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Vulnerability assessment to floods at the district and GVH level in Salima, Malawi

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LIST OF ABBREVIATIONS

Acronyms	
AR5	Assessment Report 5
COOPI	Cooperazione Internationale
EC FP7	European Commission Framework Program 7
DIPECHO	Disaster Preparedness - European Community Humanitarian Office
DRR	Disaster Risk Reduction
ENSO	El Niño-Southern Oscillation
GVH	Group Village Headmen
IPCC	International Panel for Climate Change
LoR	Lack of Resilience
LULC	Land Use/ Land Cover
MOVE	Methods for the Improvement of Vulnerability Assessment in Europe
SUS	Susceptibility
VA	Vulnerability Assessments
VIF	Variance Inflation Factor

Table 1: Abbreviations

For a **glossary** of terms please refer to the terminology developed by the UN International Strategy for Disaster Reduction (UNISDR): http://www.unisdr.org/we/inform/terminology.

1 INTRODUCTION

1.1 General background

COOPI has been carrying out DIPECHO projects since 2007 in the district of Salima, Malawi. Much data and information has been collected over the years. Therefore, there is a need to organize and process this information in order to produce significant analysis outputs in the context of disaster risk reduction. Particularly, there is a need to integrate information collected at various levels: national, district and community. Besides creating a tool that integrates data and make it available to the public, vulnerability and resilience concepts and approaches gained increased interest in the recent years. Vulnerability Assessments (VA) are important to identify intervention measures at various levels of the decision making process in the DRR context and different concepts and methods can provide support on this matter.

Vulnerability has a ‘spatial‘ characteristic that requires the integration of various datasets as well as perspectives from the disaster risk reduction community and climate change adaptation concepts, see recommendations from IPCC (IPCC 2012 and the upcoming IPCC AR5). This vulnerability study is based on the approach developed by Kienberger (2009) and Kienberger (2012) in Mozambique. According to this approach, socioeconomic vulnerability maps to floods have been produced based on existing data sources which allow the identification of vulnerability ‘hot spots’ and its characterization within the district or GVH level. The VA results are a relative measure for the district (showing hot and cold spots of vulnerability in the district of Salima). The VA has been therefore based on the following:

- the VA results are a relative measure for the district (showing hot and cold spots of vulnerability in the district)
- It allows the exploration of the different characteristics of vulnerability within the district and decomposed into different vulnerability indicators through its relative contribution of indicators
- It considers scientific but also experts and community knowledge to achieve a comprehensive representation of vulnerability
- Climate Change Adaptation is seen as an integral part
- It is aimed to be independent from administrative units representing spatial variations of vulnerability within the district

In the following the core characteristics of the VA are specified:

- Two scale levels of assessment: District level and GVH level
    - District level
        - Socioeconomic vulnerability map for the district
        - Hazard: Flood | Vulnerability domain: socioeconomic
        - It allows the identification of priority intervention areas within a district (hot and cold spots of vulnerability)
    - Community level
        - A vulnerability index valid for the whole community
        - It allows a relative comparison between the different communities
    - Link between both levels
        - Integration of expert/scientific knowledge to achieve a comprehensive representation of vulnerability
        - Common indicator framework which is adapted for the two specific scale levels

1.2 Study area

Malawi, located in Southern Africa, is influenced by a high variable climate. This is on one hand characterised by the regional climate conditions, but also influenced by the ENSO which results in frequent recurrent droughts and floods and strong inter-annual and -seasonal climate fluctuations. According to statistics the highest number of natural disasters in the past (1980-2010) includes floods, epidemics and droughts. Major flood events occurred in the years 2007, 2002, 2001 and 1997, whereas especially (i) the Shire basin in the Southern region towards the Zambezi and (ii) the river catchments in the Central region had been affected most.

The district of Salima is located in the Central Region of Malawi with the capital named Salima as well. The district covers an area of roughly 2,200 km² and has a population of around 250,000. Salima has been affected by flood events in the past, whereas the downstream areas of the Linthipe and Lingadzi river are the most flood-prone areas before the rivers discharge into Lake Malawi. In the district itself different disaster risk reduction programs have been implemented at the district as well as on the community/GVH level in the past. This includes community-based mapping of flood zones and the establishment of community-based early warning systems. As pointed out above, this study contributes to these activities by expanding the risk concept from being purely hazard focused towards a more holistic view of risk integrating socioeconomic aspects vulnerability. The assessment is also based on requirements, recommendations and conclusions achieved in previous developed in studies funded by Kienberger et al. (2011a) and Kienberger (2011b).

Figure 1 provides an overview of the district as well as the four GVHs for which the two different assessments have been carried out in this study.

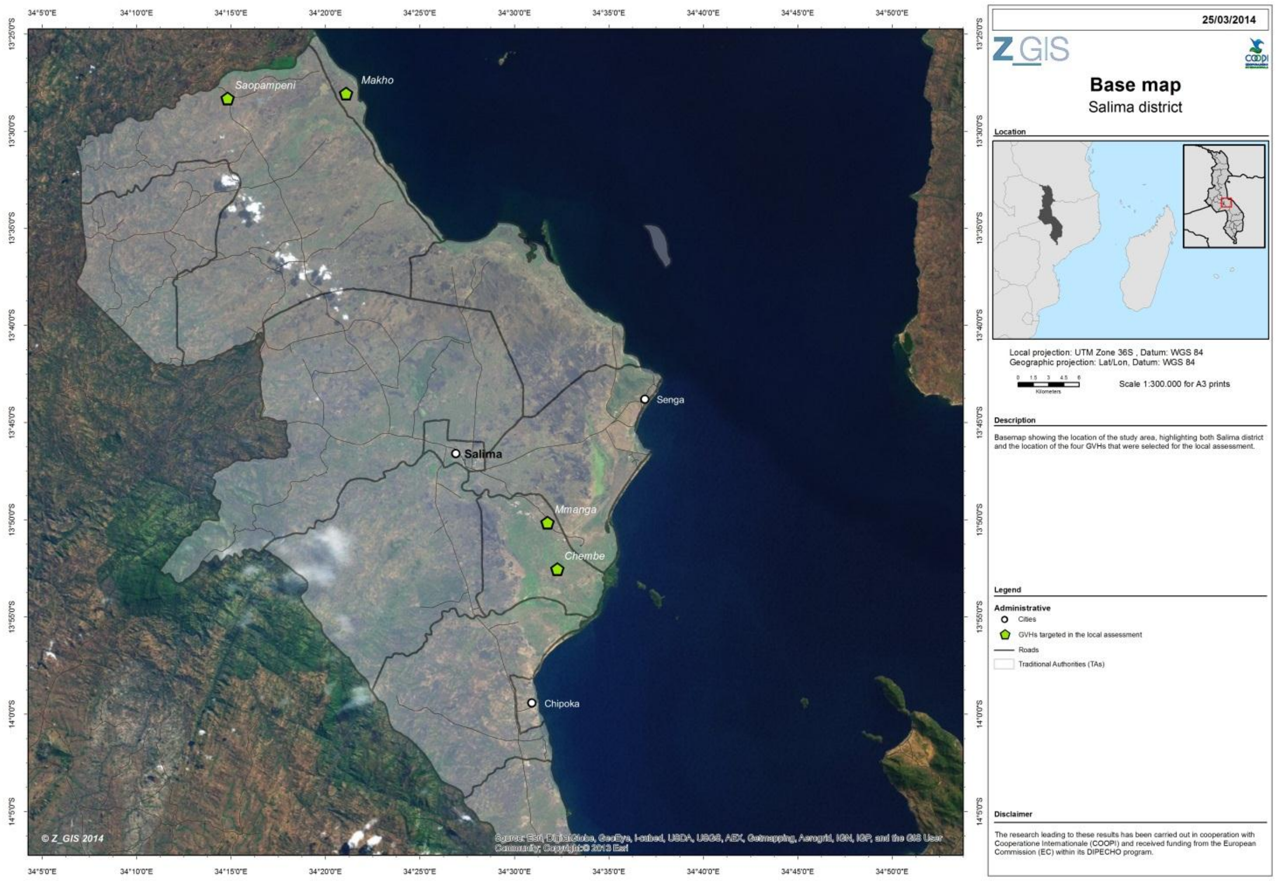

Figure 1: Base map showing the location of the study area

2 METHODOLOGY

2.1 Conceptual framework

Risk reduction to hazards of natural origin is a major challenge at present and in future regarding global environmental change. It is increasingly recognized that natural hazard induced risk and threats to human security cannot be reduced by focusing solely on hazards. Societies will have to live with changing environmental conditions and therefore they need to build resilience by reducing vulnerabilities to natural hazards. Against this background a conceptual framework that addresses vulnerability and risk to natural hazards from a holistic and multidimensional point of view has been developed by the EC FP7 research project MOVE (Methods for the Improvement of Vulnerability Assessment in Europe; www.move-fp7.eu, Birkmann et al. 2013).

A key goal when developing the MOVE framework was to provide an improved conceptualization of the multi-faceted nature of vulnerability, accounting for key causal factors, such as exposure, susceptibility/fragility and lack of resilience characterised by different dimensions of vulnerability such as the physical, social, ecological, economic, cultural and institutional dimension. The framework underlines that society and nature/environment are coupled through various linkages. Additionally, the framework incorporates the concept of adaptation into the context of disaster risk reduction, and by this explicitly differentiates coping from adaptation.

Overall, the conceptual MOVE framework underlines the importance of investigating and understanding vulnerability in order to comprehend risk and to develop appropriate adaptation strategies. Hazards which might trigger and reveal vulnerability and disaster risk, can be of natural or socio-natural origin, while the vulnerability in its multi-faceted nature is mainly linked to societal conditions and processes, however, acknowledging that both elements, (natural) environment – including hazards – and society, coexist and are characterized by constant interactions among them. Therefore, the society is also embedded into the broader context of environment (Birkmann et al. 2013). The framework itself reflects very well current agreements on terminology and concepts as for instance proposed by the IPCC (2012).

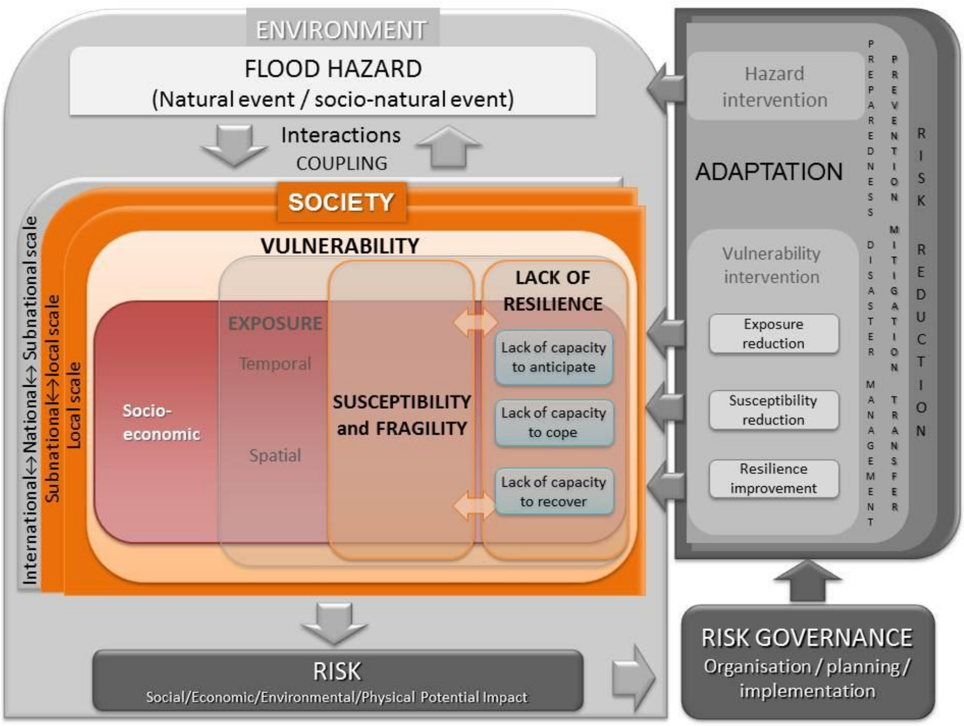

Figure 2: Modified conceptual risk and vulnerability framework highlighting the assessed components for this study (modified after Birkmann et al., 2013)

Whereas the original MOVE framework sees exposure as part of vulnerability, we excluded the exposure component from this assessment. This is due as (i) no representative and suitable flood hazard delineation exists at an appropriate resolution for the district of Salima (see also Kienberger et al, 2011b), and (ii) we think that an exposure independent vulnerability assessment better reflects the general predisposition of the society towards the flood hazard. Flood hazard zones – if available – can then be integrated towards a risk measure in combination with the vulnerability regions. Figure 2 represents this adapted framework, whereas the core focus of this assessment has been based on an integral socioeconomic perspective.

2.2 Workflow for modelling vulnerability

To provide updated information on the multi-faceted nature of prevailing vulnerabilities to flooding a composite vulnerability index was developed for both (i) Salima district (district level), and (ii) four selected GVHs (local level) in Salima district, Malawi. Both vulnerability indices build on a set of underlying socioeconomic, demographic and infrastructure-related indicators. A multi-step and iterative workflow (Figure 3) is adopted following OECD (2008) guidelines. Relevant stages include: (1) definition of the conceptual framework, (2) identification of a representative set of indicators based on literature, (3) data transformation, (4) analysis and imputation of missing values, (5) normalization, (6) multivariate analysis and establishment of final indicator set, (7) weighting, (8) aggregation and (9) visualization.

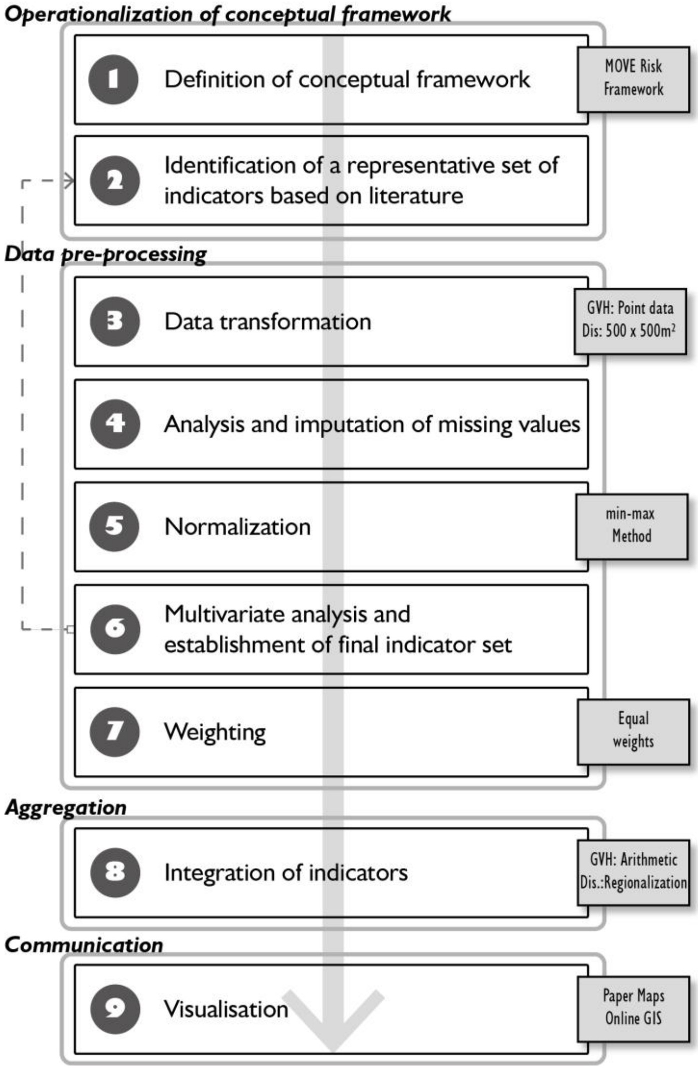

Figure 3: Workflow for modeling vulnerability to floods

A detailed description of the individual modelling steps for both levels (local and district level) are provided in the following chapters.

2.3 District level assessment

This chapter describes the individual modelling stages for the district level assessment. Vulnerability has been modelled to identify homogenous regions of vulnerability within the district being independent from administrative boundaries.

2.3.1 Indicators and datasets

Drawing on the conceptual vulnerability framework (Figure 2) a preliminary set of 12 socioeconomic, demographic and infrastructure-related indicators (Table 2) was identified based on a systematic review of literature and available datasets. The choice and selection of indicators is a critical process in the overall method as it refers to evidence provided in scientific studies.

Dimension	Domains	Sub-domains	Indicators	Sign[1]	Potential proxies	Data source
Socioeconomic	Susceptibility		Education (access to)[2]	+	Lack of access to schools	NSO COOPI
			Water (access to)[2]	+	Lack of access to water wells	NSO COOPI
			Local markets (access to)[2]	+	Lack of access to markets	MASDAP MASDAP COOPI
			Road infrastructure (access to)[2]	+	Lack of access to roads	MASDAP
			Main cities (access to)[2]	+	Lack of access to important cities	OSM
			Conflict	+	Conflict density	ACLED
			Poverty	+	Poverty below $2/day	WorldPop
			Crop density	-	Land Cover	MASDAP GLOBECOVER
			Ecosystem service (food)	-	Constanza values for land cover	MASDAP GLOBECOVER
	Lack of Resilience	Anticipation	Early warning systems	-	Early warning system density	COOPI
		Coping	Evacuation sites (access to)[2]	+	Lack of Access to safe places	COOPI
			Health Services (access to)[2]	+	Lack of access to health facilities	MASDAP COOPI
		Recovery				

[1] *Sign: h igh indicator values increase [+] or decrease [-] vulnerability*

[2] *indicators were combined to an "Access Index" due to multicollinearity in data*

Table 2: List of vulnerability indicators (district level)

From literature, the following indicators have been identified: access to education, access to water, access to local markets, access to roads/transportation network, conflict density, ecosystem services, density of early warning systems, access to evacuation sites, and access to health services (for further details see Kienberger 2012). During the selection process, standard criteria for indicator selection such as validity, sensitivity, reproducibility and scale (Birkmann, 2006; Moldan & Dahl, 2007) were accounted for. The indicators were associated with either the susceptibility (SUS) or the lack of resilience (LoR) domain of vulnerability (Table 2).

2.3.2 Data pre-processing and statistical analysis

This study builds on a variety of geospatial datasets that were acquired in different formats (vector data and continuous grids) from various sources (Table 2). This chapter briefly describes the basic data pre-processing steps. The subsequent steps were carried out using the ArcGIS Desktop 10.2

software environment (ESRI, Redlands, USA).

Before starting the analysis, all layers were projected to UTM 36S, which is the local projection for the study area. For all access/distance indicators (see Table 2) a path distance surface was calculated. This functionality carries out a cost distance analysis, while accounting for horizontal (e.g. land use/land cover) and vertical cost factors (e.g. elevation information) as well as the true surface distance. We used the 2009 GlobCover land use/land cover (LULC) dataset (300 m resolution) that was updated with a road and a river dataset to calculate a horizontal cost surface. Figure 4 shows the updated LULC dataset for the study area.

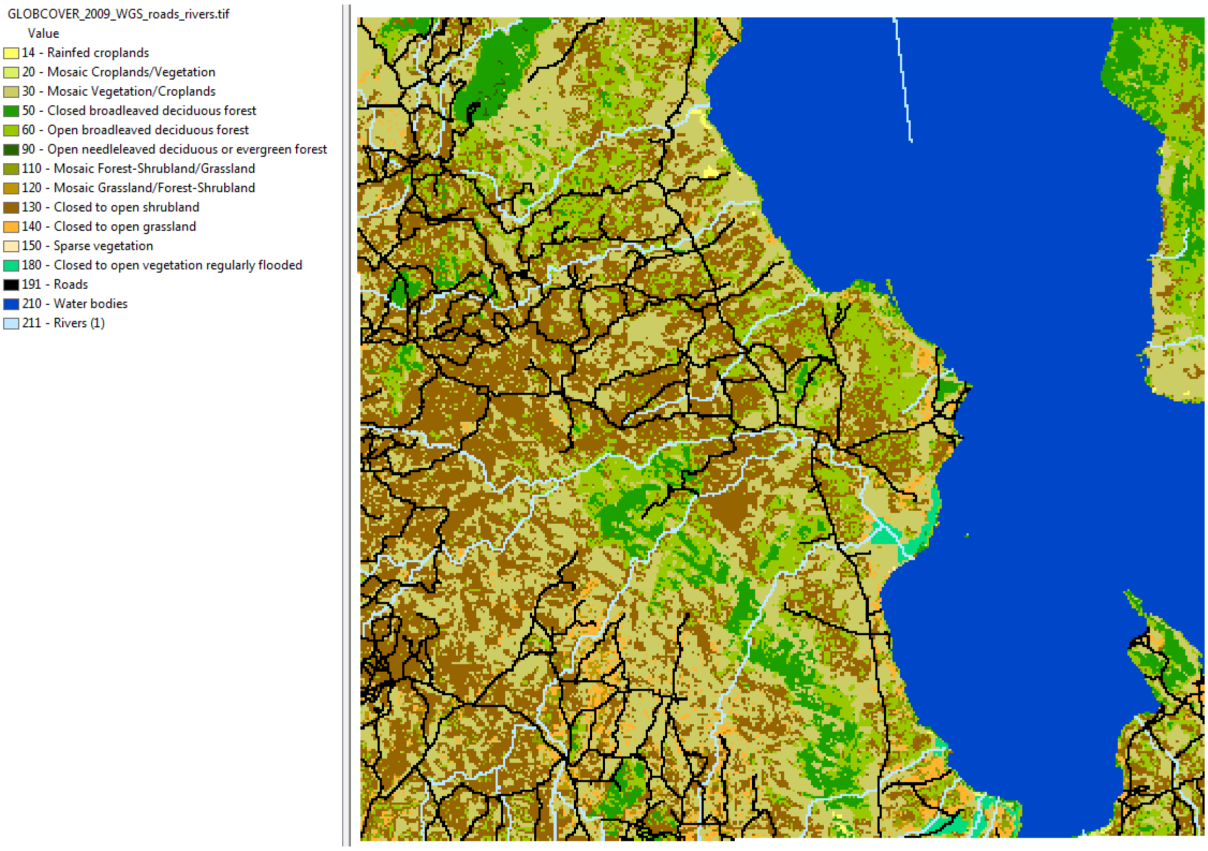

Figure 4: Updated LULC dataset (GlobCover 2009)

A set of friction values was assigned to each of the LULC categories (see Table 3) to create a cost surface based on the updated GlobCover layer, following thresholds published by Gall (2004) and Kienberger (2012).

LULC category	Description	Cost value
14	Rainfed cropland	14
20	Mosaic cropland/vegetation	40
30	Mosaic vegetation/cropland	40
50	Closed broadleafed deciduous forest	100
60	Open broadleafed deciduous forest	40
90	Open needleleafed deciduous Forest	40
110	Mosaic forest-shrubland/grassland	40
120	Mosaic grassland/forest-shrubland	40
130	Closed to open shrubland	16
140	Closed to open grassland	13
150	Sparse vegetation	10
180	Closed to open vegetation regularly flooded	100
191	Roads *(manually updated using a road dataset)*	1
210	Water bodies	No data = barrier
211	Rivers *(manually updated using a river dataset)*	1000

Table 3: Friction values for calculating the horizontal cost surface

Taking into account the resulting horizontal cost surfaces, as well as gridded elevation information (SRTMv4; 90m resolution) seven path distance surfaces were created for the following input datasets: schools, water points, markets, roads, cities, evacuation sites and health centres.

The updated GlobCover dataset was also used to create a cropland surface based on the following LULC categories: 14, 20 and 30 (Table 3). The same dataset was also used to calculate the food ecosystem service value (per ha). Therefore the updated GlobCover dataset was reclassified in the following six classes taking into account the GlobCover LULC categories as listed below:

- Forest (tropical): 50, 60, 90, 110
- Grass-/rangelands: 120, 140
- Floodplains (wetlands): 180
- Rivers/lakes: 210, 211
- Cropland: 14, 20, 30
- Other/irrelevant remaining categories

These classes were assigned an ecosystem service value (food production) per hectar based on thresholds published by Costanza (1997). Finally, all indicators were resampled to 500 x 500 m^2 grids and cropped to the boundaries of Salima district.

To detect and ultimately reduce existing multicollinearities in the data, the correlation coefficient (r), as well as variance inflation factors (VIF) were calculated. Based on thresholds published by the OECD (2008), the following indicators revealed strong cross-correlations (with $r > 0.9$ and/or VIF > 5): access to cities, access to health facilities, access to roads, access to markets, and access to schools (Table 4).

	Education (access to)	Water (access to)	Markets (acces to)	Roads (access to)	Health facilites (access to)	Cities (access to)	Conflict	Poverty	Crop density	Ecosystem services	Early warning systems	Evacuation sites
Education (access to)	**1,00**	0,83	0,90	0,83	0,89	0,82	-0,04	0,46	-0,03	0,35	0,08	0,78
Water (access to)	0,83	**1,00**	0,78	0,72	0,77	0,71	-0,03	0,29	-0,09	0,25	0,02	0,69
Markets (acces to)	0,90	0,78	**1,00**	0,89	0,91	0,87	-0,06	0,54	-0,03	0,34	0,13	0,81
Roads (access to)	0,83	0,72	0,89	**1,00**	0,95	0,99	-0,05	0,59	-0,02	0,30	0,14	0,90
Health facilites (access to)	0,89	0,77	0,91	**0,95**	**1,00**	0,94	-0,05	0,55	-0,04	0,32	0,15	0,85
Cities (access to)	0,82	0,71	0,87	**0,99**	**0,94**	**1,00**	-0,09	0,61	-0,03	0,29	0,12	0,89
Conflict	-0,04	-0,03	-0,06	-0,05	-0,05	-0,09	**1,00**	-0,33	0,02	0,02	0,07	-0,03
Poverty	0,46	0,29	0,54	0,59	0,55	0,61	-0,33	**1,00**	-0,02	0,15	-0,01	0,63
Crop density	-0,03	-0,09	-0,03	-0,02	-0,04	-0,03	0,02	-0,02	**1,00**	0,42	0,10	-0,05
Ecosystem services	0,35	0,25	0,34	0,30	0,32	0,29	0,02	0,15	0,42	**1,00**	0,27	0,17
Early warning systems	0,08	0,02	0,13	0,14	0,15	0,12	0,07	-0,01	0,10	0,27	**1,00**	-0,12
Evacuation sites	0,78	0,69	0,81	0,90	0,85	0,89	-0,03	0,63	-0,05	0,17	-0,12	**1,00**
VIF	7,8	3,8	8,8	56,9	17,0	39,4	1,3	2,4	1,3	1,6	1,6	10,0

Table 4: Multicollinearity statistics for the district level (all indicators)

To reduce these multicollinearities the following seven indicators were combined in an access index (taking into account their 'sign'), and the multicollinearity analysis was performed again:

- Access to cities [Sign: +]
- Access to health facilities [Sign: +]
- Access to roads [Sign: +]
- Access to markets [Sign: +]
- Access to schools [Sign: +]
- Access to water points [Sign: +]
- Access to evacuation sites [Sign: +]

Table 5 shows the multicollinearity statistics after that step. All multicollinearity issues in the data have been solved, while no information was lost.

	Access Index	Conflict	Poverty	Crop density	Ecosystem services	Early warning systems
Access Index	**1,000**	-0,056	0,576	-0,043	0,309	0,080
Conflict	-0,056	**1,000**	-0,333	0,021	0,017	0,065
Poverty	0,576	-0,333	**1,000**	-0,023	0,153	-0,008
Crop density	-0,043	0,021	-0,023	**1,000**	0,418	0,099
Ecosystem services	0,309	0,017	0,153	0,418	**1,000**	0,273
Early warning systems	0,080	0,065	-0,008	0,099	0,273	**1,000**
VIF	1,717	1,164	1,737	1,263	1,481	1,087

Table 5: Multicollinearity statistics for the district level (updated)

The final indicator set, which are then integrated to model homogenous regions of vulnerability are shown in in Figure 5.

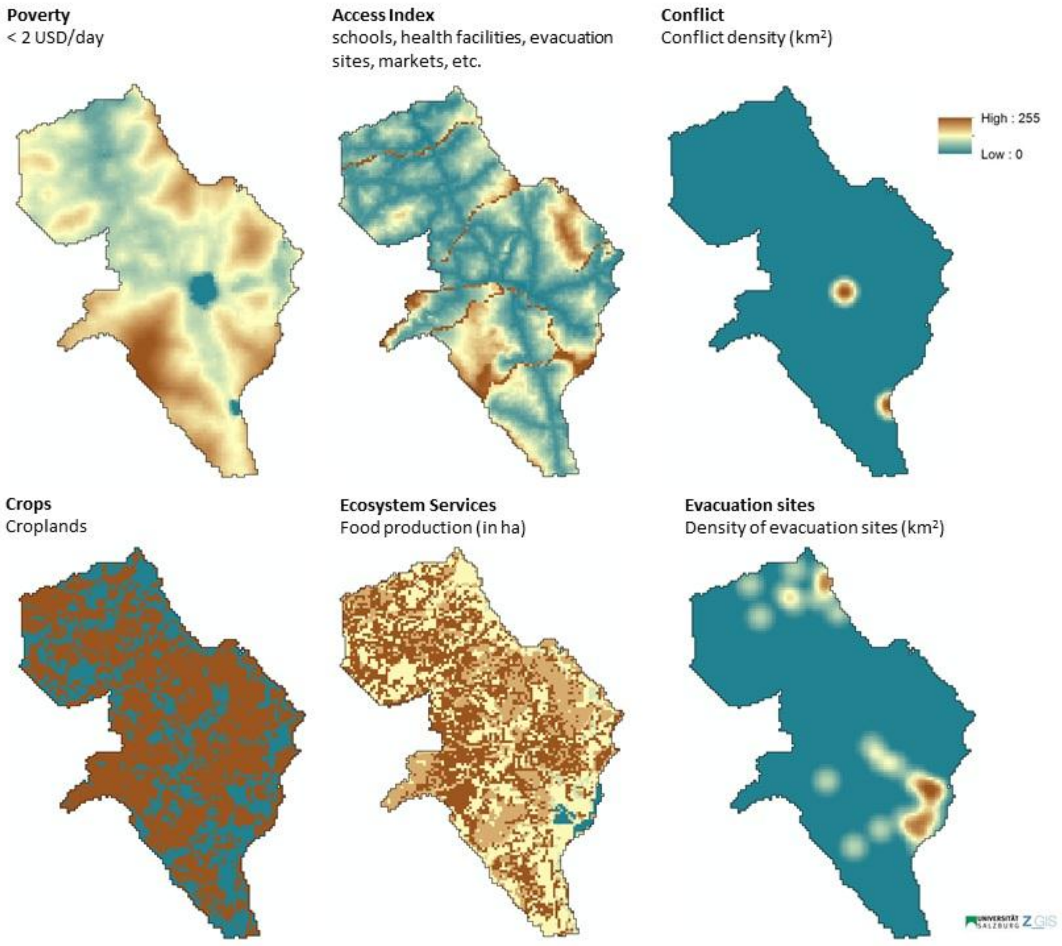

Figure 5: Raster-based indicators to be included into the modelling of homogenous regions of vulnerability at the district level

2.3.3 Modeling homogeneous regions of vulnerability

As a next step all indicators were normalized to the zero to 255 [0, 255] interval using linear min-max normalization (Equation 1). This was done to render them comparable before integrating them in a composite vulnerability index.

$$v_i' = \frac{(v_i - v_{\min})}{(v_{max} - v_{min})} * 255$$

where v_i refers to the raw pixel value, and v_{min} and v_{max} represent the minimum and maximum values, respectively, of the raw pixel value. During normalization, the final indicators were adjusted for their sign, which indicates whether the indicator contributes positively (+) or negatively (-) to vulnerability (Table 2).

A set of integrated geons, i.e., homogeneous vulnerability units, was delineated next (see also Kienberger et al 2009, Kienberger 2012). This was achieved by regionalizing the six indicators (Table 4) in a 6-dimensional indicator space using the multi-resolution segmentation algorithm (Baatz and Schäpe, 2000) which is implemented in the eCognition Developer (TRIMBLE, USA) software environment. In the absence of expert weights, each of the single indicators was weighted equally. The size of the units depends on the parameterization of the algorithm, which can be adjusted by the user. We used the 'Estimation of Scale Parameter' (ESP) tool (Dragut et al., 2014) to identify the statistically most suitable parameterization of the algorithm.

The final vulnerability index value for each geon is calculated using the weighted vector magnitude (Lang et al., in press; Kienberger et al., 2009) according to the following equation:

$$|VU| = \sqrt{w_1 v'^2_1 + w_2 v'^2_2 + w_{\dots} v'^2_{\dots} + w_n v'^2_n}$$

where *VU* refers to the vulnerability index for each geon, $v'_{i\text{-}n}$ to the normalized indicators and $w_{i\text{-}n}$ to the individual weights that were assigned to the indicators. To ease the interpretation of the results, the resulting vulnerability index values were also normalized to the zero to one interval [0,1], where zero represents no, and one very high vulnerability to floods (Figure 7).

2.4 GVH level assessment

This chapter describes the individual modelling stages for the district level assessment. For each of the four chosen GVHs a relative index value (composite indicator) has been modelled, integrating survey data.

2.4.1 Indicators and datasets

Following the identification of relevant vulnerability indicators for the vulnerability assessment at district level, a preliminary set of 18 socioeconomic, demographic and infrastructure-related indicators was identified where data was available for the four selected GVHs (Table 2).

Again, standard criteria for indicator selection such as validity, sensitivity, reproducibility and scale (Birkmann, 2006; Moldan & Dahl, 2007) were accounted for, and indicators were associated with either the susceptibility (SUS) or the lack of resilience (LoR) domain of vulnerability. In addition to the indicators and datasets that were used for the district level assessment, a range of additional datasets was acquired from the LIGHT database. The LIGHT survey is currently carried out by COOPI and other organisations to collect relevant food security related and other demographic variables at the household as well as on the GVH level. The assessment is designed to be repeated every year which will allow the monitoring of various indicators and respectively vulnerability.

Dimensions	Domains	Sub-domains	Indicators	Sign[1]	Potential proxies	Data source
Socioeconomic	Susceptibility		Female households	-	Female headed households (%)	LIGHT
			Household size	-	Average household size	LIGHT
			Age	+	Children under 5 years (%)	LIGHT
			Landhold size	-	Average landholding size per HH (acres)	LIGHT
			Education (access to)[2]	+	Lack of access to schools	NSO
						COOPI
			Water (access to)[2]	+	Lack of access to water wells	NSO
						COOPI
			Local markets (access to)[2]	+	Lack of access to markets	MASDAP
						MASDAP
						COOPI
			Road infrastructure (access to)[2]	+	Lack of access to roads	MASDAP
			Main cities (access to)[2]	+	Lack of access to important cities	OSM
			Conflict	+	Conflict density	ACLED
			Agriculture/livestock (Sub-index)	-	HH grows 3 or more crops (%)	LIGHT
				-	HH harvested enough for 2013/14 (%)	LIGHT
				-	HH has livestock (%)	LIGHT
			Dietary diversification (Sub-index)	+	HH worried about food availability	LIGHT
				-	HH consumed 3 or more food groups	LIGHT
			Ecosystem Service (food)	-	Constanza values for land cover	MASDAP
						GLOBECOVER
	Lack of Resilience	Anticipation	Climate change awareness	-	HH doing something to adapt to climate change (%)	LIGHT
			Early warning systems	-	Early warning system density	COOPI
		Coping	Evacuation sites (access to)[2]	+	Lack of Access to safe places	COOPI
			Health Services (access to)[2]	+	Lack of access to health facilities	MASDAP
						COOPI
		Recovery	Capital Assets (Sub-Index)	-	Motorcycle	LIGHT
				-	Bicycle	LIGHT
				-	TV	LIGHT
				-	Radio	LIGHT
				-	Mobile phone	LIGHT
				-	Telephone (landline)	LIGHT
				-	Number of chitetezo stoves	LIGHT

[1] *Sign: high indicator values increase [+] or decrease [-] vulnerability*
[2] *indicators were combined to an "Access Index" due to multicollinearity in data*

Table 5: List of vulnerability indicators (local level)

2.4.2 Data pre-processing and statistical analysis

Before running the analysis, the following variables/datasets were transformed into relative measurements:

- Female headed households (using # of total households)
- Children under 5 (using total population)
- Household doing something to adapt to CC (using sample size)
- Household grows 3 or more crops (using sample size)
- Household harvested enough for 2013/14 (using sample size)
- Household has livestock (using sample size)
- Household worried about food availability (using sample size)
- Household consumed 3 or more food groups (using sample size)

Moreover, the following sub-indices were created based on the individual indicators: (1) an asset sub-index, (2) an agriculture/livestock sub-index, (3) a dietary diversification sub-index, and (4) a capital asset sub-index (see Table 5). Thereby, the sign of the single indicators was taken into account.

As for the district level assessment the correlation coefficient (r), as well as variance inflation factors (VIF) were calculated to detect and reduce existing multicollinearities in the data. Table 6 shows the multicollinearity statistics for transparency purposes. However, due to the small number of observations (only 4 GVHs) the results are flawed and should not be taken into consideration (note: the small number of observations is one of the limitations of this study).

	Female households	Household size	Age	Landhold size	Access Index	Agriculture/ Livestock	Dietary diversification	Ecosystem services	Climate change awareness	Early warning systems	Capital assets
Female households	**1,000**	0,422	-0,510	-0,558	-0,615	0,732	-0,429	-0,587	-0,207	0,580	-0,692
Household size	0,422	**1,000**	-0,830	-0,025	-0,283	0,783	-0,278	-0,061	-0,412	-0,274	-0,945
Age	-0,510	-0,830	**1,000**	-0,295	0,748	-0,497	-0,183	0,574	-0,133	0,400	0,821
Landhold size	-0,558	-0,025	-0,295	**1,000**	-0,291	-0,635	0,929	-0,248	0,757	-0,919	0,250
Access Index	-0,615	-0,283	0,748	-0,291	**1,000**	-0,120	-0,440	0,973	-0,581	0,115	0,413
Agriculture/Livestock	0,732	0,783	-0,497	-0,635	-0,120	**1,000**	-0,762	0,020	-0,736	0,379	-0,901
Dietary diversification	-0,429	-0,278	-0,183	0,929	-0,440	-0,762	**1,000**	-0,473	0,944	-0,708	0,409
Ecosystem services	-0,587	-0,061	0,574	-0,248	0,973	0,020	-0,473	**1,000**	-0,665	-0,004	0,227
Climate change awareness	-0,207	-0,412	-0,133	0,757	-0,581	-0,736	0,944	-0,665	**1,000**	-0,443	0,437
Early warning systems	0,580	-0,274	0,400	-0,919	0,115	0,379	-0,708	-0,004	-0,443	**1,000**	-0,012
Capital assets	-0,692	-0,945	0,821	0,250	0,413	-0,901	0,409	0,227	0,437	-0,012	**1,000**
VIF											

Table 6: Multicollinearity statistics for the local level (updated)

2.4.3 Constructing a composite vulnerability index

Based on the pre-processed datasets, a composite vulnerability indicator (or index) was constructed using a recently developed GIS tool for constructing spatial composite indicators, which simultaneously evaluates the robustness of the resulting index by means of local sensitivity analysis (Hagenlocher et al, in preparation). The tool, which can be implemented in ArcGIS Desktop as an additional toolbox, enables the user to construct a composite vulnerability index in a fast and efficient manner. Figure 6 shows the graphical user interface (GUI) of the tool, including all relevant steps (indicator choice, weighting, normalization, aggregation) that were used to construct a vulnerability index for the four GVHs.

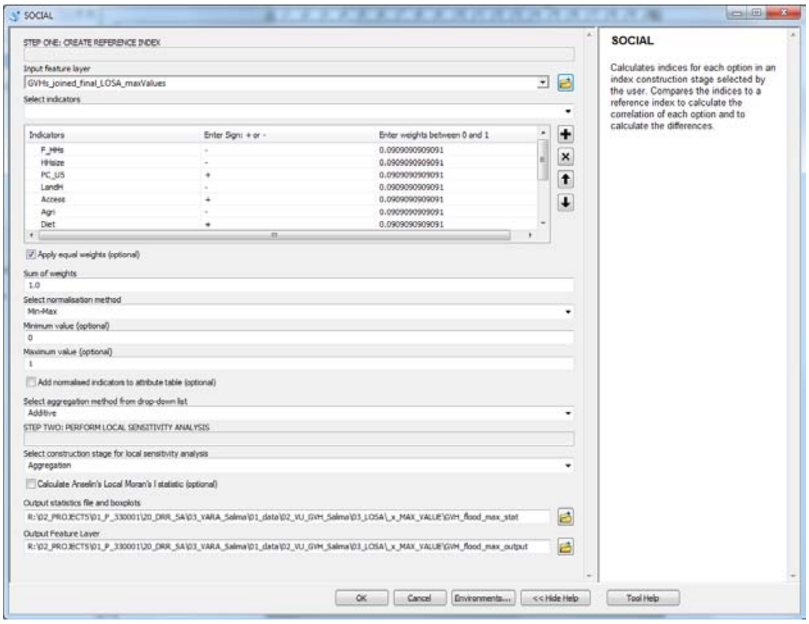

Figure 6: LOSA tool for constructing spatial composite indicators (Hagenlocher et al, in prep.)

A detailed description of the tool will be provided by Hagenlocher et al (in prep.), while the tool will be made available for free download at the ArcGIS Resource Center in summer 2014.

3 RESULTS

3.1 District level

Figure 7 shows the spatial distribution of vulnerability to floods for Salima district. In the map areas of high vulnerability are displayed in shades of red (max value = 1), while areas of low vulnerability (min value = 0) are displayed in shades of blue using a continuous colour range. As such the different values of vulnerability allow the identification of hot and cold spots across the region. From a general point of view it can be highlighted that many parts of the district are characterised by a high vulnerability to floods (which is – again – independent form the hazard itself).

Regions of very high vulnerability are found in in the western part of the district, whereas factors such as poverty, the lack of early warning systems, the lack of ecosystems lowering the impact of floods (e.g. less forested areas) as well as issues on cropland density contribute to this factor. Regions of lower vulnerability can be identified preliminary in those regions where early warning systems have been established or sufficient croplands are available.

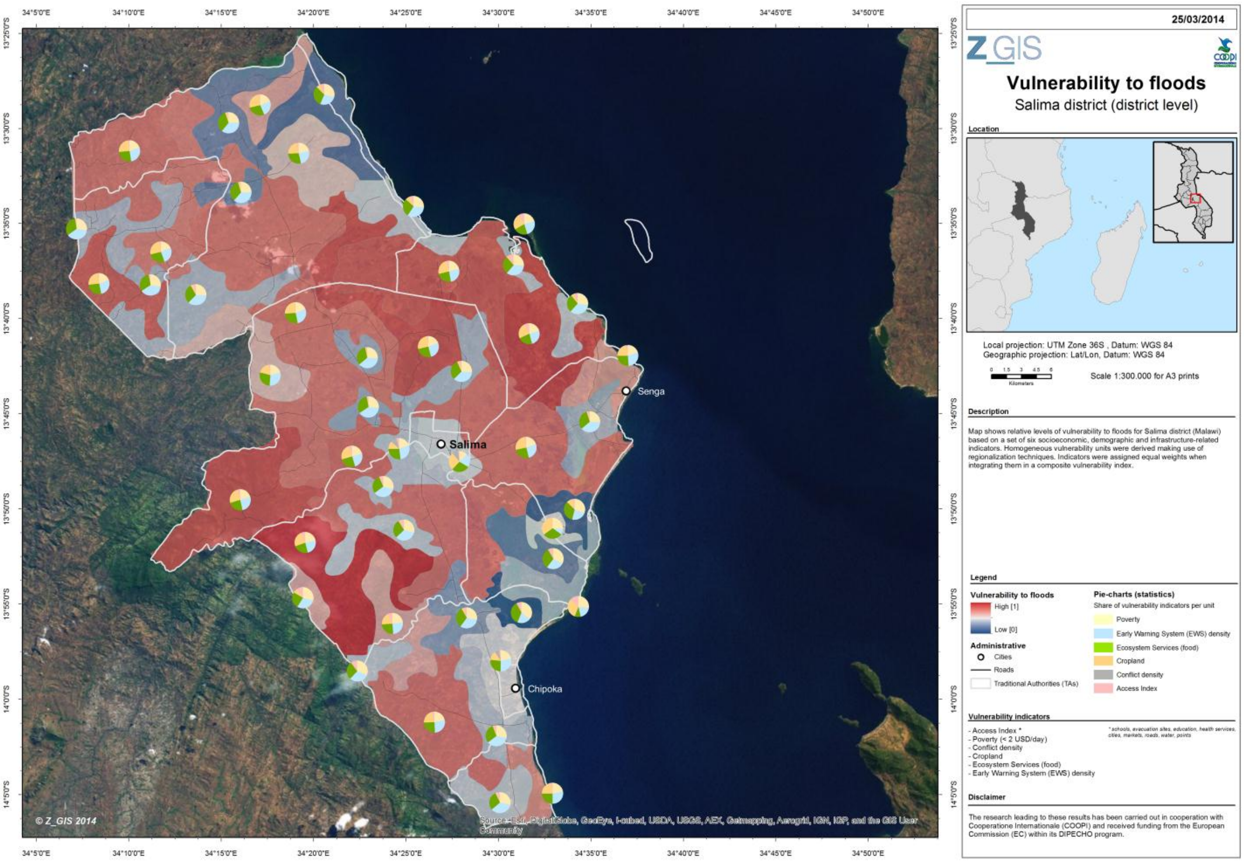

Figure 7: Vulnerability to floods in Salima district, Malawi

As it can be depicted from Figure 7, the contribution of the different vulnerability factors (indicators) varies also across this district. Next to the location of possible intervention areas (hot spots) the appropriate and required intervention measures can be identified by investigating the contribution of each vulnerability factor through the pie charts. For instance some areas may require targeted poverty reduction measures whereas in others a focus could be additionally on the establishments of community-based early warning systems.

3.2 GVH level

Figure 8 shows vulnerability to floods for four selected GVHs in Salima district. Again, high vulnerability is displayed in shades of red (max value = 1), while low vulnerability (min value = 0) is displayed in shades of blue using a continuous colour range. The GVH with the highest vulnerability value is Makho, the lowest Mmanga, whereas the other two range in between.

What can be clearly depicted from the different patterns in the pie charts is the different characteristic of vulnerability and therefore the required intervention measures. For instance in Makho all the different factors contribute equally, required intervention measures in Saopampeni could be focussed on early warning systems, the improvement of ecosystem services for food provision, improvement of the dietary index as well as the food security index. Issues in the lower ranked GVHs in the south-eastern part are around the climate awareness of the communities. These results clearly show that targeted intervention measures are important, even across a district.

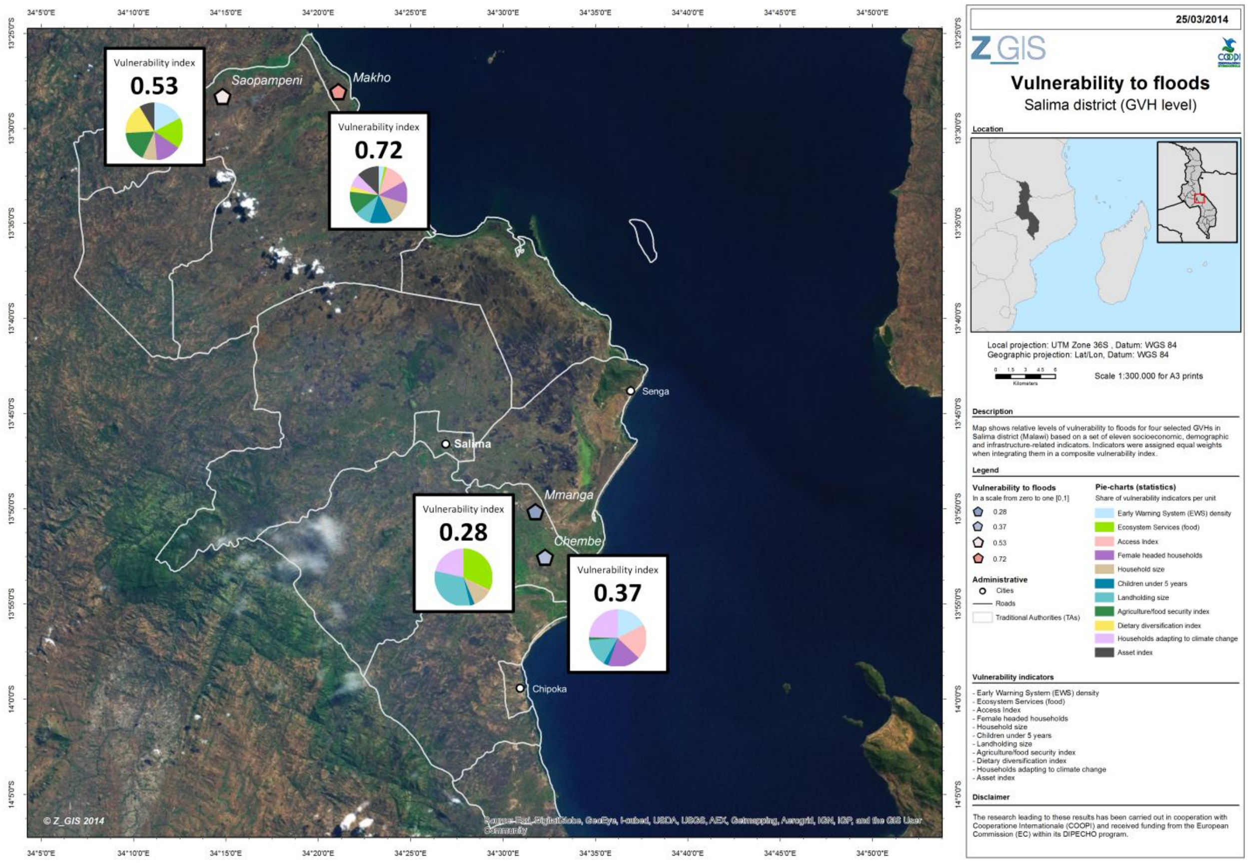

Figure 8: Vulnerability to floods for four selected GVHs in Salima district, Malawi

4 CONCLUSIONS

The assessment carried out for the district of Salima and at the GVH level demonstrates well how vulnerability can be mapped – on the district level through the application of novel regionalisation approaches independent from administrative boundaries as well as through the application of standardized composite indicator methods. As such spatial patterns can be identified, as well as the contribution of different indicators reflect required intervention measures.

What is important to highlight in this study, is that the indicators have been weighted equally. Alternative approaches could be the development of statistically based weights, or in such a context even more appropriate, weighting based on expert knowledge. However, the methodology applied represents vulnerability as homogenous regions, which share a common property of vulnerability, and reflect a valid approach to modelling such an integrative phenomenon under the given data-scarce environment.

An additional factor to consider is the quality and attached uncertainty of the input data. Whereas we could identify a number of suitable indicators, it has to be highlighted that access and the availability of high-resolution census data would have been an additional asset. As such data availability plays a critical role that determines the accuracy of such approaches and highlights again the need for the identification of basic data needs for vulnerability assessments and its continuous availability over different time periods.

High potential exists in regard of using the GVH based survey data. As a regular update will be performed in the future this provides large opportunities to link vulnerability assessment approaches with monitoring and evaluation activities.

This approach can be easily transferred to other regions of interest in Malawi. Additionally it is proposed to integrate the vulnerability results with valid hazard zones to achieve the final objective of a holistic risk assessment.

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ANNEX

Annex 1: Map - Vulnerability to floods Salima district (district level)
Annex 2: Map - Vulnerability to floods Salima district (GVH level)

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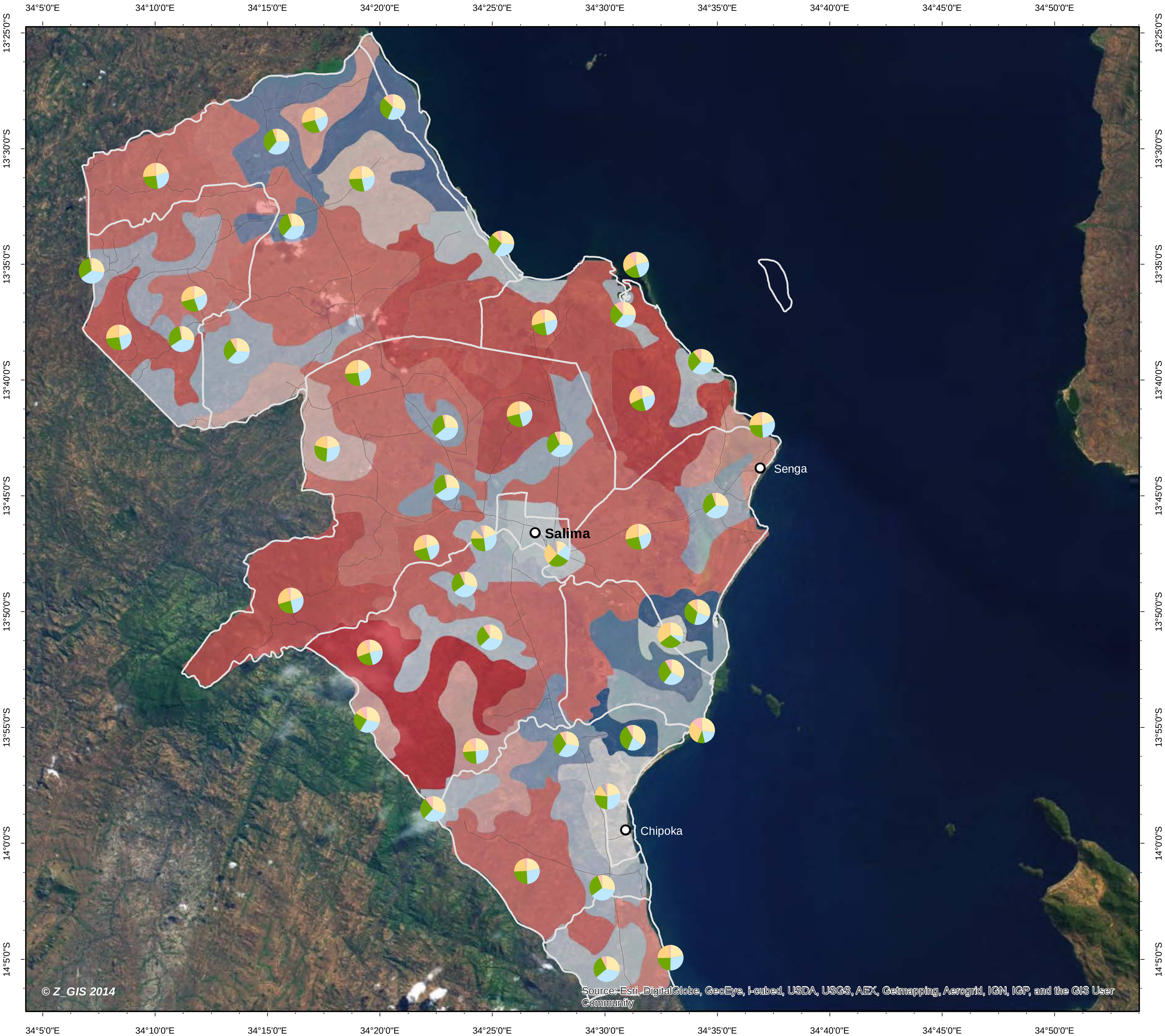


25/03/2014

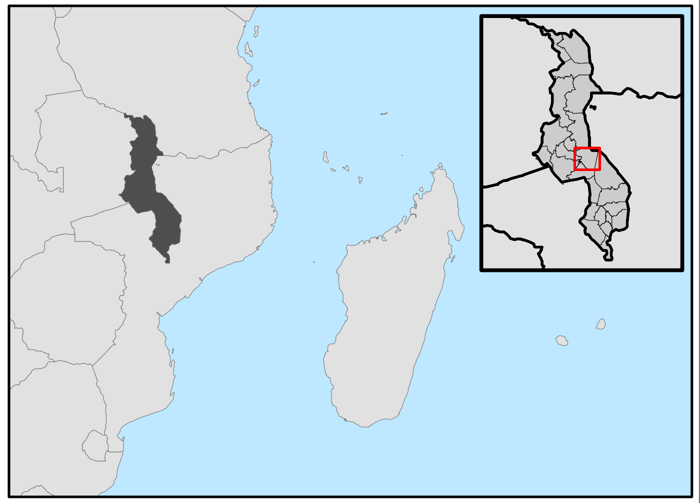
Z_GIS

COOPI

Vulnerability to floods

Salima district (district level)

Location



Local projection: UTM Zone 36S , Datum: WGS 84
Geographic projection: Lat/Lon, Datum: WGS 84

0 1.5 3 4.5 6
Kilometers

Scale 1:300.000 for A3 prints

Description

Map shows relative levels of vulnerability to floods for Salima district (Malawi) based on a set of six socioeconomic, demographic and infrastructure-related indicators. Homogeneous vulnerability units were derived making use of regionalization techniques. Indicators were assigned equal weights when integrating them in a composite vulnerability index.

Legend

Vulnerability to floods

High [1]

Low [0]

Administrative

Cities

Roads

Traditional Authorities (TAs)

Pie-charts (statistics)

Share of vulnerability indicators per unit

Poverty

Early Warning System (EWS) density

Ecosystem Services (food)

Cropland

Conflict density

Access Index

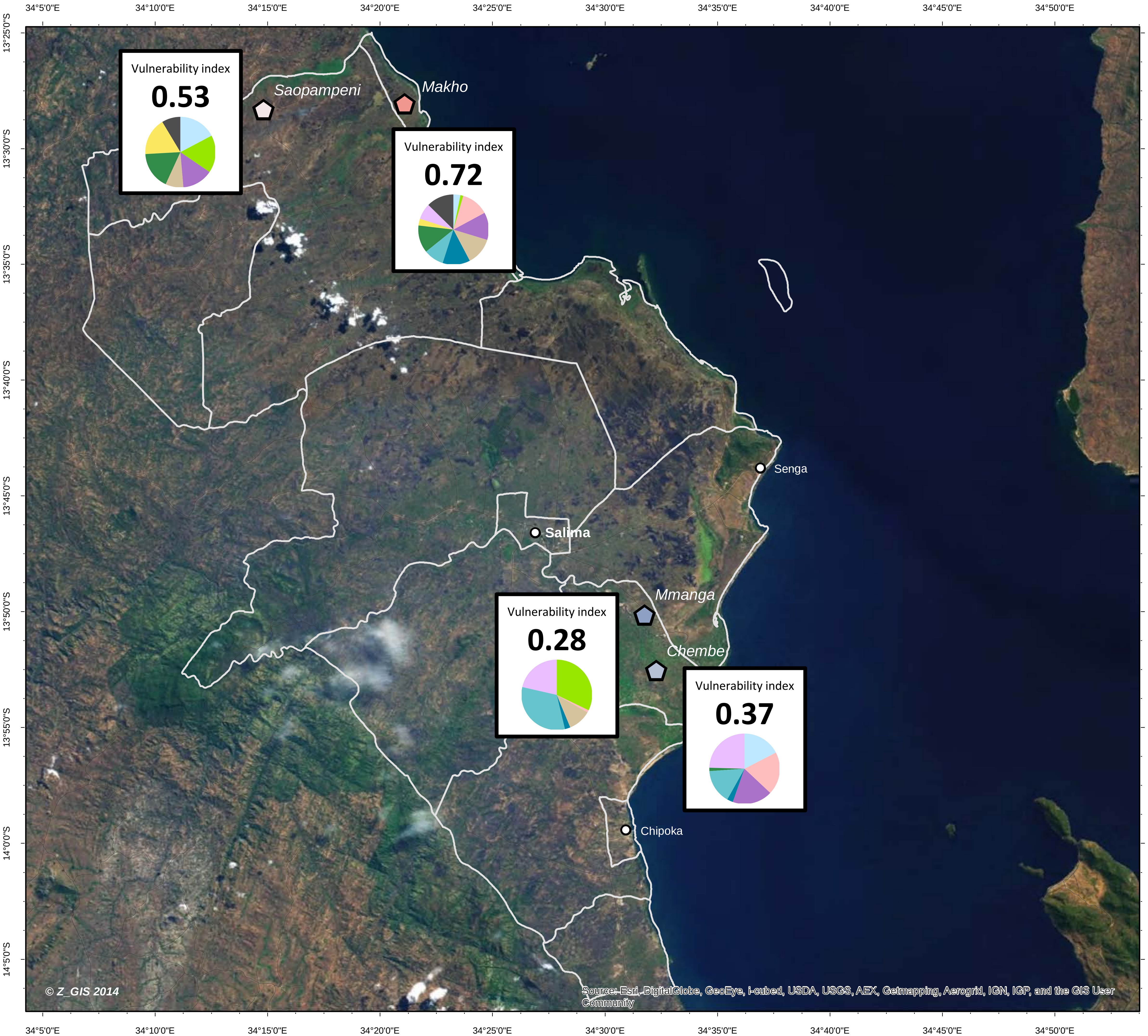
Vulnerability indicators

- Access Index *
- Poverty (< 2 USD/day)
- Conflict density
- Cropland
- Ecosystem Services (food)
- Early Warning System (EWS) density

* *schools, evacuation sites, education, health services, cities, markets, roads, water, points*

Disclaimer

The research leading to these results has been carried out in cooperation with Cooperatione Internationale (COOPI) and received funding from the European Commission (EC) within its DIPECHO program.



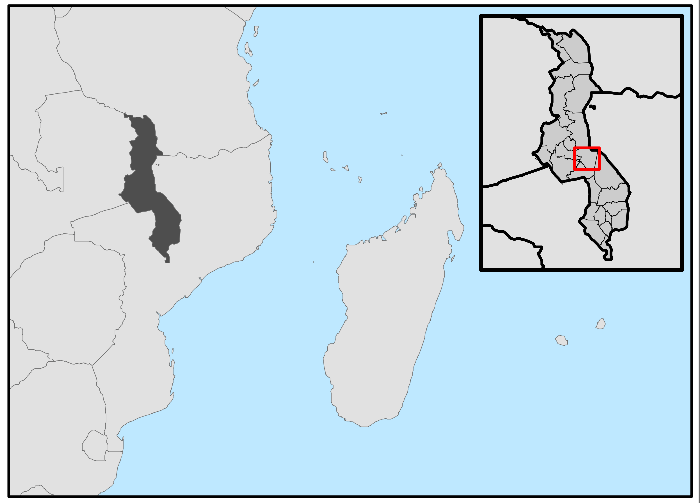
25/03/2014

Z_GIS

Vulnerability to floods

Salima district (GVH level)

Location



Local projection: UTM Zone 36S , Datum: WGS 84
Geographic projection: Lat/Lon, Datum: WGS 84

0 1.5 3 4.5 6
Kilometers

Scale 1:300.000 for A3 prints

Description

Map shows relative levels of vulnerability to floods for four selected GVHs in Salima district (Malawi) based on a set of eleven socioeconomic, demographic and infrastructure-related indicators. Indicators were assigned equal weights when integrating them in a composite vulnerability index.

Legend

Vulnerability to floods

In a scale from zero to one [0,1]

- 0.28
- 0.37
- 0.53
- 0.72

Administrative

- Cities
- Roads
- Traditional Authorities (TAs)

Pie-charts (statistics)

Share of vulnerability indicators per unit

- Early Warning System (EWS) density
- Ecosystem Services (food)
- Access Index
- Female headed households
- Household size
- Children under 5 years
- Landholding size
- Agriculture/food security index
- Dietary diversification index
- Households adapting to climate change
- Asset index

Vulnerability indicators

- Early Warning System (EWS) density
- Ecosystem Services (food)
- Access Index
- Female headed households
- Household size
- Children under 5 years
- Landholding size
- Agriculture/food security index
- Dietary diversification index
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