock diseases would be of particular interest to epidemiologists and crop diseases specialists. The study also indicates areas where there is high risk of multiple hazards (hotspots for various risk categories). These areas might require collaborative efforts in the interventions. Such information can inform a range of disaster prevention and preparedness measures, including prioritization of resources, targeting of more localized and detailed risk assessments, implementation of risk-based disaster management and emergency response strategies, and development of long-term land-use plans and multi-hazard risk management strategies.

As CAADP Pillar III focuses on the chronically food insecure and populations vulnerable to and affected by various crises and emergencies, the results of this study are expected to inform where to target in the implementation of this pillar.

5.1.3 Limitations of the COMESA hotspot mapping and possible ways for addressing them

The regional analysis undertaken in this study is limited by issues of scale as well as by the availability and quality of data.

Issues of scale

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 sub-national level interventions. In order to derive actionable, context-specific policy interventions aimed at reaching the vulnerable communities within COMESA countries there is still a need to zoom in from the aggregated level of the risk 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. One way of achieving that is to conduct detailed cases studies in some selected sites within the hotspots to gather more information about the occurrence of the identified risk in the areas and establish what would be the most appropriate interventions to suit a particular area and context. Such studies will also serve as validation for the accuracy of this mapping work. Similarly, use of information from other initiatives on vulnerability and poverty mapping in the region (see section 1.3.2) 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.

Issues of data quality and availability

As in any modelling 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 COMESA region. Even where the data exist 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 for the COMESA region. 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. Box 2 provides examples of data related issues associated with this study. 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.

Box 2: Some examples of data issues in this study

i)Data on political risks:

Number of IDPs and refugees data was used in this analysis. It is important to remember that these 2 indicators are only proxies of political risk and actually snapshots for the year 2005. The analysis would gain a lot from data over different years or inclusion of better or more proxies.

ii)Quite a number of the country-level indicators instead of than sub-national data

In this case we used one value for the whole country where we could not get sub national data on some indicators. This makes spatial variation to be rather low, higher resolution level data would be very useful.

iii) Failure to include other important indicators due to lack of data

We missed out some other important indicators in the analysis due to data limitation. For example some diseases such as CMD and BXM were left out in the hotspot analysis.

5.1.4 Vulnerability mapping methodologies

This study combined two approaches in the generation of maps, one way was the PCA analysis and the other was the participatory pairwise ranking. Preliminary results were initially generated based on the first approach using an initial list of indicators. The different risk indicators as well as the results of the above described analysis were presented to and discussed with various experts and stakeholders dealing with vulnerability issues in the region. Their views and suggestions were later incorporated into the analysis. The levels of contribution of the risk factors as assigned by the experts and stakeholders were integrated into the analysis through the use of MCE techniques. This insured stakeholder involvement in the generation of the vulnerability maps. Each of the methods has strengths as well as weaknesses. In mapping vulnerability it is important to get a good feel of what are the important risk factors on the ground as well as their level of importance in determining ultimate vulnerability status of an area. To effectively achieve this, there is a clear need for stakeholder involvement because analysts, sitting in the office might not be able to accurately capture all dimensions of risk based on varied perspectives. As a result, they might miss out some important indicators. For example ARI and Diarrhea were originally not included in the preliminary analysis of this study. However, the participatory process typically yields a very long list of indicators/variables. The danger in this is that a number of them are bound to be very highly correlated and will therefore be double counted. Through PCA these correlations are removed and that problem is therefore solved. In addition to that, the PCA is a much faster and cheaper process, that is easily replicable when more up-to-date data comes in or when a new indicator needs to be included.

5.2. Recommendations on the way forward

- **Knowledge management / targeted packaging and provision of information.** Hotspots maps presented here will have more chances to be of use to policy and decision makers dealing with vulnerability issues in COMESA if packaged with other additional information on specific risk for vulnerability and their recommended interventions. Use of existing information might be valuable here. For example it will be good to together with these maps, provide specific research/policy documents on issues such as HIV/AIDS recommendations, integrated tick & tsetse control among others. It would be good to explore how this packaging can be done and disseminated in the near future.

- **Need for a future update of the mapping work**
Maps presented in this report provide information on the hotspots based on the currently available data; this can serve as baseline on the existing situation. A similar work on vulnerability hotspot mapping will be required in future (after about one to two years) to provide an update of the vulnerability status based on updated data for the indicators. Such kind of analysis will provide useful Monitoring and Evaluation data for agriculture and rural development initiatives in the region (e.g. PRSPs, MDGs and CAADP), hence creating an indication of their impacts. Depending on data availability, this future work will also need to include indicators that could not be included in the analysis in this report (see section 5. 1.3) to enhance the accuracy of the hotspot predictions.

- **In-depth analysis**
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.

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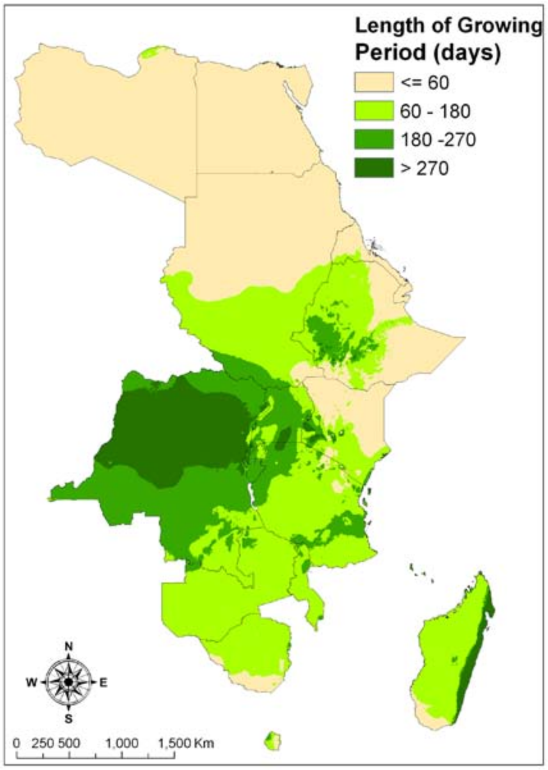
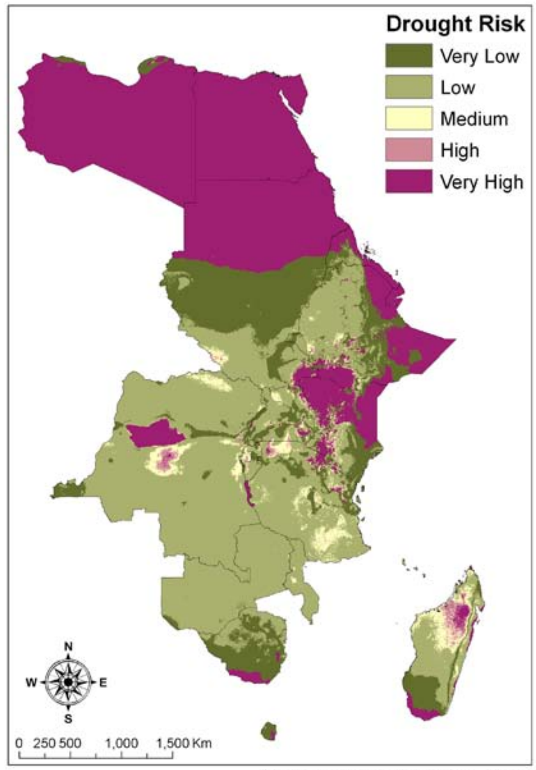
8. List of Acronyms

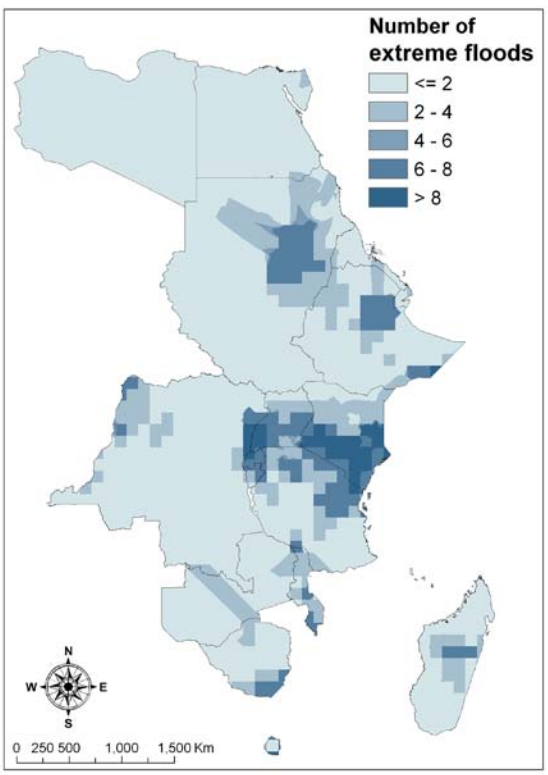
AARN	Animal Agricultural Research Network
AATF	African Agricultural Technology Foundation
AHP	Analytical Hierarchical Structure
ARI	Acute Respiratory Infection
ARMA	*Atlas du Risque de la Malaria en Afrique*
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
BXW	Banana Xanthomonas Wilt
CAADP	Comprehensive African Agriculture Development Program
CIESIN	Center for International Earth Science Information Network
CMD	Cassava Mosaic Disease
COMESA	Common Market for Eastern and Southern Africa
C3P	Crops Crisis Control Project
DHS	Domestic Household Survey
DFID	Department for International Development
DRC	Democratic Republic of Congo
ECA	Eastern and Central Africa
ECF	East Coast Fever
ESSP-IFPRI	Ethiopia Strategy Support Program
FAO	Food and Agricultural Organisation
FAOSTAT	Food and Agricultural Organisation Statistics
FEWSNET	Famine Early Warning Systems Network
FIVIMS	Food Insecurity and Vulnerability Information and Mapping Systems
FMD	Food and Mouth Disease
GIS	Geographical Information Systems
GRUMP	Global Rural Urban Mapping Project
HIV/AIDS	Human Immuno-Defficiency Syndrome/ Acquired Immuno Deficiency Syndrome
IDMC	Internal Displacement Monitoring Centre
IDPs	Internally Displaced Persons
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute
INIBA	International network for improvement of banana and plantain
IPC	Integrated Food Security and Humanitarian Phase Classification
IPMS	Improving Productivity and Market Success of Ethiopian Farmers
IWMI	International Water Management Institute
KACCAL	Kenya Adaptation Climate Change in Arid Lands
LGP	Length of Growing Period
MARA	Mapping Malaria Risk in Africa
MCE	Multi-Criteria Evaluation
MDGs	Millennium Development Goals

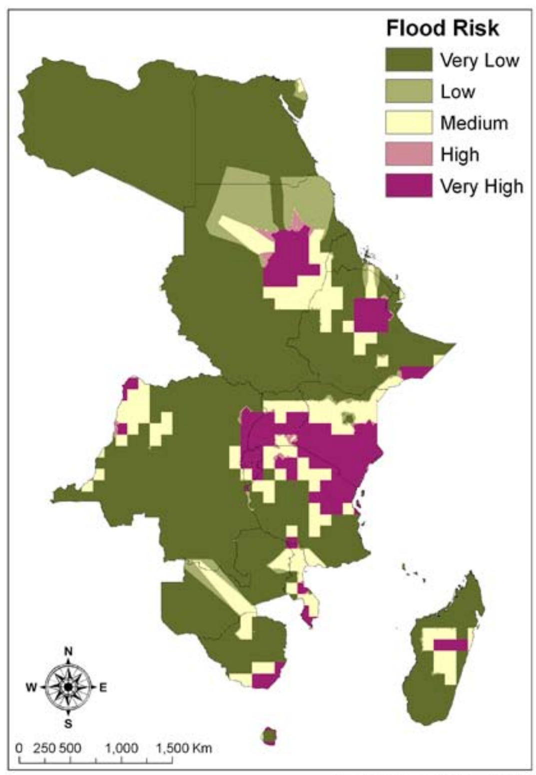
METs	Multi criteria Evaluation Techniques
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics Space Administration
NCAR	National Center for Atmospheric Research
NEPAD	New Partnership for Africa's Development
NGOs	Non Government Organisations
NI	Natural Inflow
NRI	Natural Resources Institute
RELPA/PACAPS	Regional Enhanced Livelihoods in Pastoral Areas
ReSAKSS-ECA	Regional Strategic Analysis Knowledge Management System-Eastern and Central Africa
RHVP	Regional Hunger Vulnerability Programme
OAU	Organization of Afican Union
PAATS	Program Against African Trypanosomiasis
PACAPS	Pastoral Areas Coordination, Analysis & Policy Support
PC	Principal Components
PCA	Principal Component Analysis
PRSPs	Poverty Reduction Strategy Papers
SSA	Sub Saharan Africa
UBOS	Ugandan Bureau of Statistics
UK	United Kingdom
UN	United Nations
UNEP	United Nation Environmental Program
UNICEF	United Nations Children's Fund
VAM	Vulnerability Analysis and Mapping
WFP	World Food Program
WHO	World Health Organization
WMS	Welfare Monitoring Survey
WR	World Resource





Source: Thornton et al, 2006





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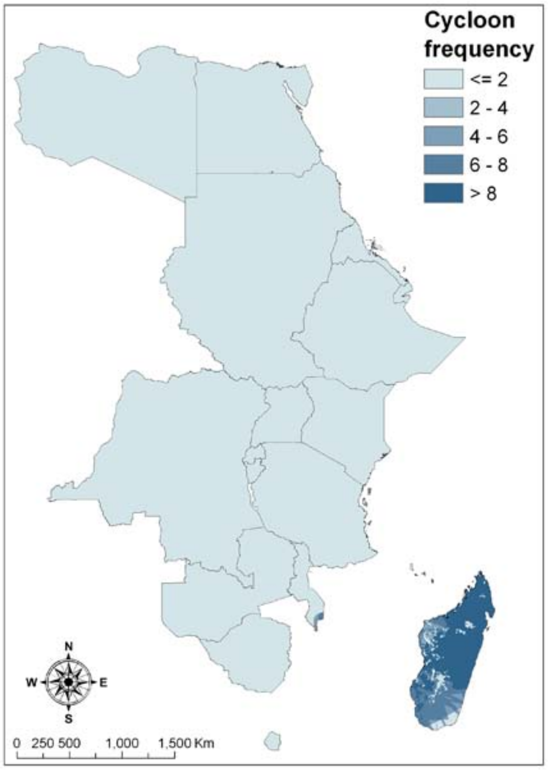

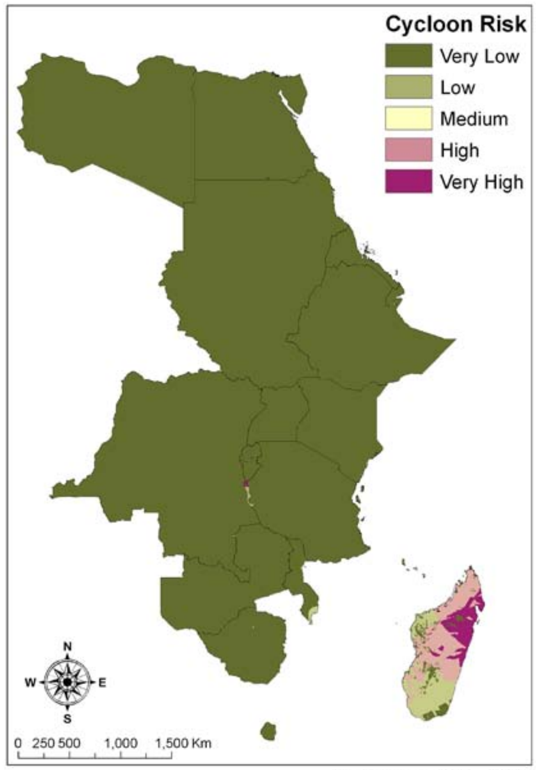

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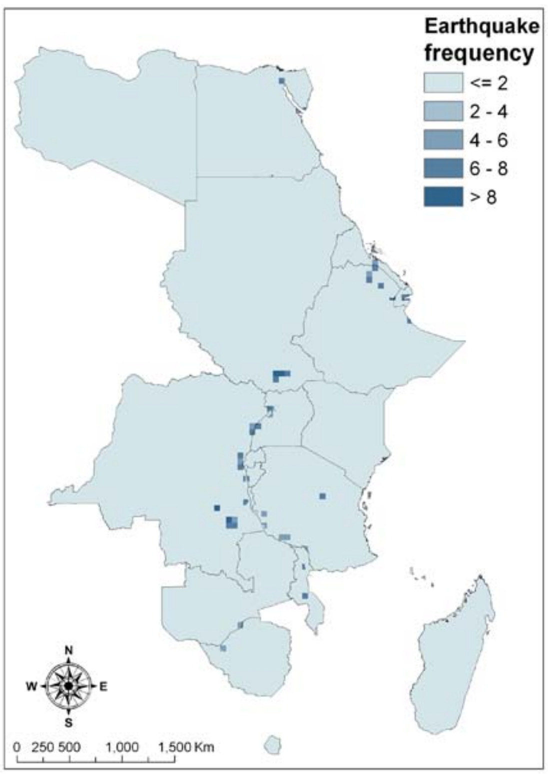

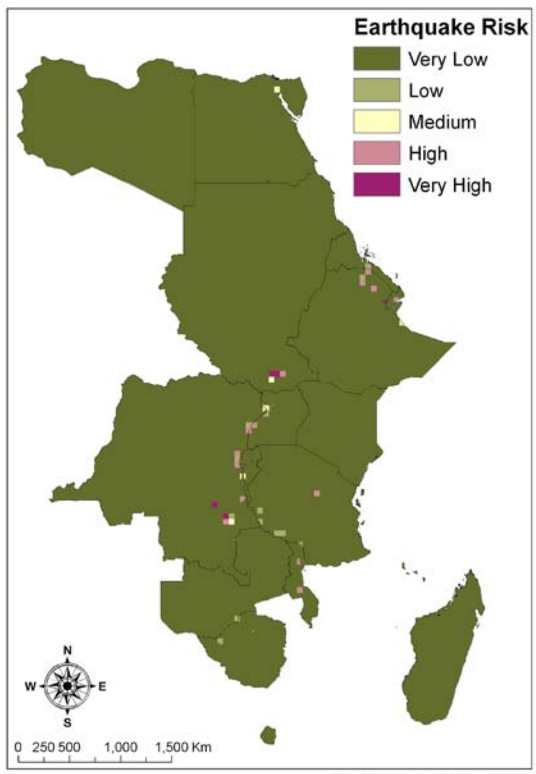

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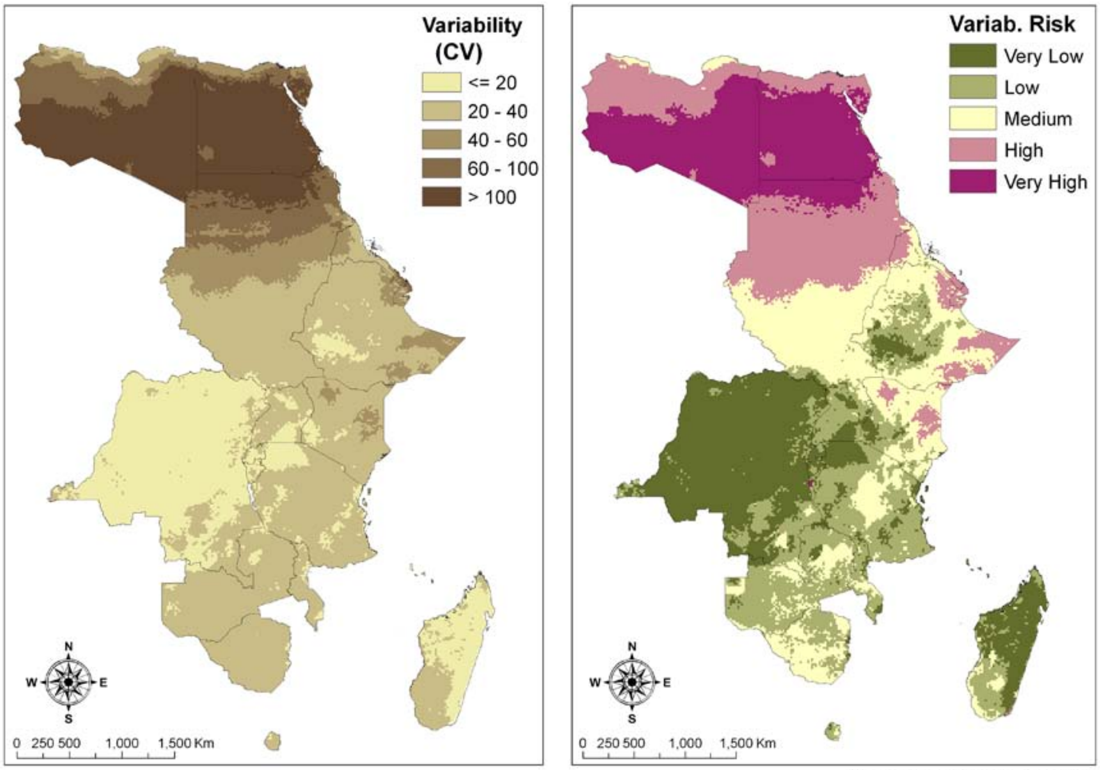

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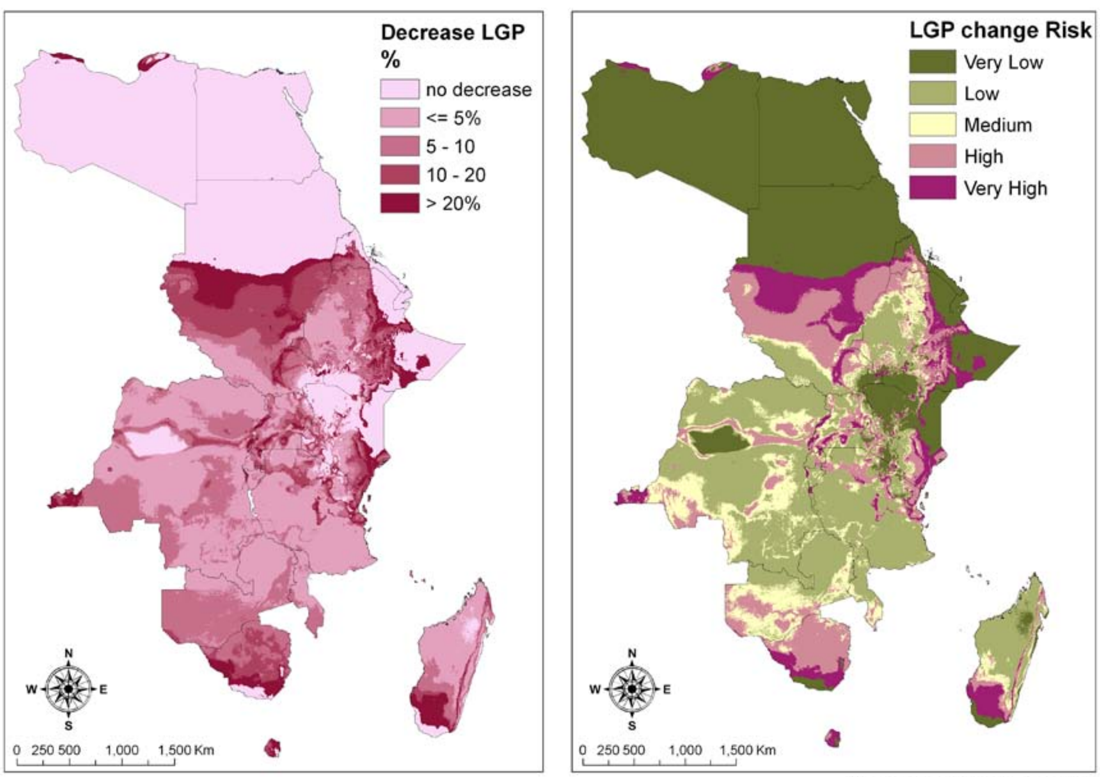

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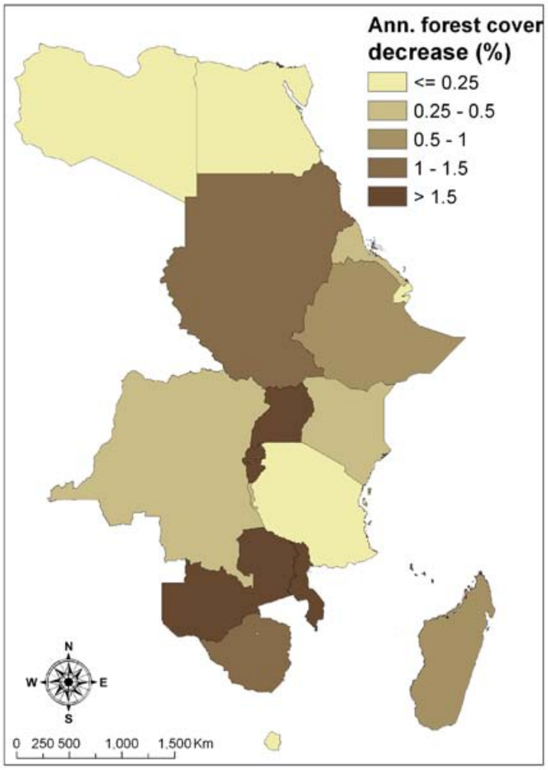

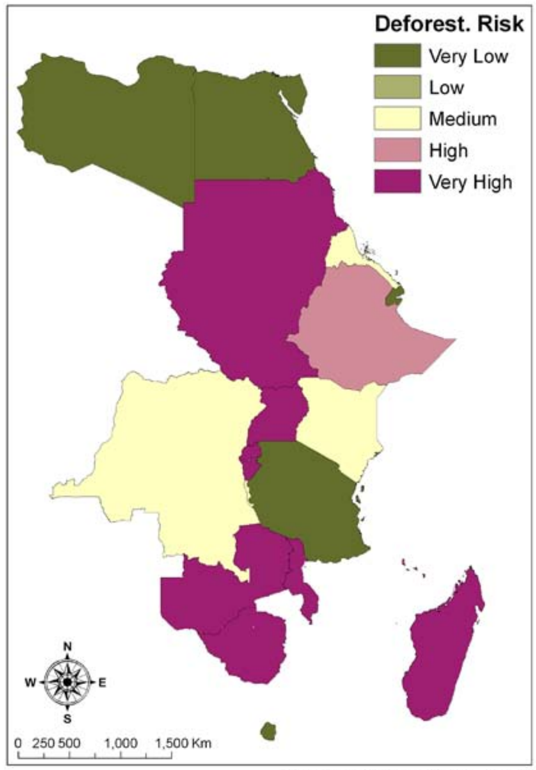

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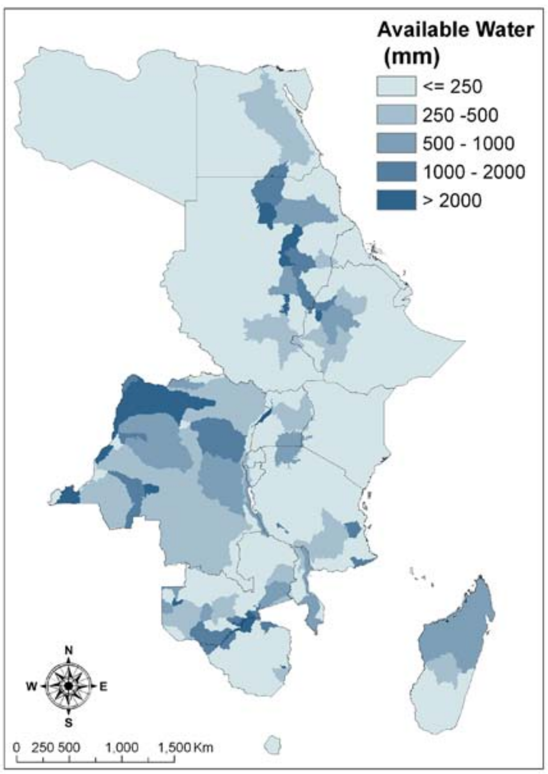

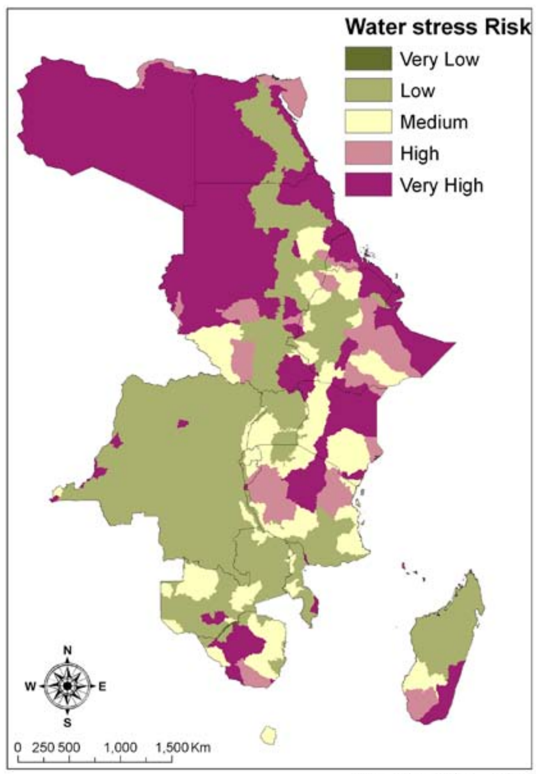

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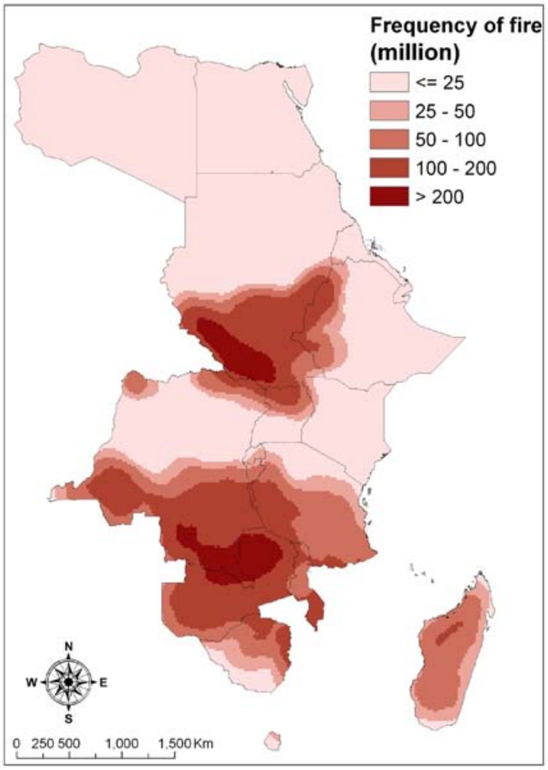

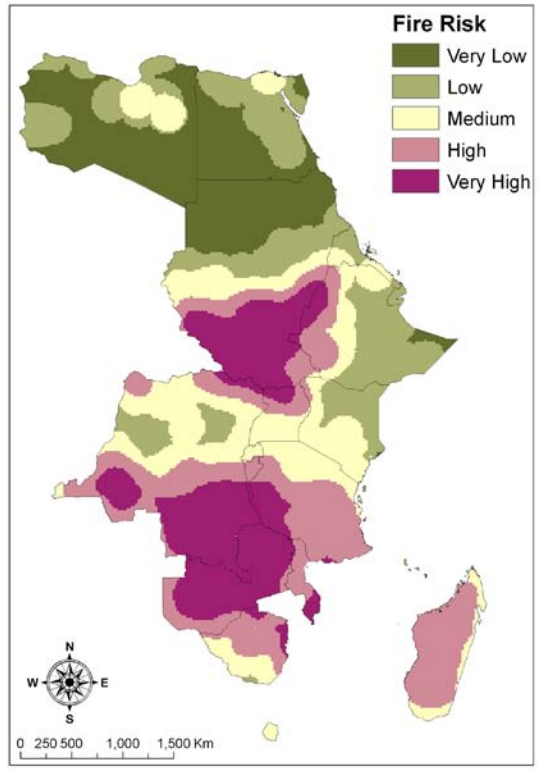

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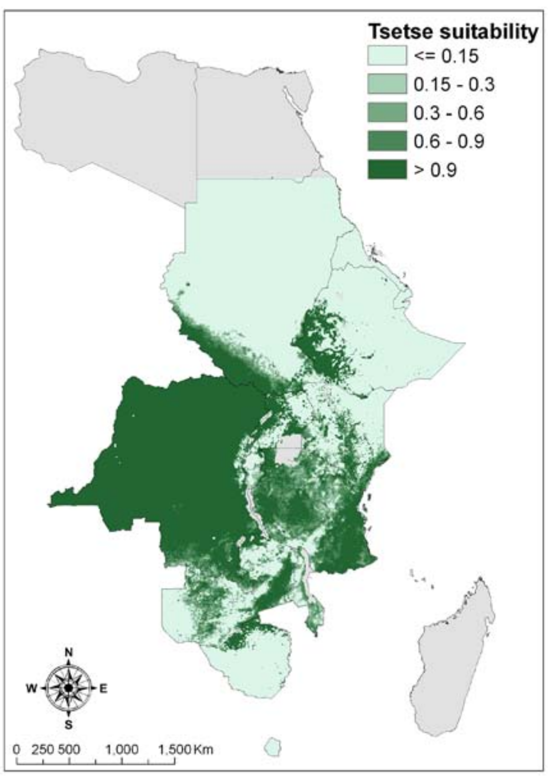

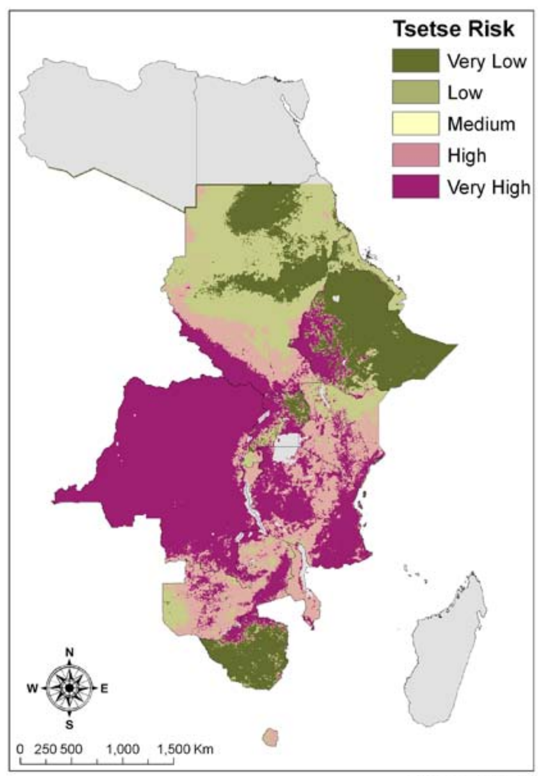

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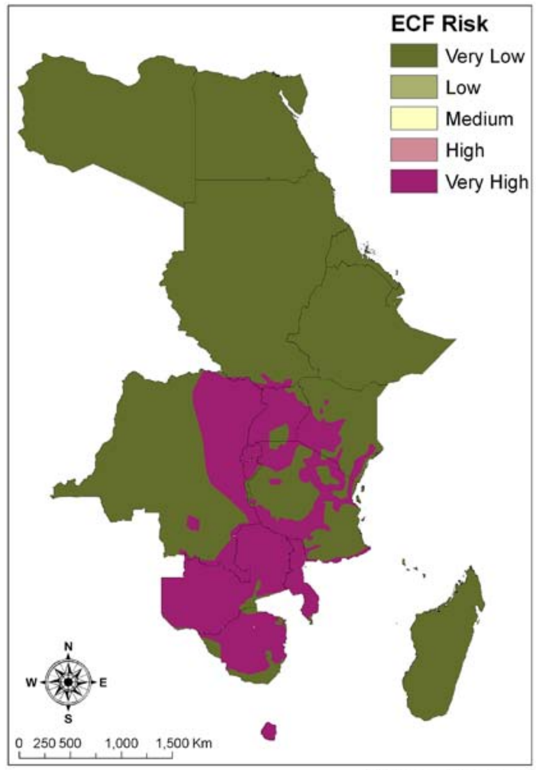

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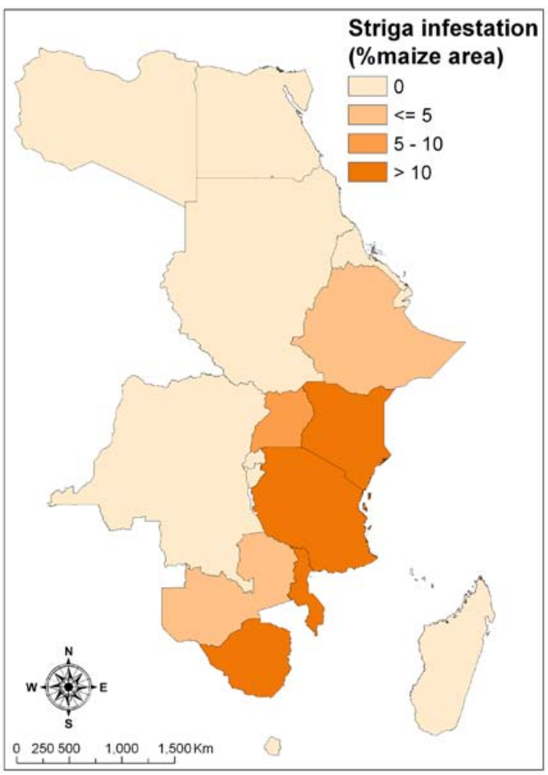

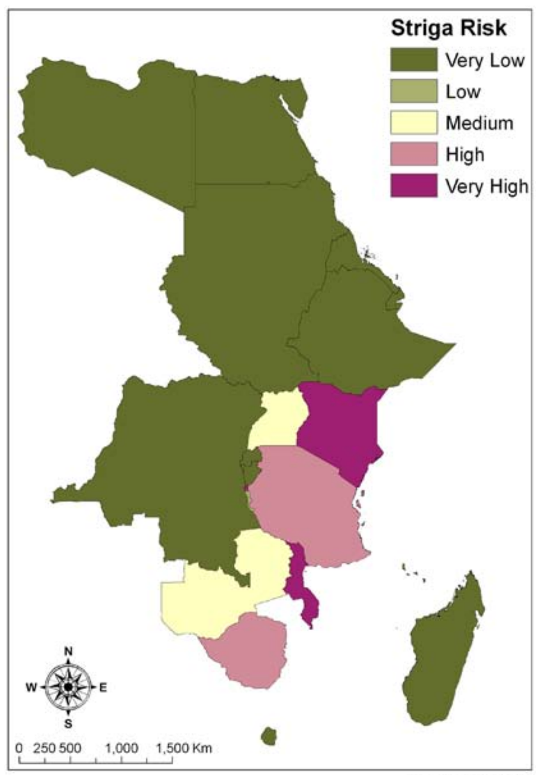

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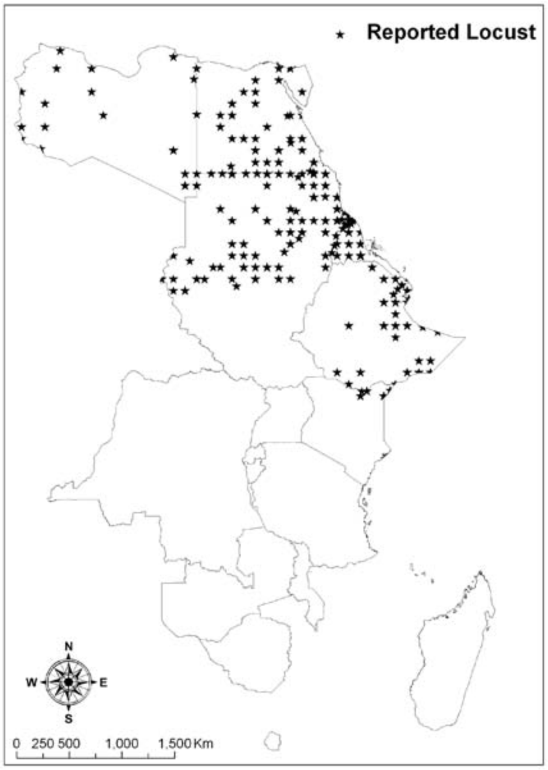

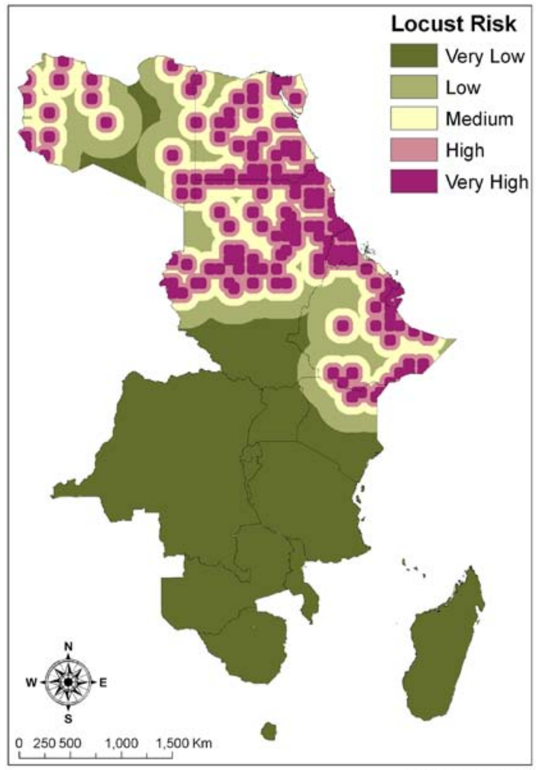

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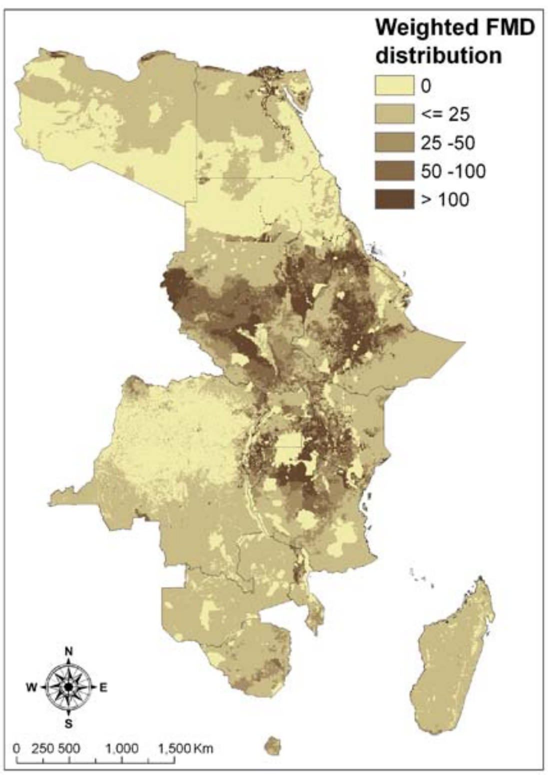

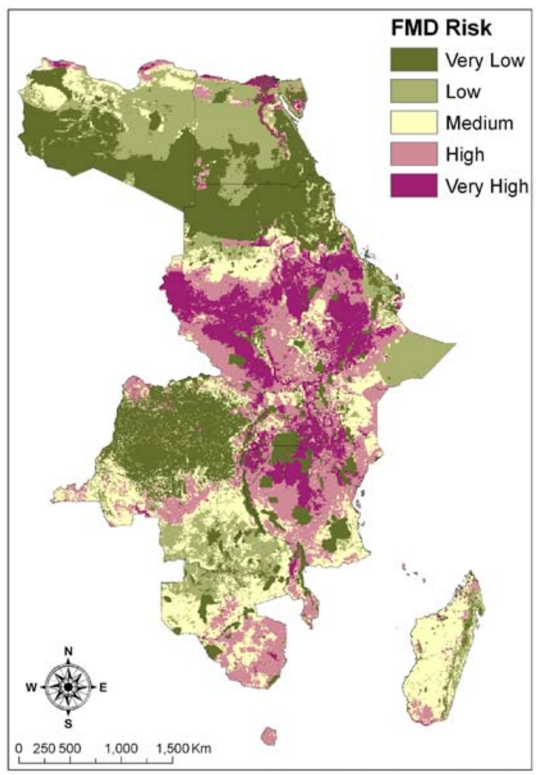

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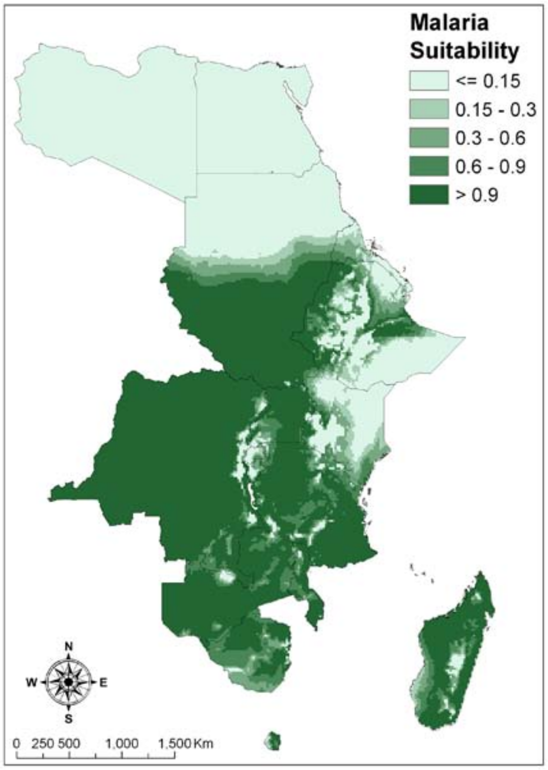

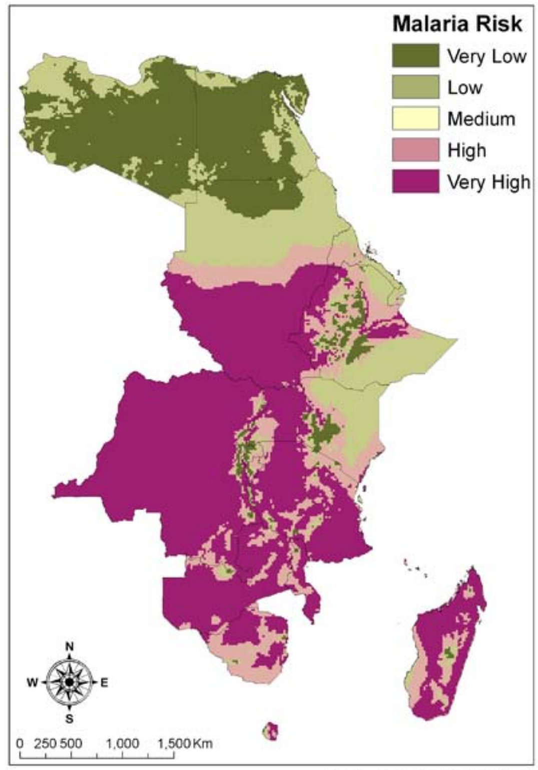

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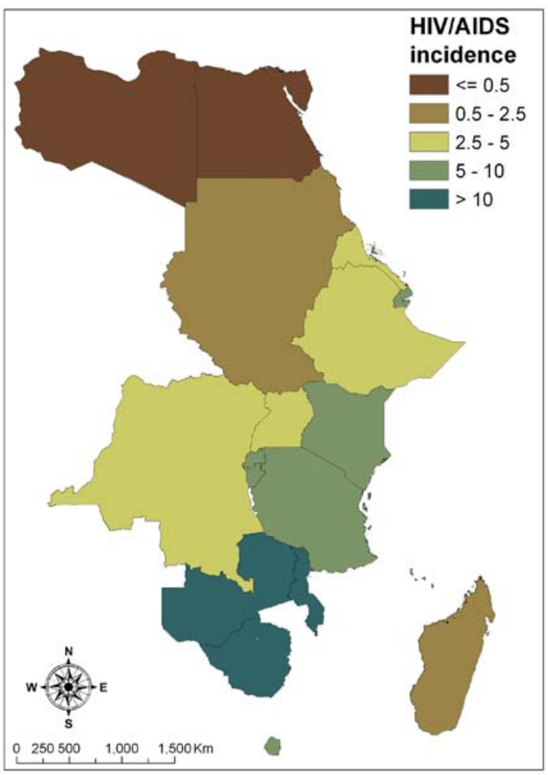

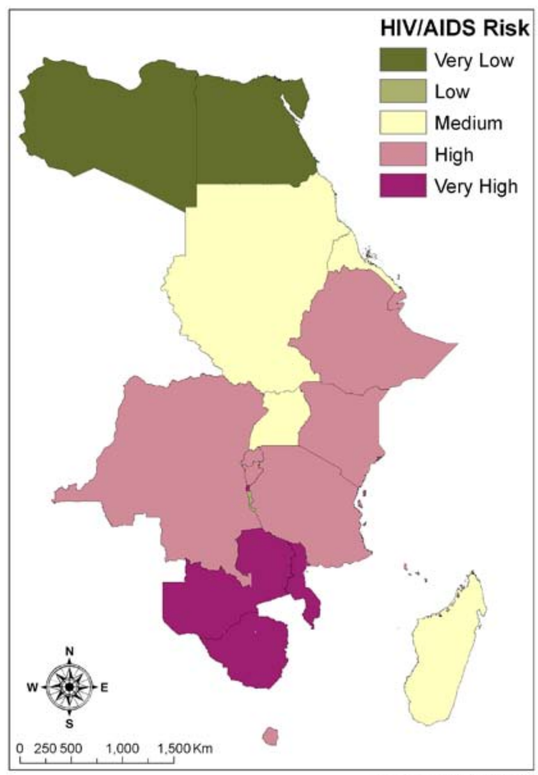

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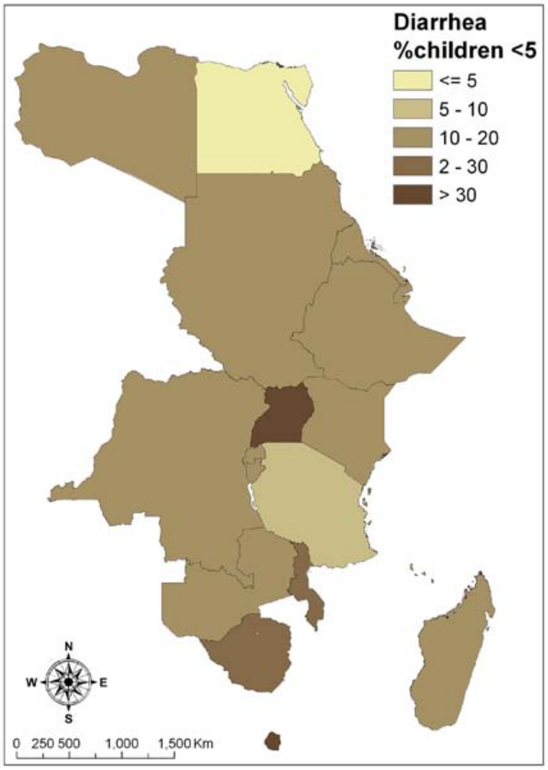

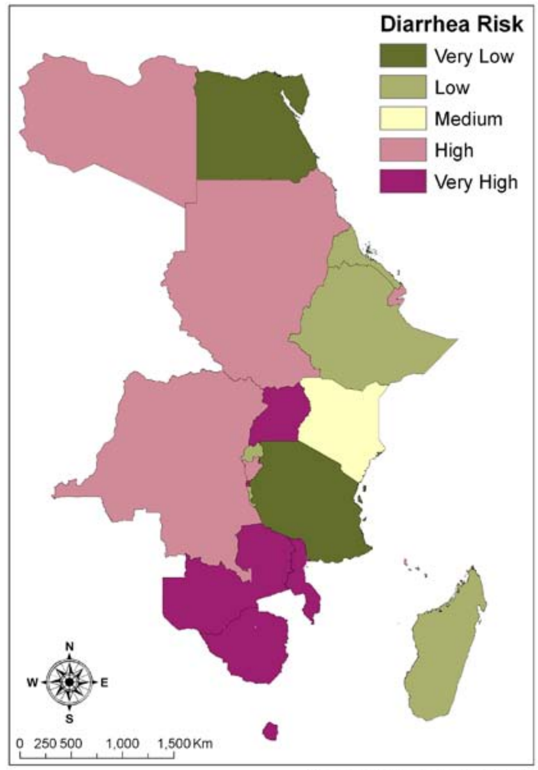

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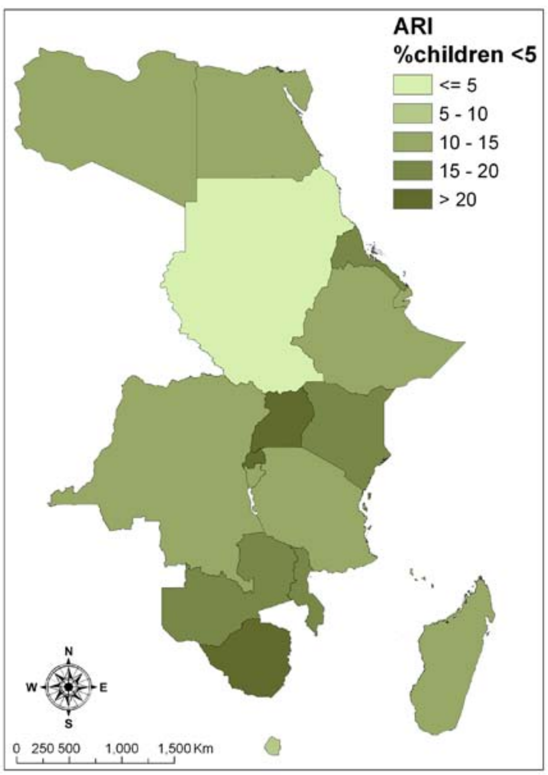

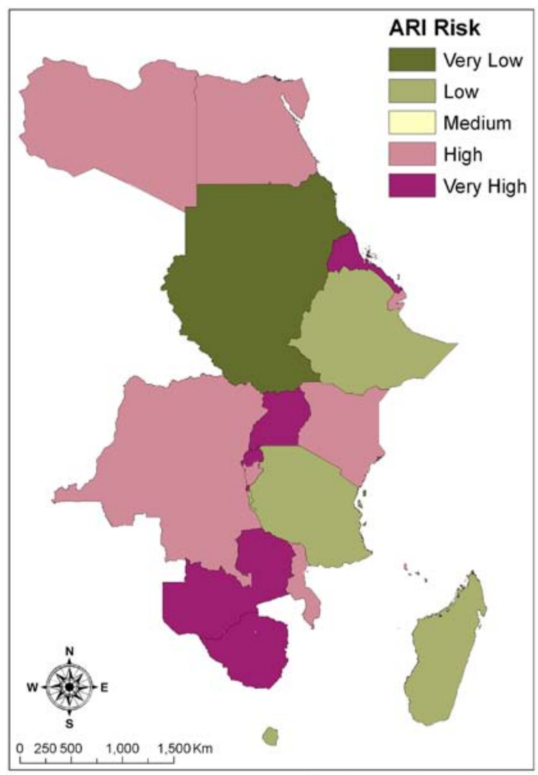

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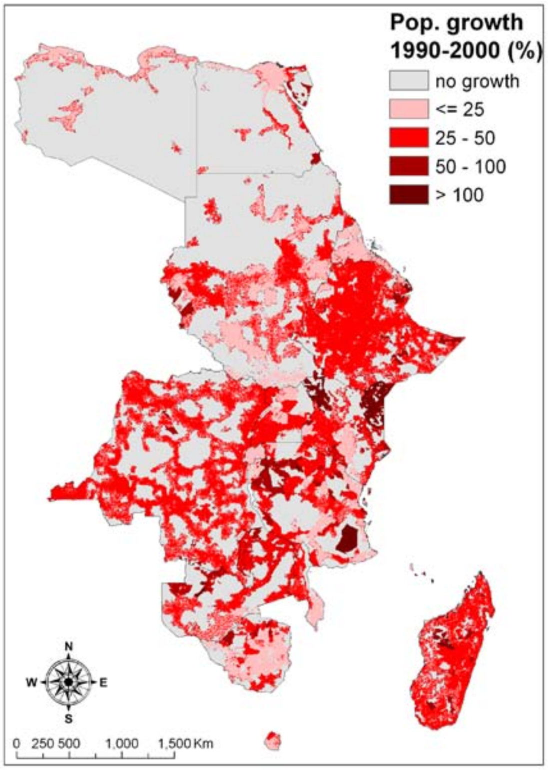

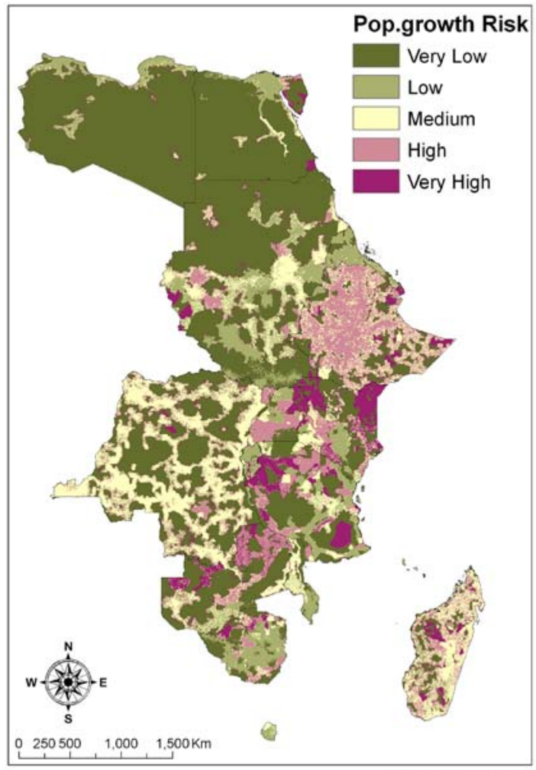

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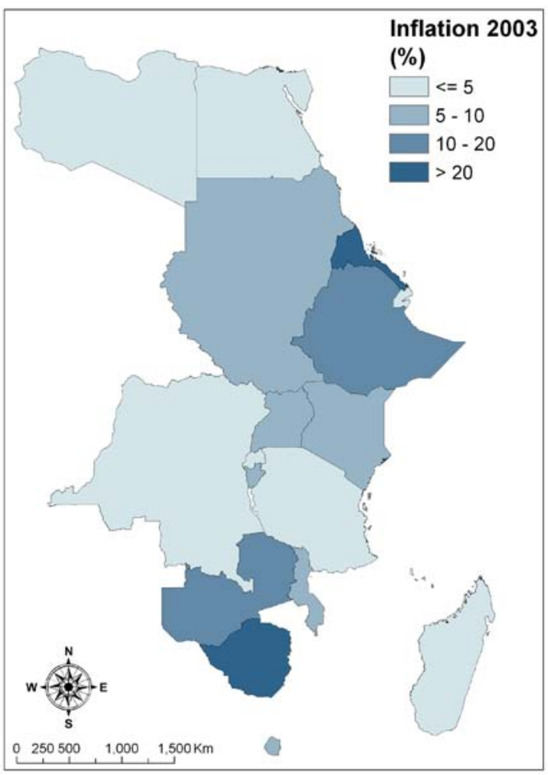

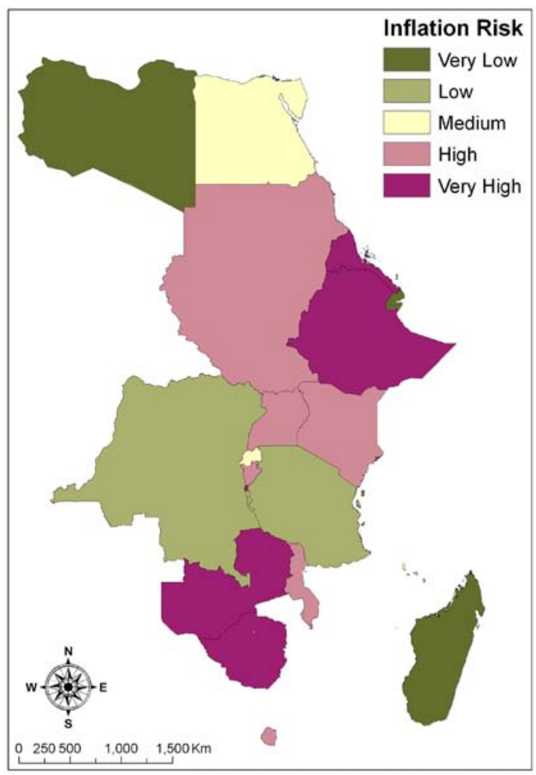

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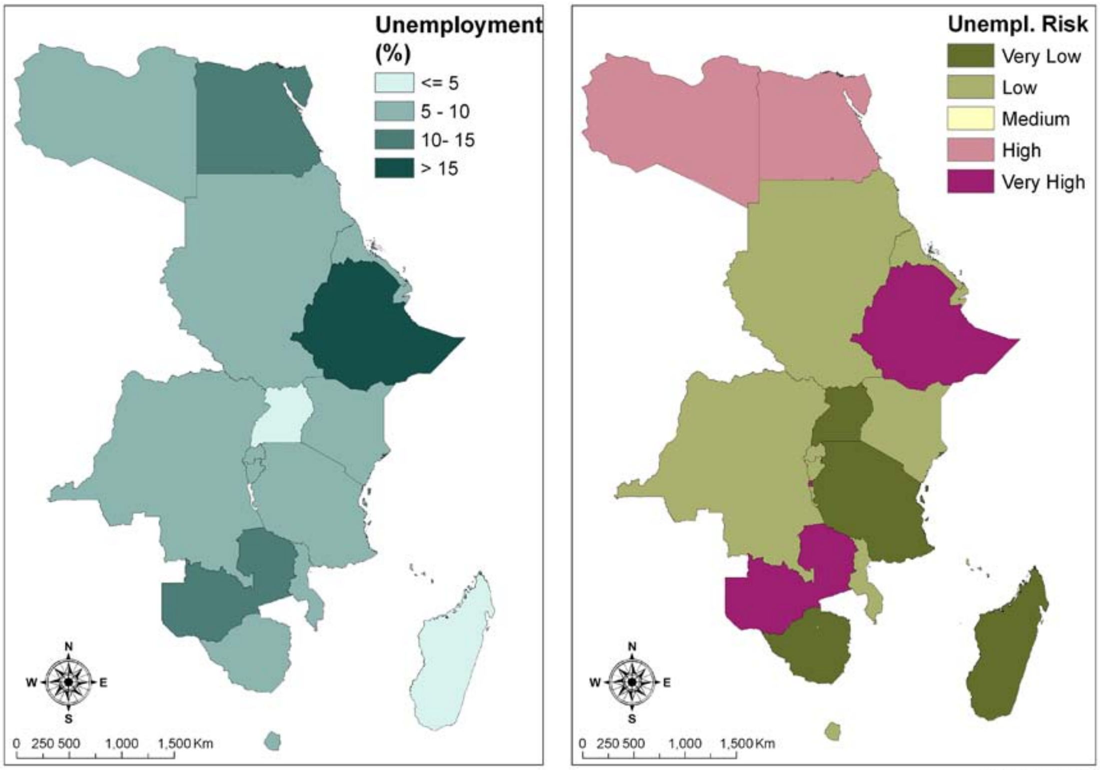

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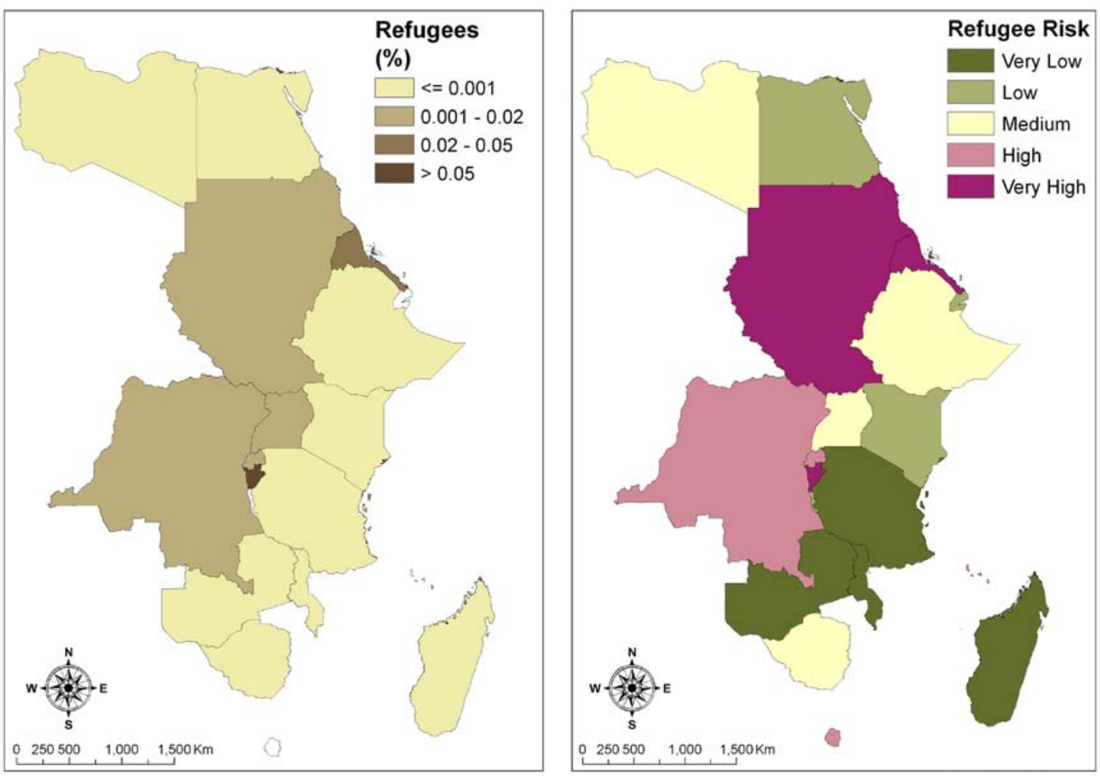

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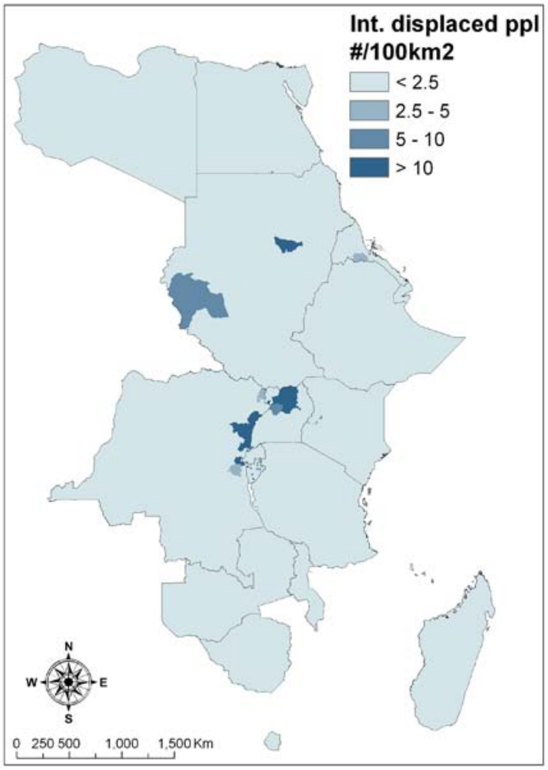

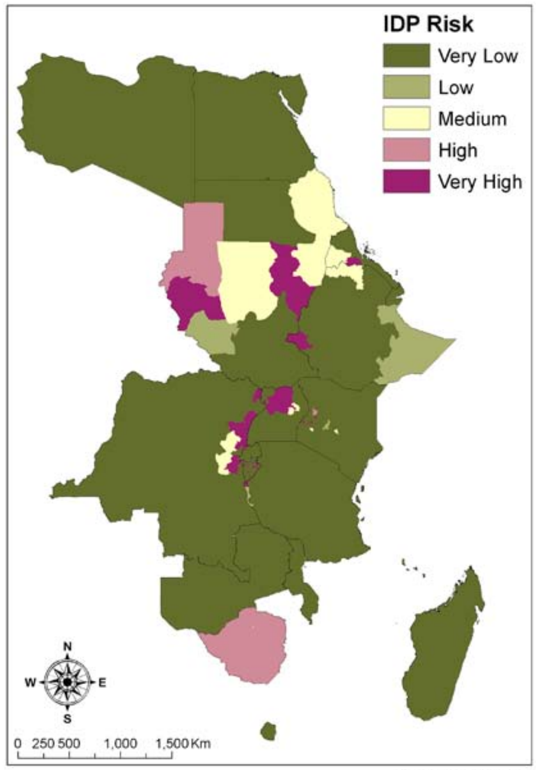

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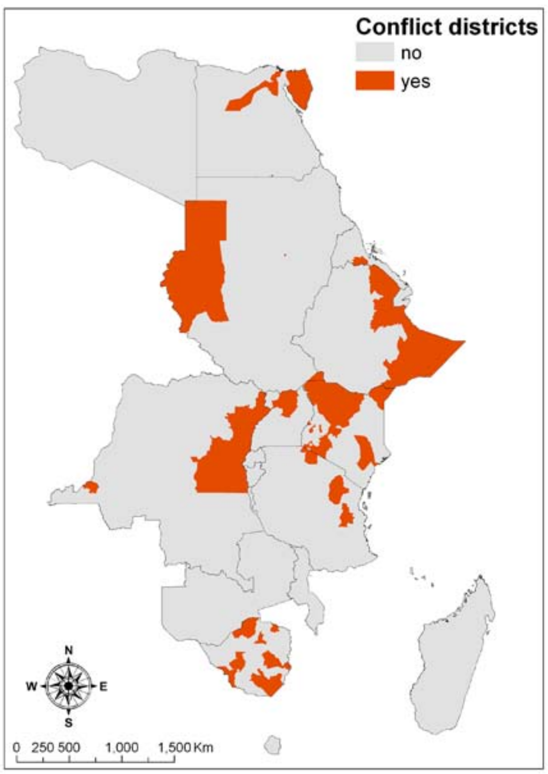

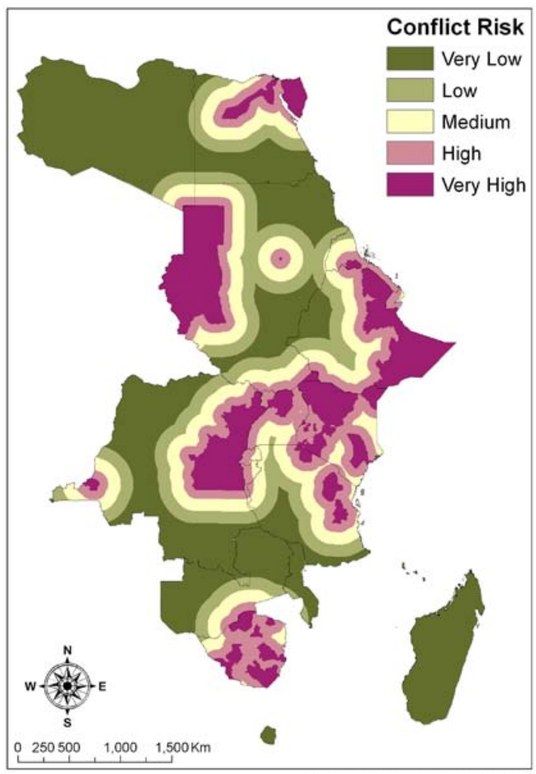

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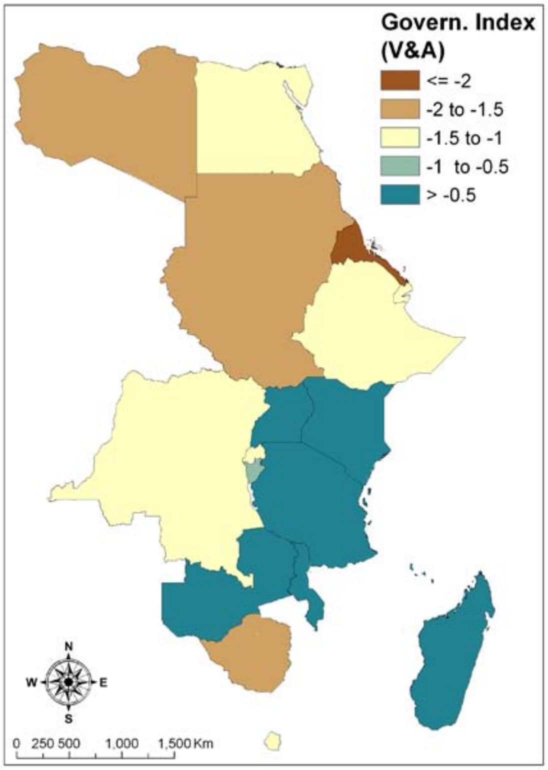

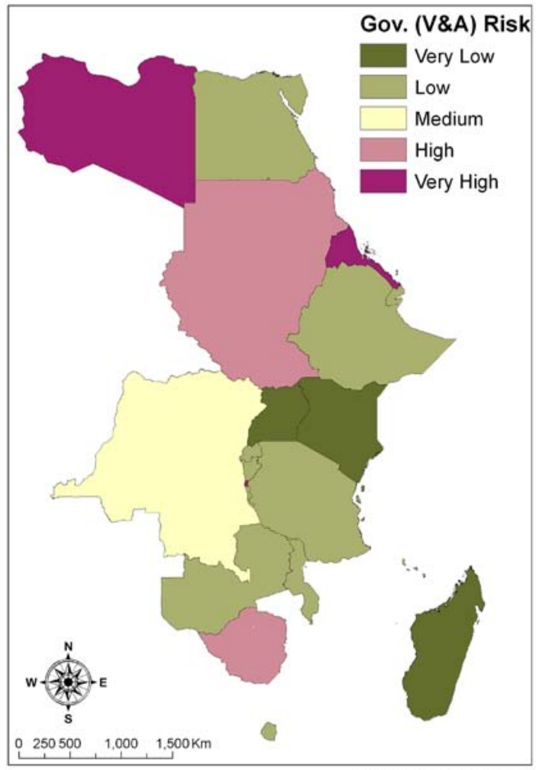

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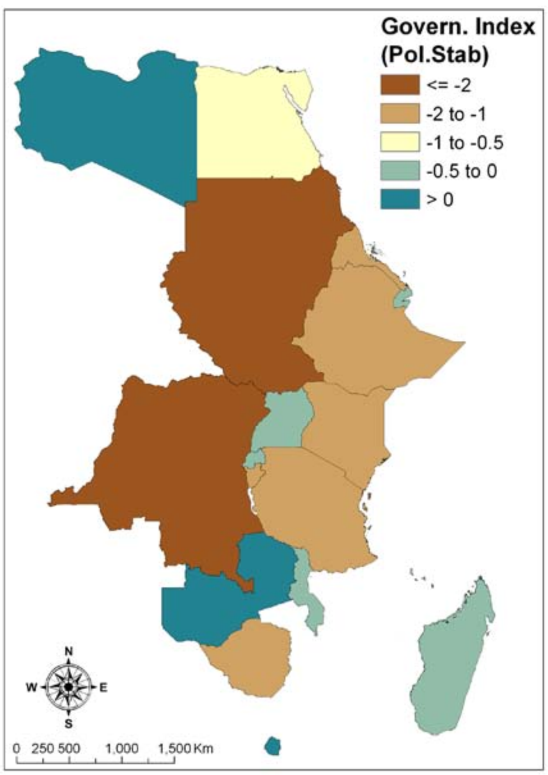

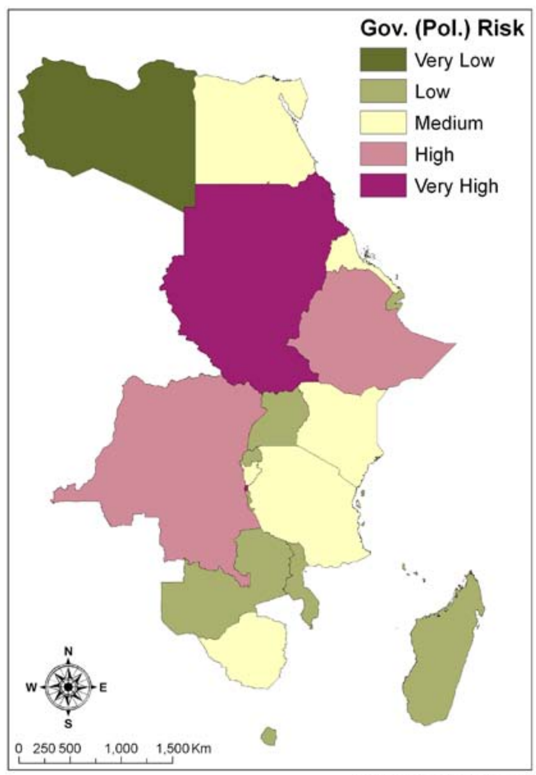

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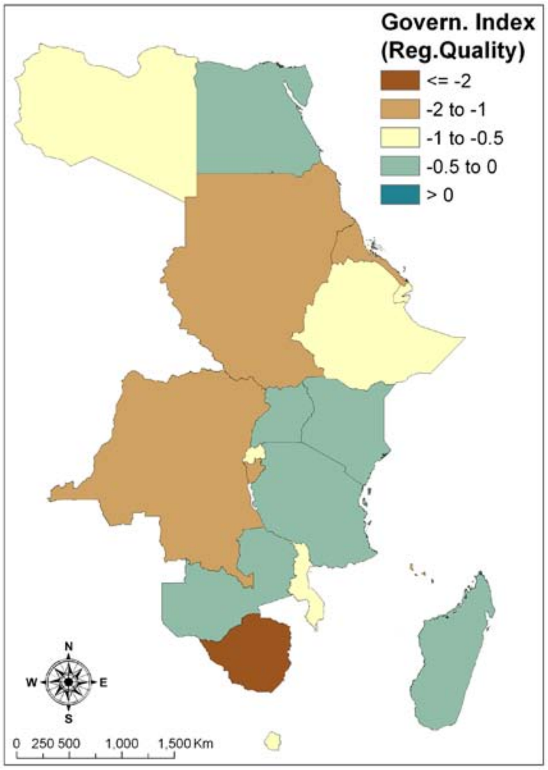

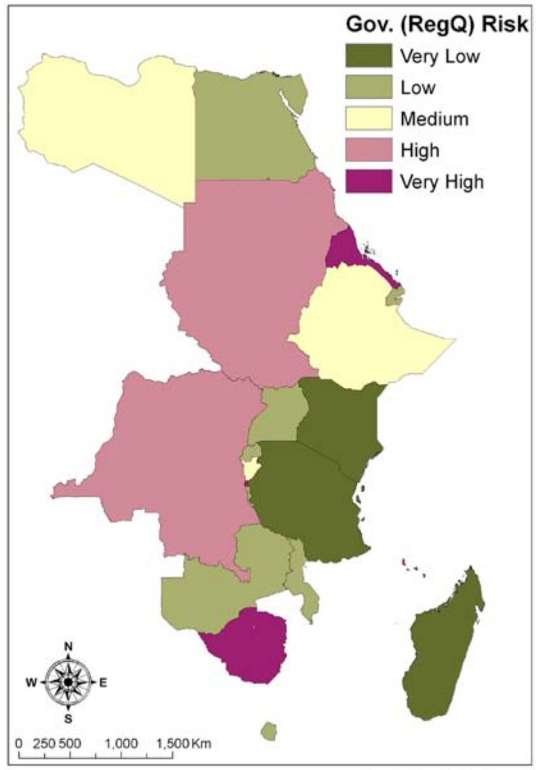

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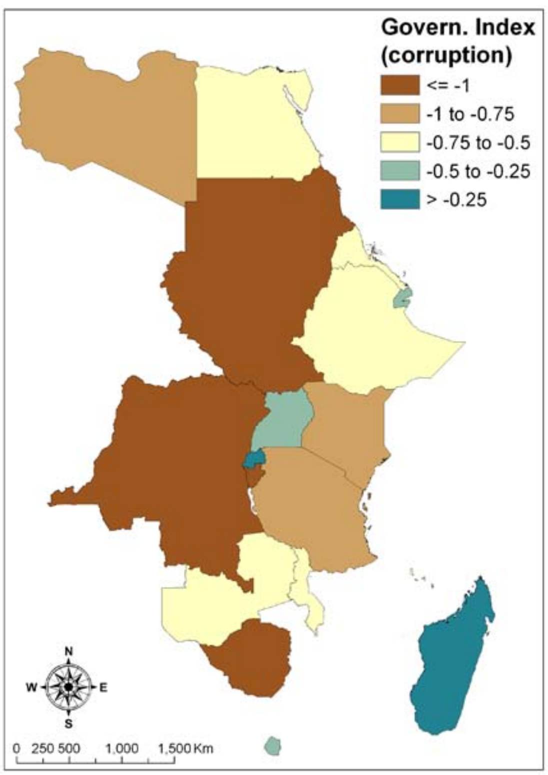

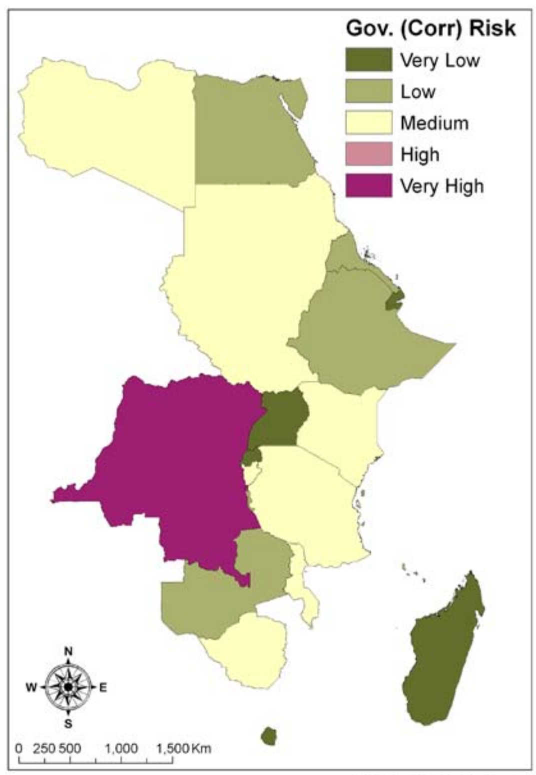

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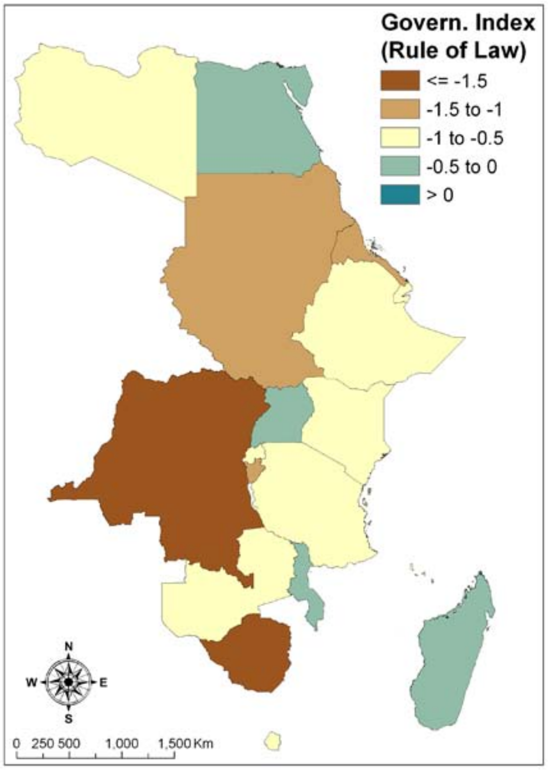

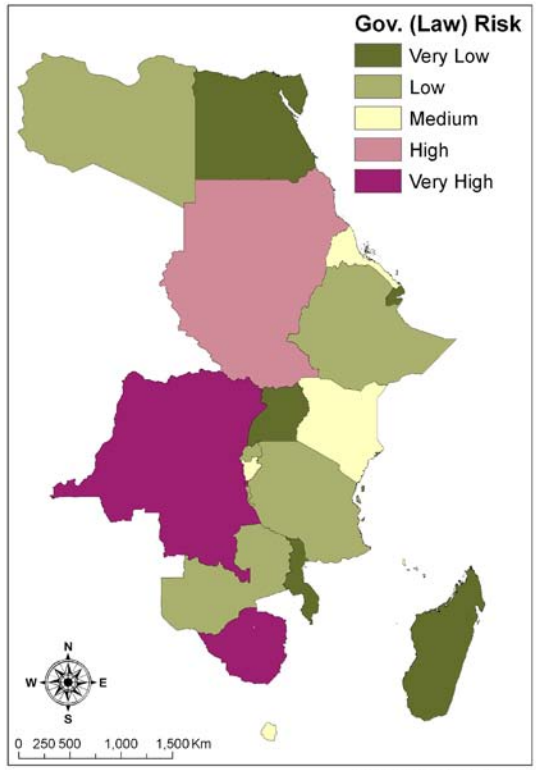

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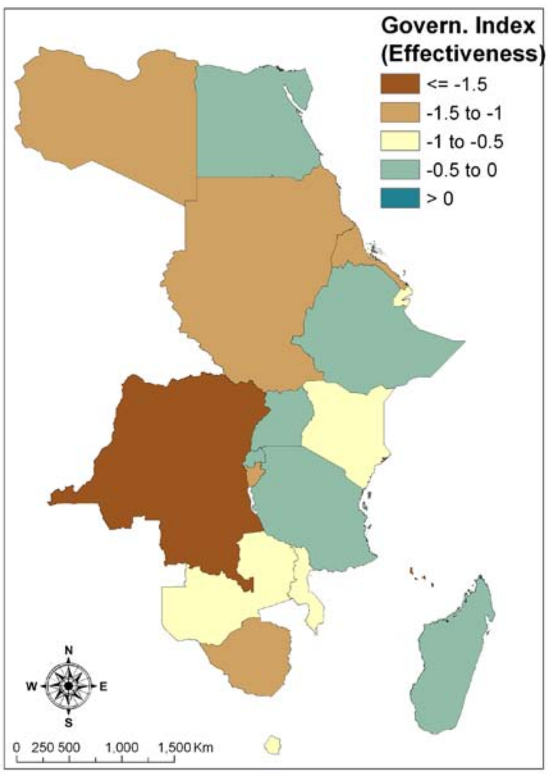

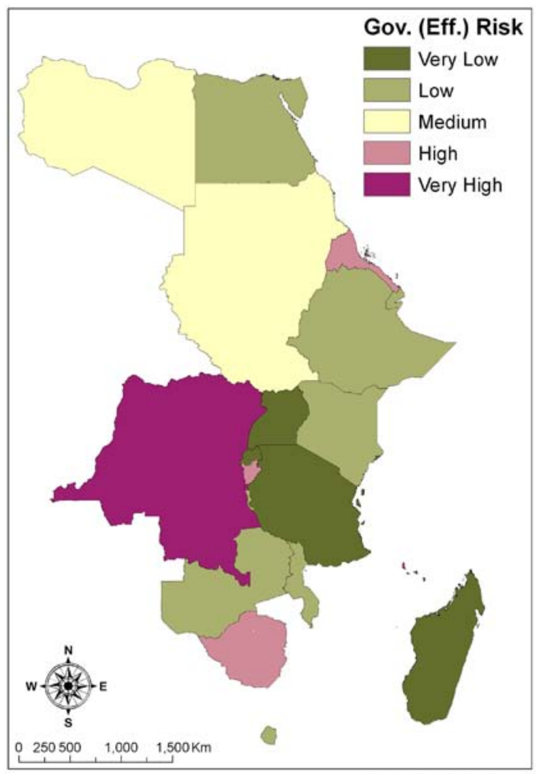

Source: Worldbank

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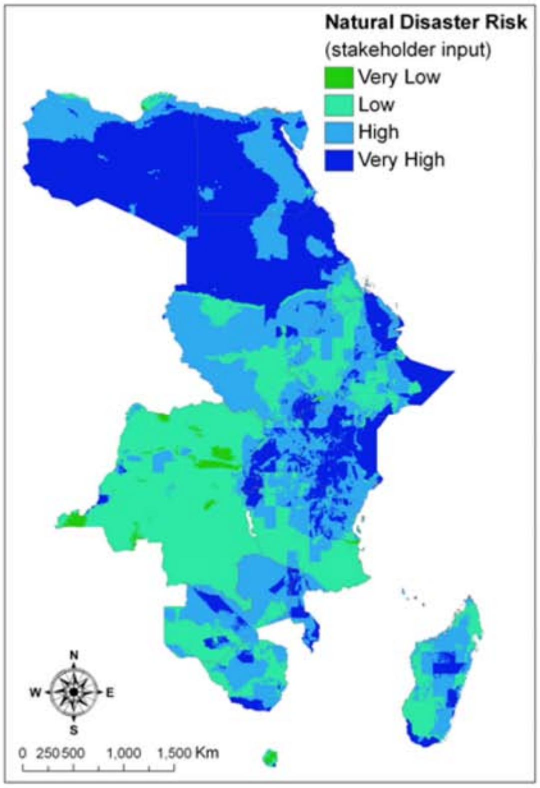
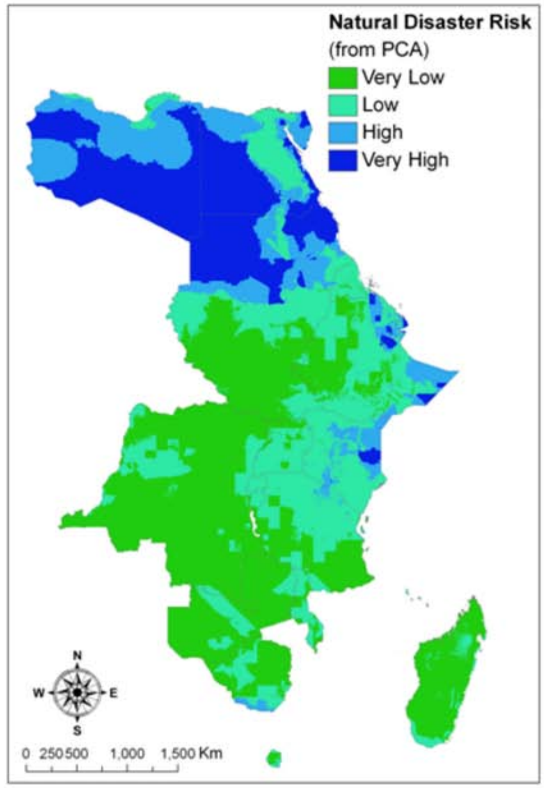
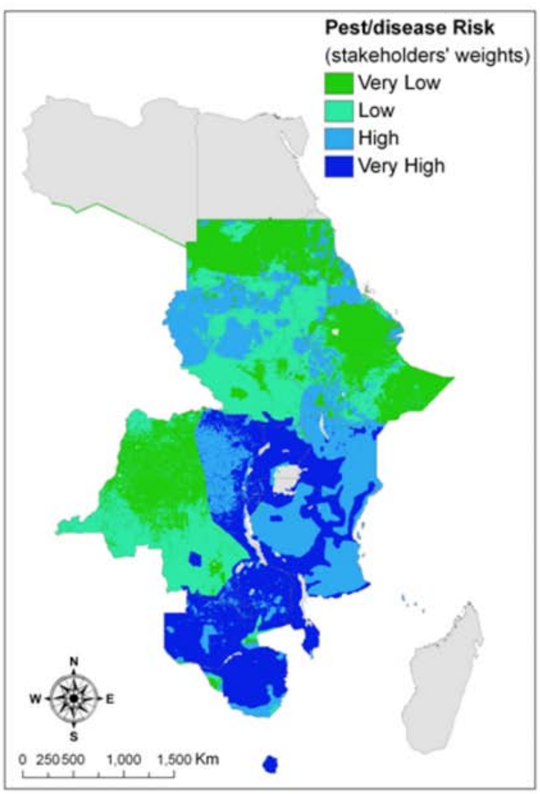
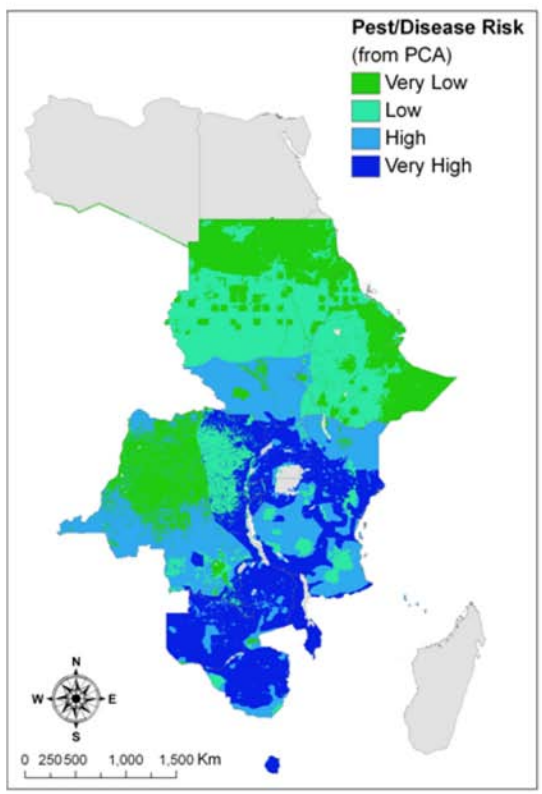


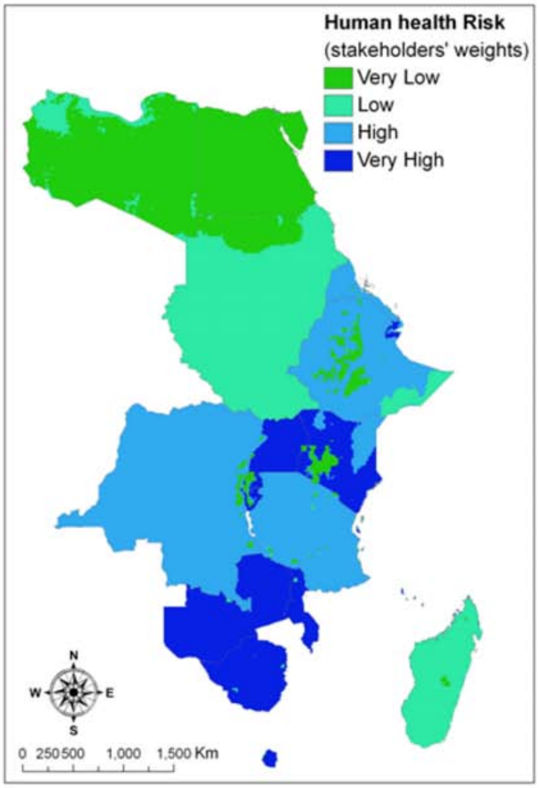


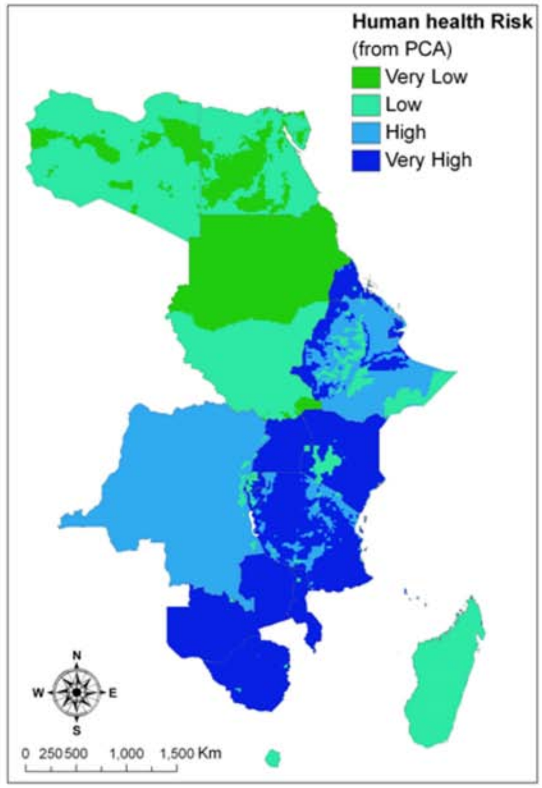
Omission	
very low	**67%**
low	**45%**
high	**41%**
very high	**69%**
Commission	
very low	**65%**
low	**46%**
high	**42%**
very high	**69%**
Overall accuracy	
	55%
Kappa statistic	
	40%



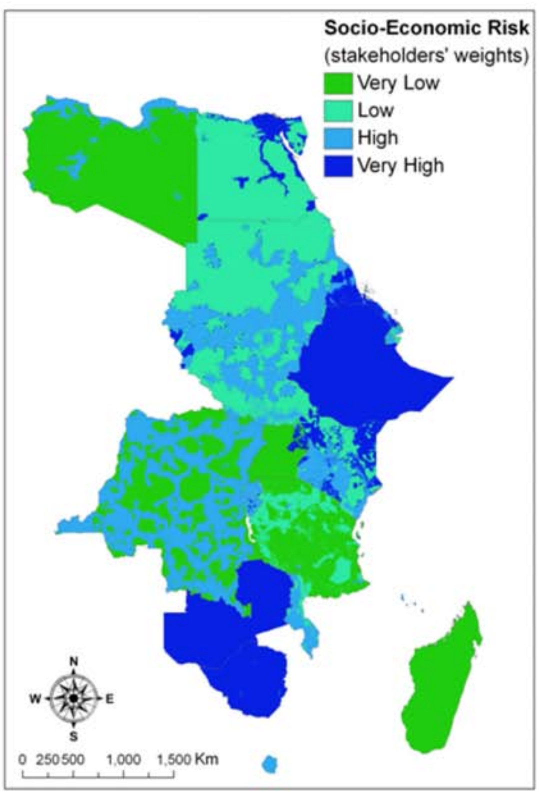


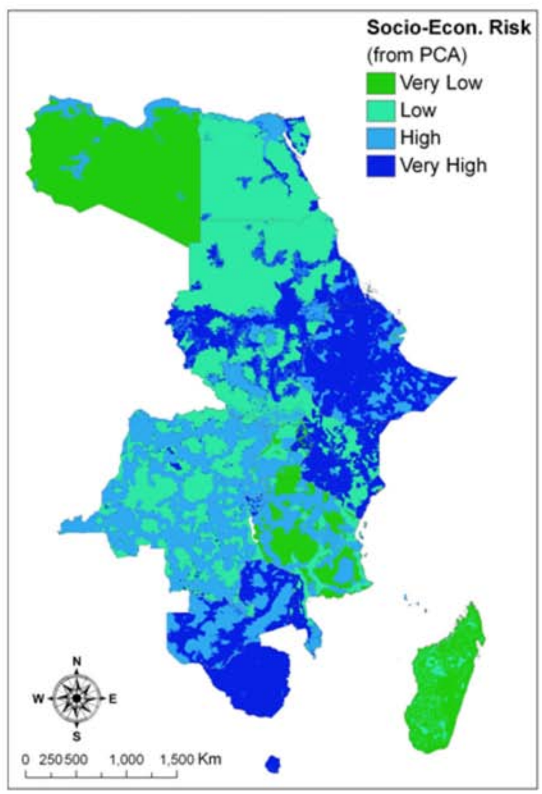
Omission	
very low	**88%**
low	**34%**
high	**35%**
very high	**95%**
Commission	
very low	**89%**
low	**38%**
high	**31%**
very high	**93%**
Overall accuracy	
	62%
Kappa statistic	
	50%



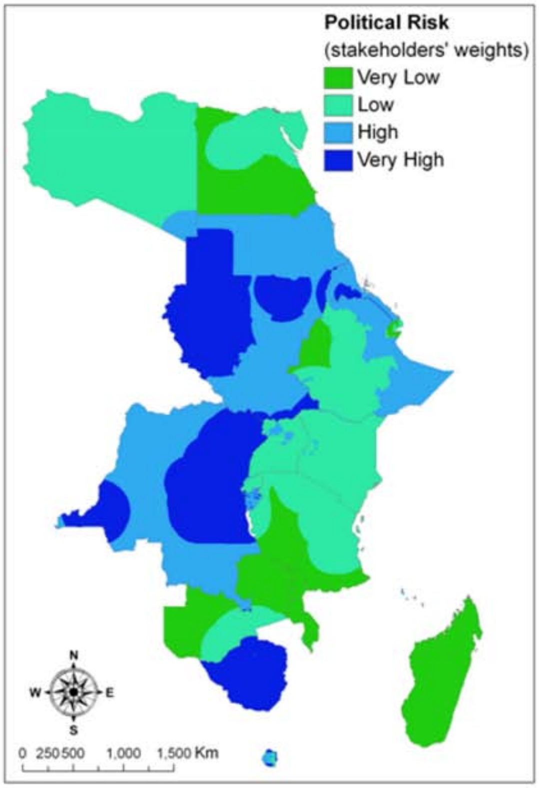


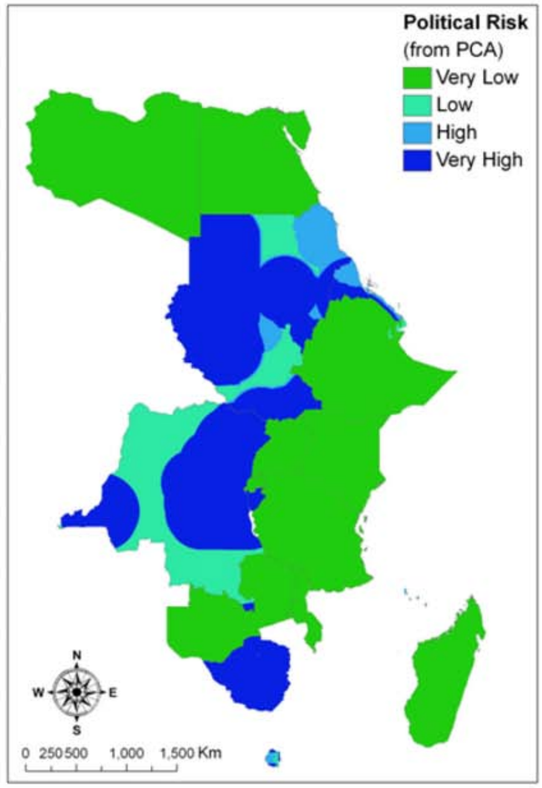
Omission	
very low	43%
low	46%
high	100%
very high	62%
Commission	
very low	30%
low	61%
high	73%
very high	99%
Overall accuracy	
	63%
Kappa statistic	
	51%





Omission	
very low	100%
low	68%
high	61%
very high	69%
Commission	
very low	62%
low	91%
high	66%
very high	76%
Overall accuracy	
	73%
Kappa statistic	
	64%





Omission	
very low	71%
low	96%
high	91%
very high	91%
Commission	
very low	95%
low	72%
high	91%
very high	100%
Overall accuracy	
	87%
Kappa statistic	
	83%

For more information, contact:

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