EUROPEAN COMMISSION

Humanitarian Aid

Final Report

Resilience assessment in the context of food security at the district and GVH level in Salima, Malawi

Lilongwe, Malawi
Salzburg, Austria
27/03/2014

"This document has been produced with the financial assistance of the European Commission. The views expressed herein should not be taken, in any way, to reflect the official opinion of the European Commission."

Funded by:
"European Commission Humanitarian Aid department"

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Project title	Resilience assessment in the context of food security at the district and GVH level in Salima, Malawi
Period of implementation	From: 01/09/2013 To: 31/03/2014

Document information	
Deliverable reference number	Internal document
Due date	After conclusion of project
Actual submission date	-
Version/issue no.	Version 1.0 (27/03/2014)

Project details	
Start date of project	01/09/2013
Duration	6 months
Name of contractor/s	Cooperazione Internationale (COOPI); Interfaculty Department of Geoinformatics - Z_GIS, University of Salzburg, Austria
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Dissemination level: RE	
PU	Public
PP	Restricted to other programme participants
RE	Restricted to a group specified by ECHO
CO	Confidential, only for members of the consortium

Issue	Date	Pages	Changes
1.0	27/03/2014	28	Final report to be submitted to ECHO

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Acronyms	
ABS	Access to basic services
ACP	Adaptive capacity
AGA	Agricultural assets
COOPI	Cooperazione Internationale
DIPECHO	Disaster Preparedness - European Community Humanitarian Office
ENSO	El Niño-Southern Oscillation
GVH	Group Village Headmen
IPCC	International Panel for Climate Change
IFA	Income and food access
LULC	Land Use/ Land Cover
RA	Resilience Assessment
NAA	Non agricultural assets
SSN	Social safety nets
STA	Stability
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 food security. 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. Resilience Assessments (RA) are important to identify intervention measures at various levels of the decision making process in the food security context and different concepts and methods can provide support on this matter.

Resilience has a 'spatial' characteristic that requires the integration of various datasets as well as perspectives from the food security community and climate change adaptation concepts see recommendations from IPCC (IPCC 2012 and the upcoming IPCC AR5). This resilience study is based on the approach developed by Kienberger (2009) and Kienberger (2012) in Mozambique. According to this approach and adapted here to the resilience concept, resilience maps to food insecurity have been produced based on existing data sources which allow the identification of resilince 'hot spots' and its characterization within the district or GVH level. The RA results are a relative measure for the district (showing hot and cold spots of resilience in the district of Salima). The RA has been therefore based on the following:

- the RA results are a relative measure for the district (showing hot and cold spots of resilience 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 RA are specified:

- Two scale levels of assessment: District level and GVH level
  - District level
    - Resilience map for the district
    - Hazard: Food Insecurity | Resilience domain: socioeconomic
    - It allows the identification of priority intervention areas within a district (hot and cold spots of resilience)
  - Community level
    - A resilience 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 resilience
    - 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. Additionally different drought events contribute to food insecurity. In the district itself different disaster risk reduction and food security 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, to use of drought resistant crops etc. As pointed out above, this study contributes to these activities by expanding the resilience concept by mapping its spatial patterns. 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.

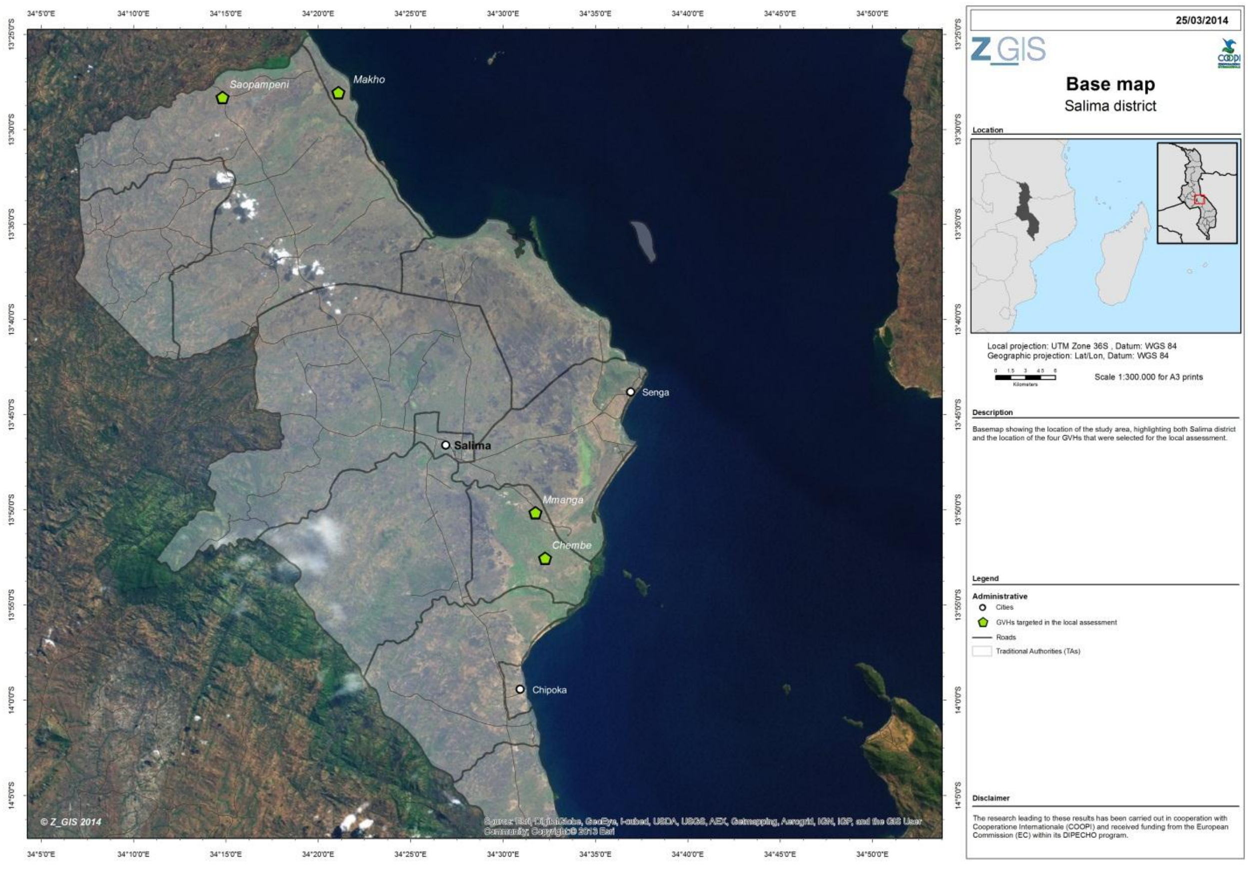

Figure 1: Base map showing the location of the study area

2 METHODOLOGY

2.1 Conceptual framework

The way a household copes with and withstands economic shocks depends on the options available, in terms of capabilities, assets (including both material and social resources) and activities. A livelihood strategy is the way those options are arranged and selected. Comprehending the driving factors of each livelihood strategy is crucial to improve the response mechanisms related to poverty and food security in developing countries (Alinovi et al., 2010).

The assessment framework (see Figure 2) has been based on the resilience framework developed by Alinovi et al. (2009) and Alinvoi et al (2010). As such this framework has been applied the first time in such a spatial assessment of resilience. The following is taken from Alinovi et al. (2009). The concept of resilience has recently been introduced into food security literature. It aims to measure households' capability to absorb the negative effects of unpredictable shocks, as a legitimate component of vulnerability analysis.

The definition of resilience to food insecurity has a direct effect on the methodology used to measure it, and the model described in this document, considers resilience to be a latent variable defined according to four building blocks: income and food access (IFA), access to basic services (ABS), agricultural assets (AGA), non-agricultural assets (NAA) and social safety nets (SSN). Two additional dimensions – stability (STA) and adaptive capacity (ACP) – cut across these building blocks and account for households' capacity to respond and adapt to shocks.

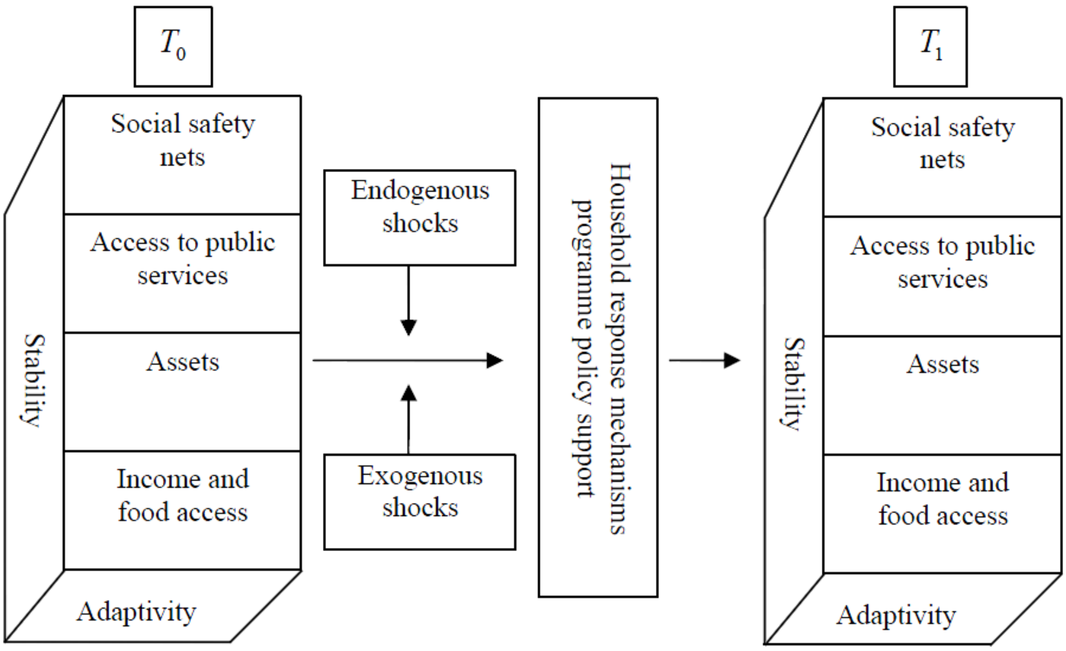

Figure 2: Conceptual resilience framework (Alinovi et al., 2009)

For the aggregation towards the resilience value a hierarchical approach has been chosen. This is illustrated in Figure 3. First all indicators are aggregated either through weighted sum (pixel-based) or arithmetic aggregation to the eight components of resilience, which are then in a later stage integrated through regionalisation approaches at the district level and through arithmetic aggregation at the GVH level.

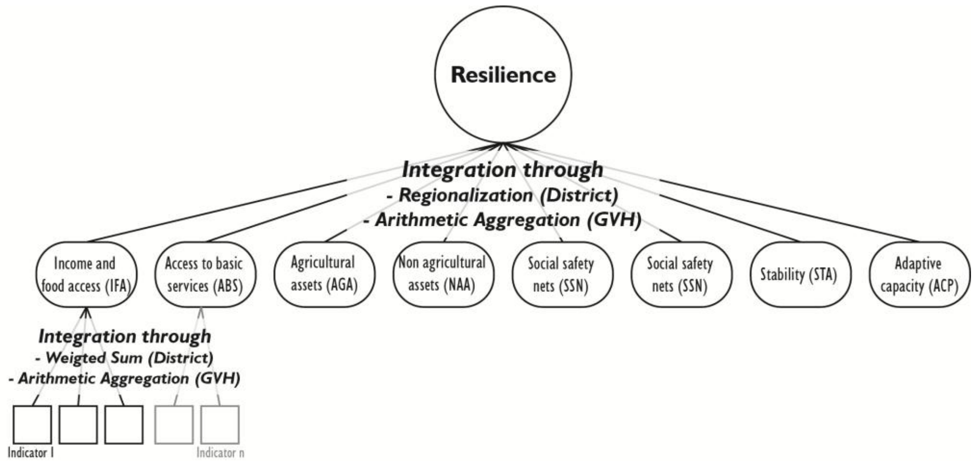

Figure 3: Aggregation scheme for resilience

2.2 Workflow for modelling resilience

To provide updated information on the multi-faceted nature of resilience to food insecurity a composite resilience index was developed for both (i) Salima district (district level), and (ii) four selected GVHs (local level) in Salima district, Malawi. Both resilience indices build on a set of underlying socioeconomic, demographic and infrastructure-related indicators. A multi-step and iterative workflow (Figure 4) 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.

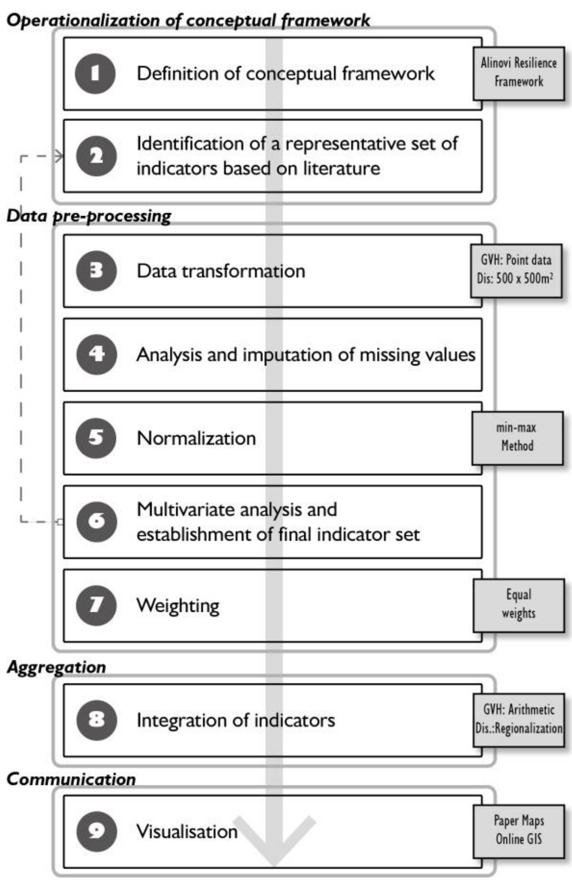

Figure 4: Workflow for modeling resilience to food insecurity

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.

2.3.1 Indicators and datasets

Drawing on the conceptual resilience framework (Figure 2) a preliminary set of 13 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
Resilience	Basic living options	Income and Food Access (IFA)	Poverty	-	Poverty below $2/day	WorldPop
			Crop density	+	Land cover	MASDAP
			Main cities (access to)	-	Lack of access to important cities	OSM
			Local markets (access to)	-	Lack of access to markets	MASDAP
						MASDAP
						COOPI
		Access to Basic Services (ABS)	Water (access to)	-	Lack of access to water wells	NSO
						COOPI
			Road infrastructure (access to)[2]	-	Lack of access to roads	MASDAP
		Agricultural Assets (AGA)	Ecosystem service (food)	+	Constanza values for land cover	MASDAP
						GLOBECOVER
		Non Agricultural Assets (NAA)				
		Social safety nets (SSN)	Aid projects	+	Aid project density	AIDDATA
						WORLDBANK
	Adaptice Capacity	Adaptive Capacity (ACP)	Education (access to)	-	Lack of access to schools	NSO
						COOPI
			Health services (access to)	-	Lack of Access to health facilities	MASDAP
						COOPI
	Stability	Stability (STA)	Conflict	-	Conflict density	ACLED
			Flood zones	-	Occurenc of flooding events	expert based
			Drought zones	-	Occurenc of drought events	expert based

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

[2] *indicator was not considered for analysis due to multicollinearity in data*

Table 2: List of resilience indicators

From literature, the following indicators have been identified: poverty, crop density, access to main cities, access to local markets, access to water, access to roads/transportation network, ecosystem services, aid project density, access to education, access to health services, conflict density, flood zones and drought zones (based on Kienberger et al., 2012, as well as Alinovi et al., 2009, Alinovi et al. 2010). 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 to the resilience sub-domains of Income and Food Access (IFA), Access to Basic Services (ABS), Agricultural Assets (AGA), Social safety nets (SSN), Adaptive Capacity (ACP) and Stability (STA). For the sub-domain of Non Agricultural Assets (NAA) no suitable datasets for indicators could be found (Table 2).

2.3.2 Data pre-processing and statistical analysis of original indicators

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 5 shows the updated LULC dataset for the study area.

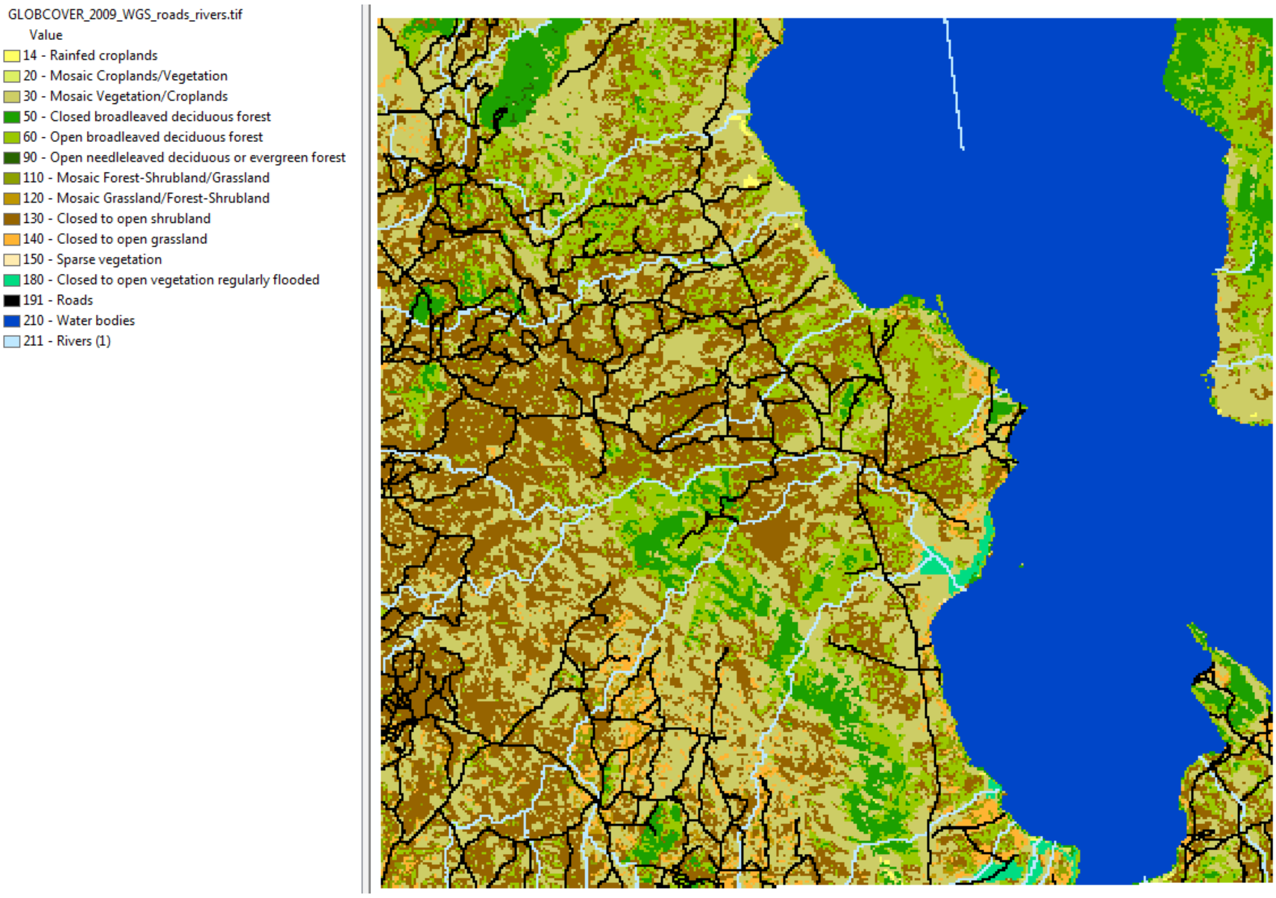

Figure 5: Updated LULC dataset (GlobCover 2009)

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) six path distance surfaces were created for the following input datasets: schools, water points, markets, roads, cities 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.

For all density indicators (poverty, crop, aid project and conflict density) a Kernel density estimation was conducted. The indicators flood and drought zones were converted into a binary layer of occurrence (0= no flood/drought occurred; 1= flood/drought occurred).

To detect and ultimately reduce existing multicollinearities in the data, the correlation coefficient (r), as well as variance inflation factors (VIF) were calculated. These values were calculated separately for each sub-domain pillar (see Table 2). Based on threshold values published by the OECD (2008), no indicators within a subdomain pillar revealed strong cross-correlations (with $r < 0.9$ and/or $VIF < 5$; Table 4).

IFA	Poverty	Crop density	Cites (access to)	Markets (access to)
Poverty	**1,000**	-0,023	0,613	0,540
Crop density	-0,023	**1,000**	-0,029	-0,032
Cites (access to)	0,613	-0,029	**1,000**	0,874
Markets (access to)	0,540	-0,032	0,874	**1,000**
VIF	1,601	1,001	4,809	4,241

ABS	Water (access to)	Roads (access to)
Water (access to)	**1,000**	0,718
Roads (access to)	0,718	**1,000**
VIF	2,063	2,063

STA	Conflict	Flood zones	Drought zones
Conflict	**1,000**	0,017	
Flood zones	0,017	**1,000**	
Drought zones			
VIF	1,000	1,000	

ACP	Education (access to)	Health services (access to)
Education (access to)	**1,000**	0,888
Health services (access to)	0,888	**1,000**
VIF	4,710	4,710

Table 4: Multicollinearity statistics (indicators grouped on sub-domain pillars)

2.3.3 Building the sub-domain indices

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 the sub-domain indices.

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

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 resilience (Table 2).

After this the following indicators were combined in respective indices of the sub-domain pillars using a weighted sum approach with equal weights:

Income and access to food (IFA)
- Poverty [Sign: -]
- Crop density [Sign:+]
- Access to main cities [Sign: -]

Access to basic services (ABS)
- Access to water [Sign: -]
- Access to roads [Sign: -]

Adaptive capacity (ACP)
- Access to education [Sign: -]
- Access to health facilities [Sign: -]

Stability (STA)
- Conflicts [Sign: -]
- Flood zones [Sign: -]
- Drought zones [Sign: -]

The resulting indices were then again normalized to the zero to 255 [0, 255] interval. For the sub-domain indices Agricultural Assests (AGA) the original indicator Ecosystem services was used, for Social safety nets (SSN) the indicator Aid projects was used. For the sub-domain of Non Agricultural Assets (NAA) no suitable datasets for indicators could be found (Table 2).

To detect multicollinearities between the sub-domain indices a multicollinearity analysis was performed again.

	IFA	ABS	AGA	SSN	ACP	STA
IFA	**1,000**	0,382	0,225	0,061	0,393	0,264
ABS	0,382	**1,000**	-0,228	0,067	0,939	0,065
AGA	0,225	-0,228	**1,000**	0,014	-0,278	0,060
SSN	0,061	0,067	0,014	**1,000**	0,083	-0,089
ACP	0,393	0,939	-0,278	0,083	**1,000**	0,060
STA	0,264	0,065	0,060	-0,089	0,060	**1,000**
VIF	1,478	8,486	1,279	1,021	9,084	1,090

Table 5: Multicollinearity statistics (sub-domain indices)

The sub-domain indices Access to basic services (ABS) and Adaptive capacity (ACP) revealed strong cross-correlations (with r > 0.9 and/or VIF > 5;Table 5). To reduce these multicollinearities the original indicator “Road infrastructure (access to)” was exclude from further analysis due to its high correlation with the indicator “Access to health service” (r=0,952) and its global scale level and only the indicator “Access to water” was used for the sub-domain index Access to Basic Services (ABS).Table 6 shows the multicollinearity statistics after that step.

	IFA	ABS	AGA	SSN	ACP	STA
IFA	**1,000**	0,297	0,225	0,061	0,393	0,264
ABS	0,297	**1,000**	-0,177	0,050	0,822	0,053
AGA	0,225	-0,177	**1,000**	0,014	-0,278	0,060
SSN	0,061	0,050	0,014	**1,000**	0,083	-0,089
ACP	0,393	0,822	-0,278	0,083	**1,000**	0,060
STA	0,264	0,053	0,060	-0,089	0,060	**1,000**
VIF	1,491	3,149	1,288	1,021	3,823	1,091

Table 6: Multicollinearity statistics (sub-domain indices after correcting for high correlations)

Figure 6 shows the final six sub-domain indices that were used for the modelling of homogenous regions of resilience.

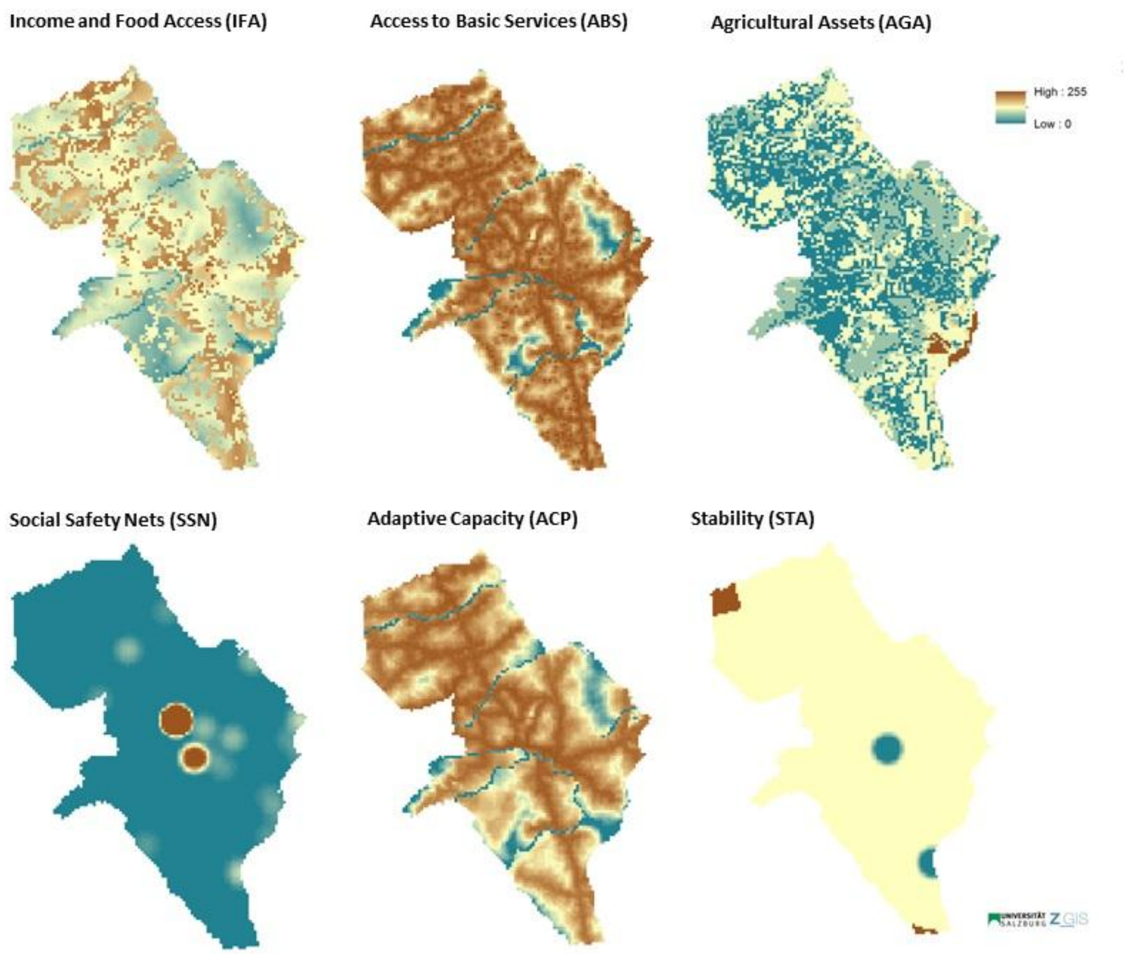

Figure 6: Sub-domain indices used for calculating the resilience index on district level

2.3.4 Modeling homogeneous regions of resilience

A set of integrated geons, i.e., homogeneous resilience units, was delineated next. This was achieved by regionalizing the six indicators (Table 6) 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 resilience 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:

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

where *RE* refers to the resilience index for each geon, $v'_{i\text{-}n}$ to the normalized sub-domain indices and $w_{i\text{-}n}$ to the individual weights that were assigned to the indicators. To ease the interpretation of the results, the resulting resilience index values were also normalized to the zero to one interval [0,1], where zero represents no, and one very high resilience to food insecurity (Figure 8).

2.4 GVH level assessment

This chapter describes the individual modelling stages for the GVH 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 20 socioeconomic, demographic and infrastructure-related indicators was identified where data was available for the four selected GVHs Chembe, Mmanga, Makho and Saopampeni (Table 7).

Dimension	Domains	Sub-domains	Indicators	Sign[1]	Potential proxies	Data source
Resilience	Basic living options	Income and Food Access (IFA)	Food diversification	+	HH consumed 3 or more food groups (%)	LIGHT
			Main cities (access to)	-	Lack of access to important cities	OSM
			Local markets (access to)	-	Lack of access to markets	MASDAP
						MASDAP
						COOPI
		Access to Basic Services (ABS)	Water (access to)	-	Lack of access to water wells	NSO
						COOPI
			Road infrastructure (access to)	-	Lack of access to roads	MASDAP
		Agricultural Assets (AGA)	Landhold size	+	Average landholding size per HH (acres)	LIGHT
			Crop diversification	+	HH grows 3 or more crops (%)	LIGHT
			Livestock	+	HH has livestock (%)	LIGHT
			Ecosystem services	+	Constanza values for land cover	MASDAP
						GLOBECOVER
			Agricultural assests (Sub-Index)	+	Plough/ridge	LIGHT
				+	Treadle pump	LIGHT
				+	Panga	LIGHT
				+	Hoe	LIGHT
				+	Wheel barrow	LIGHT
				+	Pick	LIGHT
				+	Shovel	LIGHT
				+	Axe	LIGHT
				+	Genset	LIGHT
				+	Sickle	LIGHT
		Non Agricultural Assets (NAA)	Capital assets (Sub-Index)	+	Motorcycle	LIGHT
				+	Bicycle	LIGHT
				+	TV	LIGHT
				+	radio	LIGHT
				+	mobile phone	LIGHT
				+	telephone (landline)	LIGHT
				+	# of chitetezo stoves	LIGHT
		Social Safety Nets (SSN)	Aid projects	+	Aid project density	WORLDBANK
	Adaptice Capacity	Adaptive Capacity (ACP)	Climate change awareness	+	HH doing something to adapt to climate change (%)	LIGHT
			Education (access to)[2]	-	Lack of access to schools	NSO
						COOPI
			Health services (access to)	-	Lack of Access to health facilities	MASDAP
						COOPI
	Stability	Stability (STA)	Conflict	-	Conflict density	ACLED
			Flood zones	-	Occurenc of flooding events	expert based
			Drought zones	-	Occurenc of drought events	expert based
			Food availability[2]	-	HH worried about food availability (%)	LIGHT
			Harvest output	+	HH harvested enough for 2013/14 (%)	LIGHT

[1] *Sign: h igh indicator values increase [+] or decrease [-] resilience*
[2] *indicator was not considered for analysis due to due to multicollinearity in data*

Table 7: List of resilience indicators (local GVH level)

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 the resilience sub-domains of Income and Food Access (IFA), Access to Basic Services (ABS), Agricultural Assets (AGA), Non Agricultural Assets (NAA), Social safety nets (SSN), Adaptive Capacity (ACP) and Stability (STA; Table 7). 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 resilience.

2.4.2 Data pre-processing and statistical analysis

Before running the analysis, the following variables/datasets from the LIGHT data base were transformed into relative measurements:

- HH doing something to adapt to climate change (using sample size, i.e. 19 HHs)
- HH grows 3 or more crops (using sample size, i.e. 19 HHs)
- HH harvested enough for 2013/14 (using sample size, i.e. 19 HHs)
- HH has livestock (using sample size, i.e. 19 HHs)
- HH worried about food availability (using sample size, i.e. 19 HHs)
- HH consumed 3 or more food groups (using sample size, i.e. 19 HHs)

Moreover, the following sub-indices were created based on the individual indicators: (1) an agricultural asset sub-index and (2) a capital asset sub-index. Thereby, the sign of the single indicators was taken into account.

Agricultural asset subindex:

- Asset plough/ride Sign: [+]
- Asset treadle pump Sign: [+]
- Asset panga Sign: [+]
- Asset hoe Sign: [+]
- Asset wheel barrow Sign: [+]
- Asset pick Sign: [+]
- Asset shovel Sign: [+]
- Asset axe Sign: [+]
- Asset genset Sign: [+]
- Asset sickle Sign: [+]

Capital asset sub-index

- Asset motorcycle Sign: [+]
- Asset bicycle Sign: [+]
- Asset TV Sign: [+]
- Asset radio Sign: [+]
- Asset mobile phone Sign: [+]
- Asset telephone (Landline) Sign: [+]
- Asset stoves Sign: [+]

For those indicators also used in the district level, the pixel value of the respective surface (with a 3m x 3m filter applied) at the 4 GHV locations were used.

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. These values were calculated separately for each sub-domain pillar (see Table 7). Based on thresholds published by the OECD (2008), within the ACP pillar the indicators: Education (access to) and Food availability revealed strong cross-correlations (with $r > 0.9$ and/or $VIF > 5$; Table 8; note: the small number of observations is one of the limitations of this study and thus sometimes the VIF value could not be calculated). It was decided to not consider the indicator Education (access to) for further analysis due to this high correlation and nation-wide dataset (compared to the specifically for the used GHVs collected data from the LIGHT data base).

IFA	Food diversification	Cites (access to)	Markets (access to)
Food diversification	**1,000**	-0,124	0,527
Cites (access to)	-0,124	**1,000**	0,274
Markets (access to)	0,527	0,274	**1,000**
VIF	1,551	1,212	1,651

ABS	Water (access to)	Roads (access to)
Water (access to)	**1,000**	0,152
Roads (access to)	0,152	**1,000**
VIF	1,024	1,024

ACP	Food availability	Education (access to)	Health services (access to)
Food availability	**1,000**	0,992	0,311
Education (access to)	0,992	**1,000**	0,263
Health services (access to)	0,311	0,263	**1,000**
VIF	72,407	70,233	1,290

STA	Harvest output	Food availability
Harvest output	**1,000**	-0,661
Food availability	-0,661	**1,000**
VIF	1,775	1,775

AGA	Landhold size	Crop diversification	Livestock	Ecosystem services	Agricultur assets
Landhold size	**1,000**	0,861	0,773	-0,255	0,888
Crop diversification	0,861	**1,000**	0,659	-0,507	0,550
Livestock	0,773	0,659	**1,000**	-0,688	0,806
Ecosystem services	-0,255	-0,507	-0,688	**1,000**	-0,130
Agricultur assets	0,888	0,550	0,806	-0,130	**1,000**
VIF					

Table 8: Multicollinearity statistics for the local GVH level

Table 9 shows the multicollinearity statistics for the ACP pillar after removal of the indicator Education (access to).

ACP	Food availability	Health services (access to)
Food availability	**1,000**	0,311
Health services (access to)	0,311	**1,000**
VIF	1,107	1,107

Table 9: Multicollinearity statistics of the ACP for the local GVH level (updated)

2.4.3 Building the sub-domain indices

The following indicators were combined in respective indices of the sub-domain pillars using a weighted sum approach with equal weights:

Income and access to food (IFA)

- Food diversification [Sign:+]
- Access to main cities [Sign: -]
- Access to local markets [Sign: -]

Access to basic services (ABS)

- Access to water [Sign: -]
- Access to roads [Sign: -]

Agricultural assets (AGA)

- Landhold size [Sign:+]
- Crop diversification [Sign:+]
- Livestock [Sign:+]
- Ecosystem services [Sign:+]

- Agricultural assets (sub-index) [Sign:+]
- Crop diversification [Sign:+]
-

Adaptive capacity (ACP)
- Climate change awareness [Sign: -]
- Access to health services [Sign: -]

Stability (STA)
- Conflicts [Sign: -]
- Flood zones [Sign: -]
- Drought zones [Sign: -]
- Harvest output [Sign: -]

The resulting indices were then again normalized to the zero to 255 [0, 255] interval. For the sub-domain indices Non Agricultural Assests (NAA) the original indicator Capital assets (Sub-inex) was used, for Social safety nets (SSN) the indicator Aid projects (Table 7).

To detect multicollinearities between the sub-domain indices a multicollinearity analysis was performed again (Table 10). As the sub-domain indices Stability and Non-agricultural Assets showed a strong cross-correlation, it was decided to remove the original indicator Food availability from the Stability" index due to its high correlation with the NAA (r=0,995).

	IFA	ABS	AGA	NAA	SSN	ACP	STA
IFA	**1,000**	0,838	0,590	0,237		0,897	0,582
ABS	0,838	**1,000**	0,074	-0,132		0,883	0,155
AGA	0,590	0,074	**1,000**	**0,430**		0,431	0,689
NAA	0,237	-0,132	**0,430**	**1,000**		-0,214	0,916
SSN							
ACP	0,897	0,883	0,431	-0,214		**1,000**	0,176
STA	0,582	0,155	0,689	0,916		0,176	**1,000**
VIF							

Table 10: Multicollinearity statistics of the sub-domain indices for the local GVH level

After this removal all correlation values of the sub-domain indices were below the given threshold values (Table 11).

	IFA	ABS	AGA	NAA	SSN	ACP	STA
IFA	**1,000**	0,838	0,590	0,237		0,897	0,786
ABS	0,838	**1,000**	0,074	-0,132		0,883	0,338
AGA	0,590	0,074	**1,000**	**0,430**		0,431	0,874
NAA	0,237	-0,132	**0,430**	**1,000**		-0,214	0,687
SSN							
ACP	0,897	0,883	0,431	-0,214		**1,000**	0,493
STA	0,786	0,338	0,874	0,687		0,493	**1,000**
VIF							

Table 11: Multicollinearity statistics of the sub-domain indices for the local GVH level (updated)

2.4.4 Constructing a composite resilience index

Based on the pre-processed datasets, a composite resilience 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 index in a fast and efficient manner. Figure 7 shows the graphical user interface (GUI) of the tool, including all relevant steps (indicator choice, weighting, normalization, aggregation) that were used to construct a resilience index for the four GVHs. 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. For calculating the composite resilience index out of the sub-domain indices an additive aggregation method with equal weights was used.

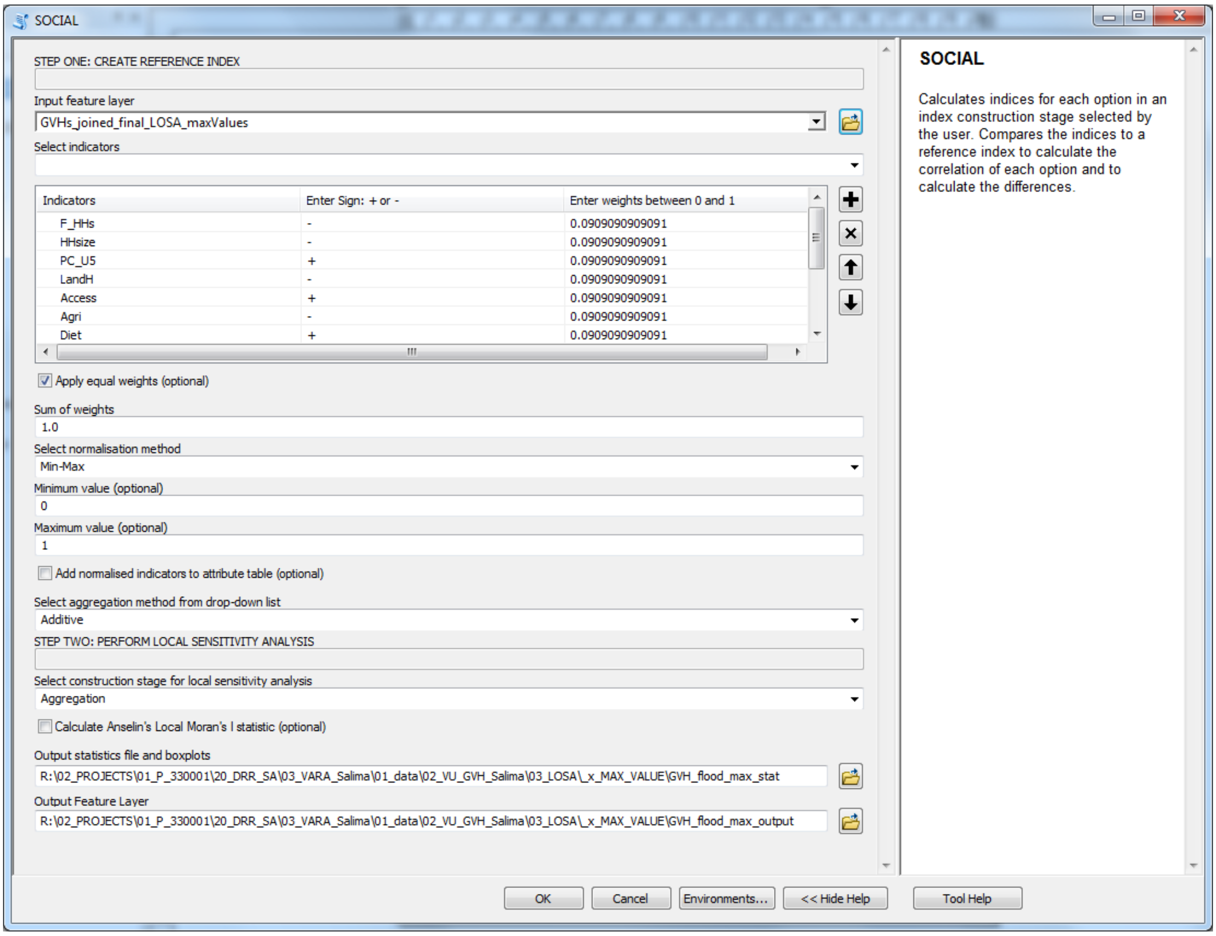

Figure 7: LOSA tool for constructing spatial composite indicators (Hagenlocher et al, in prep.)

3 RESULTS

3.1 District level

Figure 8 shows the spatial distribution of resilience to food insecurity for Salima district. In the map areas of high resilience are displayed in shades of blue (max value = 1), while areas of low resilience (min value = 0) are displayed in shades of red using a continuous colour range. As such the different values of resilience 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 resilience to food insecurity, however having certain hot spots located in the centre but also in the western part of the district.

For instance the eastern hot spot is characterised within its low value of resilience through issues in the domain of access to basic services as well as adaptive capacity and stability. The western hot spots show a similar pattern as the eastern one.

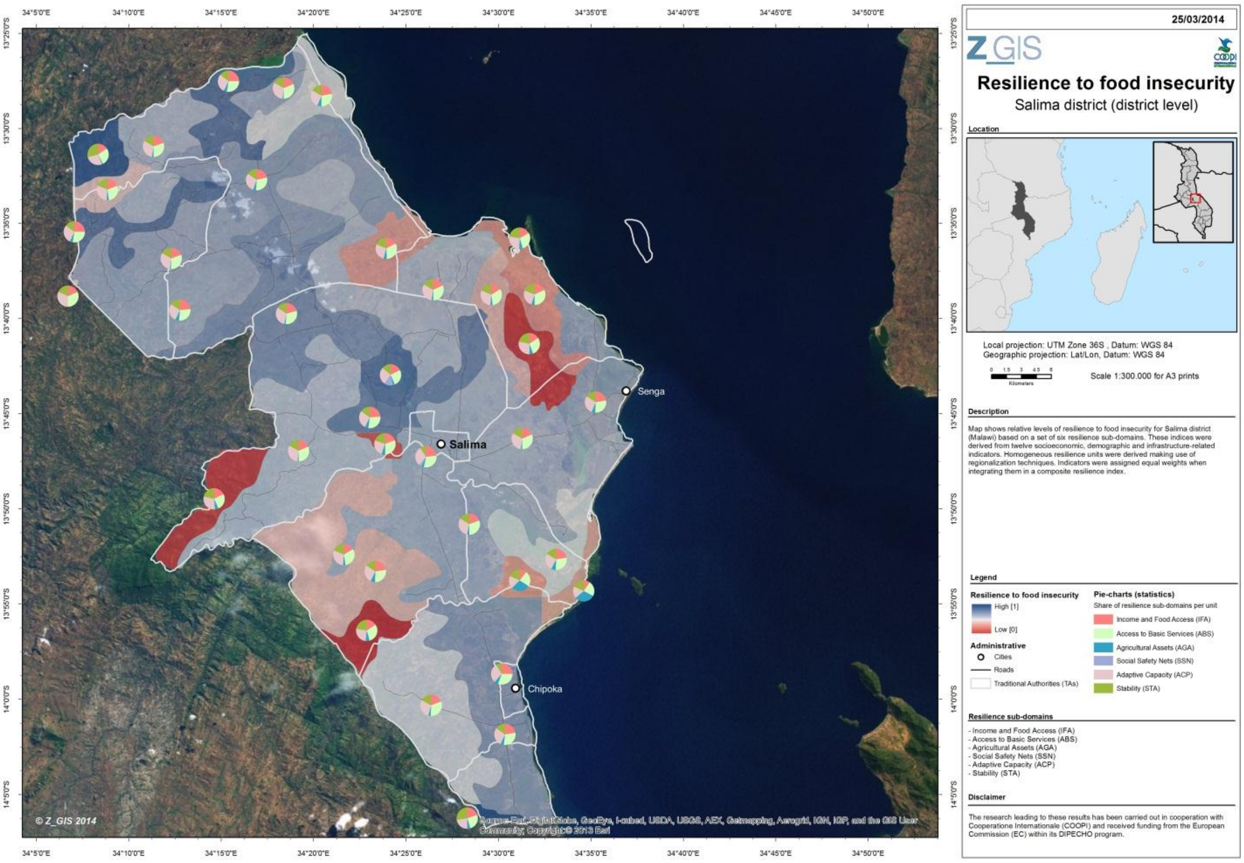

Figure 8: Resilience to food insecurity in Salima district, Malawi

As it can be depicted from Figure 8, the contribution of the different resilience factors (indicators) varies also across the 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 resilience 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 social safety nets.

3.2 GVH level

Figure 9 shows resilience to food insecurity for four selected GVHs in Salima district. In the map areas of high resilience are displayed in shades of blue (max value = 1), while areas of low resilience (min value = 0) are displayed in shades of red using a continuous colour range. The GVH with the highest resilience index is Saopampeni followed by Makho in the northern area of the district. Lower values are achieved in the southern part with Chembe having the lowest resilience index.

What can be clearly depicted from the different patterns in the pie charts is the different characteristic of resilience and therefore the required intervention measures. For instance Chembe has a good resilience on non-agricultural and agricultural assets, whereas all other indicators perform very badly. Mmanga shows a different picture where income and food access, access to basic services, adaptive capacity and non-agricultural assets perform well. The higher resilient GVHs show a better distribution among the different components, for instance Saopampeni.

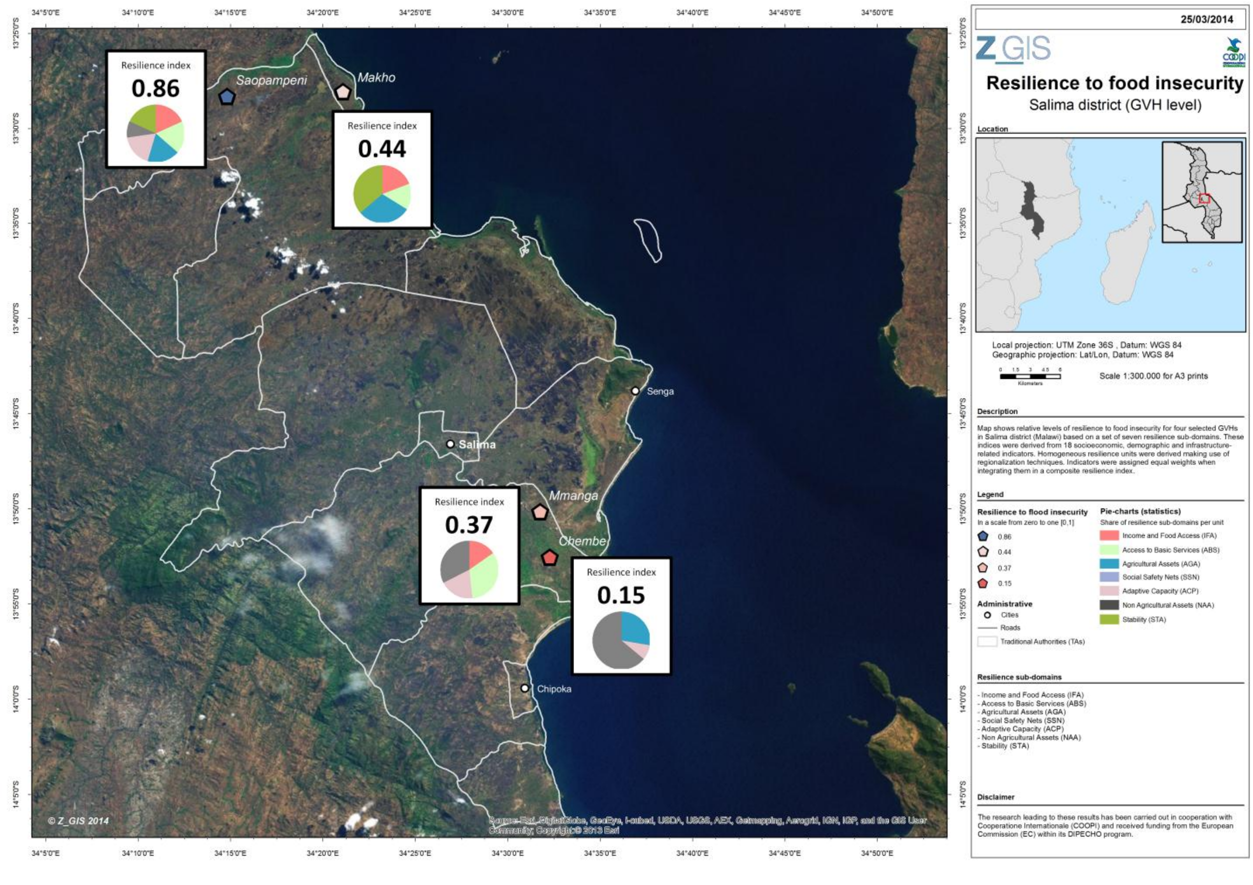

Figure 9: Resilience to food insecurity for four selected GVHs in Salima district, Malawi

4 CONCLUSIONS

The assessment carried out for the district of Salima and at the GVH level demonstrates well how resilience 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 resilience as homogenous regions, which share a common property of resilience, 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 resilience assessment approaches with monitoring and evaluation activities.

This approach can be easily transferred to other regions of interest in Malawi.

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ANNEX

Funded by:
"European Commission Humanitarian Aid department"

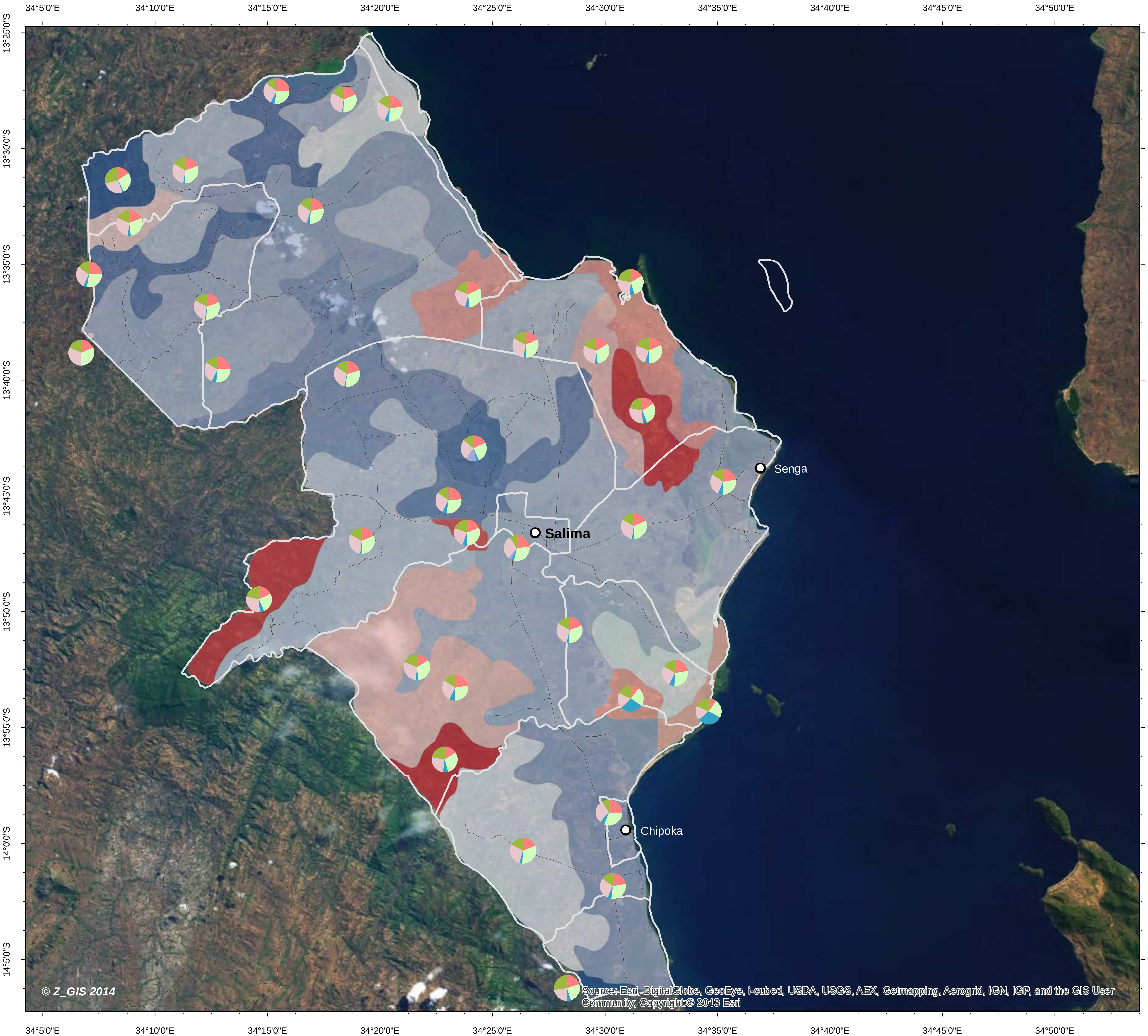
EUROPEAN COMMISSION
Humanitarian Aid

The European Commission's Humanitarian Aid department funds relief operations for victims of natural disasters and conflicts outside the European Union. Aid is channelled impartially, straight to people in need, regardless of their race, ethnic group, religion, gender, age, nationality or political affiliation.

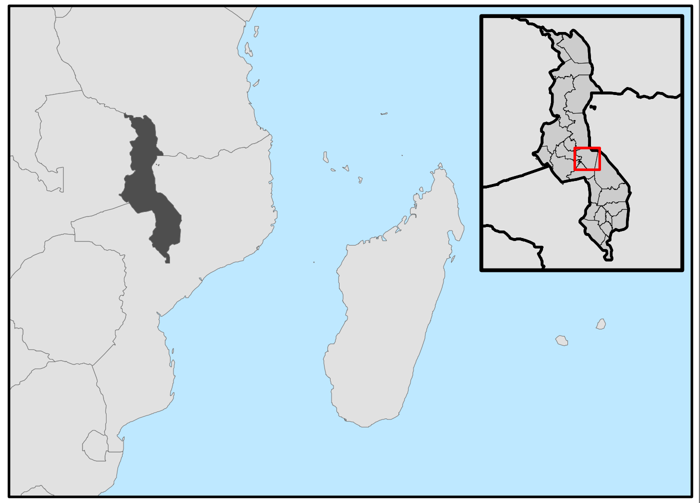
25/03/2014

Resilience to food insecurity

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 resilience to food insecurity for Salima district (Malawi) based on a set of six resilience sub-domains. These indices were derived from twelve socioeconomic, demographic and infrastructure-related indicators. Homogeneous resilience units were derived making use of regionalization techniques. Indicators were assigned equal weights when integrating them in a composite resilience index.

Legend

Resilience to food insecurity

High [1]

Low [0]

Administrative

Cities

Roads

Traditional Authorities (TAs)

Pie-charts (statistics)

Share of resilience sub-domains per unit

Income and Food Access (IFA)

Access to Basic Services (ABS)

Agricultural Assets (AGA)

Social Safety Nets (SSN)

Adaptive Capacity (ACP)

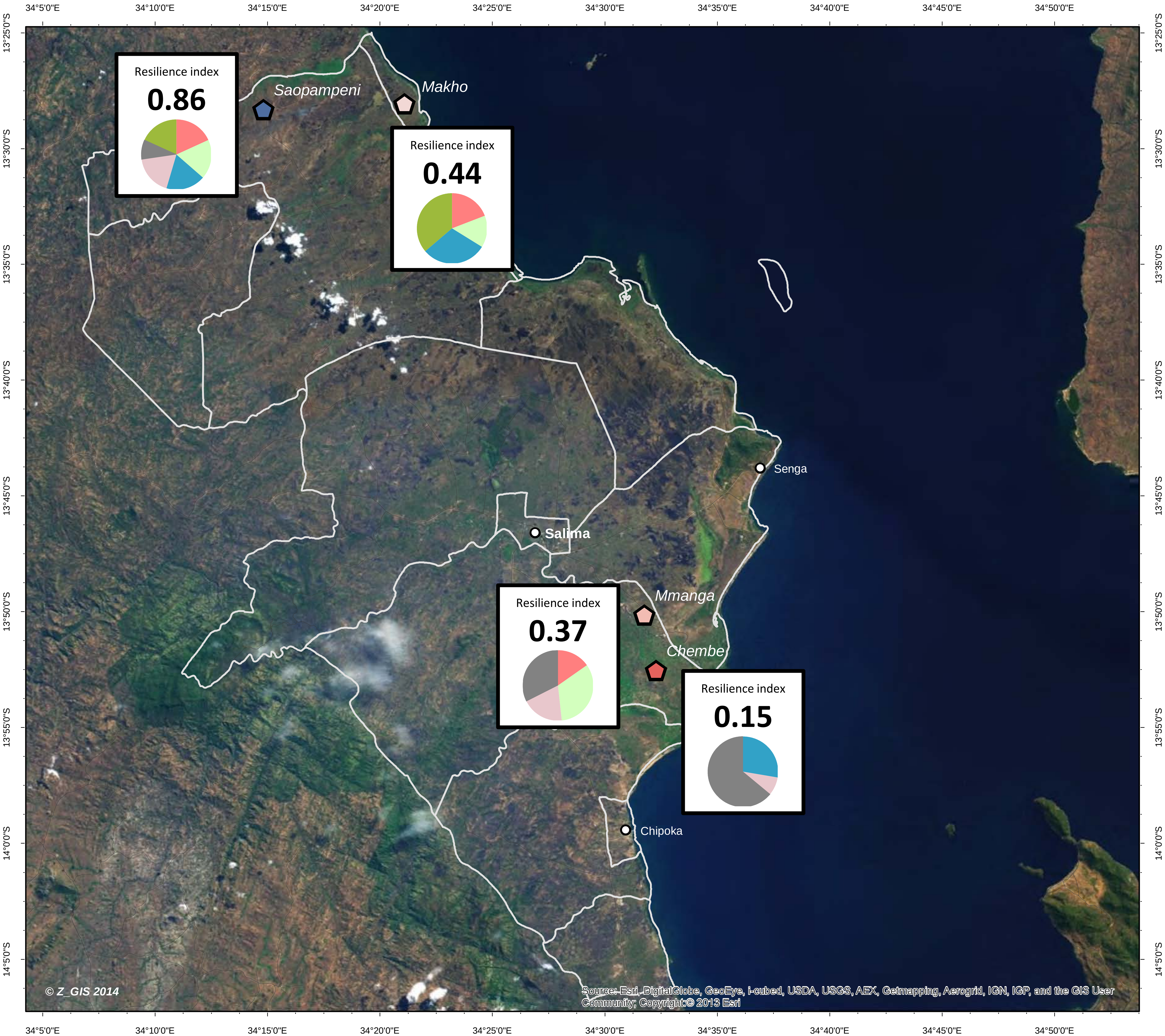
Stability (STA)

Resilience sub-domains

- Income and Food Access (IFA)
- Access to Basic Services (ABS)
- Agricultural Assets (AGA)
- Social Safety Nets (SSN)
- Adaptive Capacity (ACP)
- Stability (STA)

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

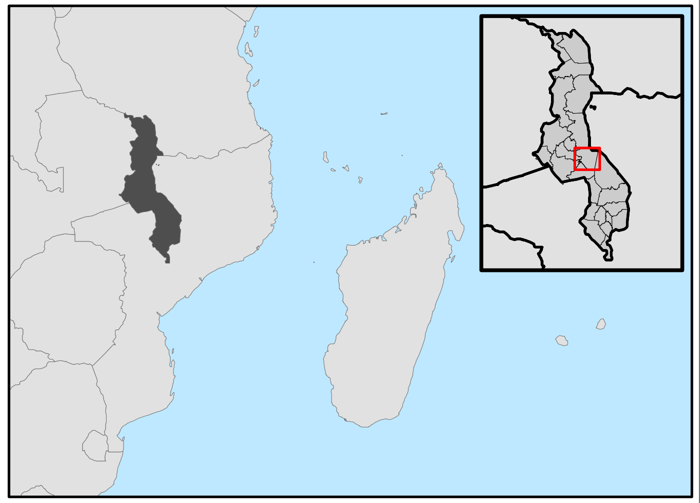
Z_GIS

COOPI

Resilience to food insecurity

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 resilience to food insecurity for four selected GVHs in Salima district (Malawi) based on a set of seven resilience sub-domains. These indices were derived from 18 socioeconomic, demographic and infrastructure-related indicators. Homogeneous resilience units were derived making use of regionalization techniques. Indicators were assigned equal weights when integrating them in a composite resilience index.

Legend

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

- 0.86
- 0.44
- 0.37
- 0.15

Administrative

- Cities
- Roads
- Traditional Authorities (TAs)

Pie-charts (statistics)
Share of resilience sub-domains per unit

- Income and Food Access (IFA)
- Access to Basic Services (ABS)
- Agricultural Assets (AGA)
- Social Safety Nets (SSN)
- Adaptive Capacity (ACP)
- Non Agricultural Assets (NAA)
- Stability (STA)

Resilience sub-domains

- Income and Food Access (IFA)
- Access to Basic Services (ABS)
- Agricultural Assets (AGA)
- Social Safety Nets (SSN)
- Adaptive Capacity (ACP)
- Non Agricultural Assets (NAA)
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