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Title: Quantifying vulnerability of rural communities to flooding in SSA: a contemporary disaster management perspective applied to the Lower Shire Valley, Malawi

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Abstract: In response to the increasing frequency and economic damages of natural disasters globally, disaster management has evolved significantly to incorporate vulnerability assessments that are multi-dimensional, integrated and metric-based. This is to support knowledge-based decision making and hence sustainable disaster risk reduction. In Malawi and most of Sub-Saharan Africa (SSA), however, flood vulnerability assessments mainly focusing on social vulnerability, have been largely qualitative. The subjective nature of such qualitative assessments makes their use for identifying relative vulnerabilities of specific people and places, targeting of interventions, allocation of scarce resources and monitoring of benefits that may arise from interventions extremely problematic. Viewing vulnerability through exposure, susceptibility and capacity dimensions, all linked to social, economic, physical and environmental factors, this study has used an index-based approach to quantify and profile vulnerability to flooding of rural, subsistent communities in the Lower Shire Valley, Malawi. Results show that vulnerability to flooding is susceptibility-driven with susceptibility magnitudes manifesting as high to very high. In particular, socio-economic and to a large extent environmental susceptibilities are predominantly high to very high. Economic and physical capacities tend to be low but societal capacity tends to be high thereby attenuating overall capacity-induced vulnerability to medium levels. Physical exposure is medium. Except for environmental vulnerability, spatial differentiation in all forms of vulnerability across communities is in general marginal.

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Response to reviewer's comments by Mwale at al.

We are grateful to the two anonymous reviewers for the thorough review provided. We are pleased to re-submit the revised manuscript. The comments raised have been addressed as outlined below. The paragraphs and page numbers refer to the original manuscript commented on unless otherwise stated.

In-text comments

1. Title- The term contemporary refers to "present times". Therefore in the title, the term has been used to denote a present style of disaster management. The term is therefore retained.

2. Abstract – the reviewers suggested that the type of vulnerability being investigated be qualified e.g. as social vulnerability. This has been addressed where applicable and not just in the abstract. However, there also still remains several areas where vulnerability has been used without qualification, e.g. when referring collectively to all the different dimensions. It is also implicit that it pertains to human vulnerability to a hazard – in this case the flood hazard. Such interpretation is normal in vulnerability literature to natural hazards (Adger, 2006; Birkmann et al., 2013; Fussel, 2010).

3. 1st paragraph – It has been underscored in the paper that the paper largely draws from a natural hazard also called disaster risk community. There are differences in the way vulnerability is viewed from these disciplines. Therefore while concepts and definitions in the SREX report and climate change literature in general have been referred to where appropriate, most definitions and concepts used are those from the disaster risk community.

4. Page 2, paragraph 3. The meanings of social and biophysical vulnerability have been included as suggested. They now come earlier in the revised manuscript (page 1, paragraph 2). The importance of integrating the two has also been highlighted (page 1, paragraph 2 and page 2, paragraph 1 of the revised manuscript). Similarly, the difference between factors and components or dimensions has been made clearer in the revised manuscript.

5. Page 2, last paragraph. It was suggested by the reviewers that reference be made to new risk framework in WG2AR5. The novelty emphasised in the WG2AR5 as opposed to previous IPCC reports is that of risk – a combination of the hazard and vulnerability, a framework already advanced in the disaster risk community from which this paper is largely drawn. The difference however arises as to how

vulnerability is treated. In the WG2AR5, exposure is considered as an aspect outside vulnerability whilst in the natural hazards or disaster risk community, vulnerability encapsulates exposure alongside susceptibility/sensitivity and capacity/resilience. In any case, the authors are cognisant of risk. However, as highlighted on page 2, paragraph 1 of the revised manuscript, this paper focuses only on the vulnerability component. In this regard, the components or dimensions used are those only relevant to vulnerability.

Since the paper draws from the disaster risk community, this paper settles for the broad vulnerability themes in this discipline and not the WG2AR5. These are *exposure, susceptibility* and *capacity* – which are nonetheless all underscored in most climate change publications. The paper further uses sustainable development thematic areas i.e. *social*, *economic*, *environmental* and *physical* which also characterises vulnerability studies from the disaster risk community.

6. Page 2, last paragraph - The reviewers suggested reference also be made to the work of Birkmann et al. (2013) when defining vulnerability components. This has been done on page 2, paragraph 2 of the revised manuscript.

7. Section 2 - The reviewers suggested substantial improvement to the quality of the map. This has been made. The Ruo sub-catchment has also been highlighted in the map as suggested.

8. Spatial scale of analysis (section 3.1). The reviewers suggested linking the choice of scale to work by Kienberger et al. (2013). This has been done and is reflected in the same section of the revised manuscript.

9. Section 3.2.2, 1st paragraph. The reviewers suggested consistence in the use of the term *resilience* rather than mixing with *capacities.* As indicated in the introduction, the two terms have been used synonymously across literature (Birkmann et al., 2013) While *resilience* would therefore have been preferred throughout this study, the challenge arises because the adapted CBDRI index (the section comes much later) uses the term *capacities* rather than *resilience*. This language of the index developers is therefore maintained from the methodology section to conclusion bearing in mind that the two terms have been used synonymously across literature.

10. Section 3.2.2, 1st paragraph – The reviewers asked for justification for weights. The use of weights in index-based vulnerability or risk measurements is very much the choice of the developer/modeller. While some indices attach no weights to variables arguing there is no scientific basis on the relative importance of variables or components, other authors have gone ahead to prescribe some weights. The CBDRI is one such index. A statement has therefore been added to

the section stating that the CBDRI is one of the many indices that incorporate differential importance to variables in their contribution to vulnerability.

11. Section 3.2.2, 1st paragraph. The explanation of weighting was adjudged confusing by the reviewers. Attempts have been made, with examples, to make the section clearer.

12. Section 3.2.2, 2nd paragraph. The reviewers questioned as to why the hazard components *(H)* and hence *CBDRI* were not used as stated in the section. It is explained in the introduction of the revised manuscript and even the original manuscript that the paper just focuses on the vulnerability component. In the natural hazard or disaster risk community from which the paper draws the conceptual framework, vulnerability is independent of the hazard. Including the hazard *(H)* therefore leads to the calculation of risk, an aspect that is not the focus of this paper. This explanation has been reinforced again in the index selection section (section 3.3) of the revised manuscript in which it is explained that the CBDRI through its additive nature has only been used to provide exposure, susceptibility and capacities components which are sufficient inputs for vulnerability assessment.

13. Section 3.3. The reviewers pointed out the importance of justifying vulnerability indicators used. It was also observed that important information had been pushed to the appendix section. This has been addressed. A separate sub-heading (vulnerability factors – section 3.2) has been included in the methodology section which outlines vulnerability factors in general. A discussion on their causal pathways has not been included due to space limits but a citation on their comprehensive discussion has been provided.

    In addition, the actual indicators used in the CBDRI have also been brought into the text from the appendix section as suggested (Table 1). Again, a comprehensive discussion of 38 indicators in the CBDRI has not been accommodated due to space limits but readers have been referred to the authors of the index i.e. Bollin et al. (2003).

14. Page 10, last paragraph. The reviewers wondered whether some form of normalization e.g. min-mix had been applied to the values. In the methodology section, ‘index selection’, it is to be noted that indicators carry scores (1 or 2 or 3) that are dimensionless. The weights attached are also dimensionless. Therefore calculated magnitudes of vulnerability and all its dimensional components are also dimensionless and specifically fall in the range of 0 – 100 or alternatively 0 - 1. In this case, there is no need for normalization; comparisons cross places are made straight away. Normalisation is used to bring indicators to a common dimensionless unit to allow comparison- a form already inherent in the method.

As to what constitutes very low, low, medium, high or very high, the study adopts quintiles – a method widely used in vulnerability literature (Balica et al., 2013; Tingsanchali and Karim, 2005).

Response to reviewer #1

1. The reviewer expressed concern over the mix-up on the use of the terms vulnerability and risk and different schools of thought. As earlier stated, it is now made clear in the revised manuscript that the paper is guided by disaster risk community conceptual framework.

   While cognisant of importance of addressing both vulnerability and hazard and hence risk, a concept also shared recently in the IPCC SREX, AR5 WG2, it is underscored in the paper that the paper only addresses the vulnerability component and therefore integration is confined to social vulnerability and the vulnerability of the physical environment in which the human system resides.

   The overlap of two words has been avoided as much as possible. Where risk has been used, it has been used with a meaning in the disaster risk discipline.

2. The reviewer noted that the authors did not provide a justification for the indicators used. This aspect has been addressed by incorporation in the methodology section of factors that, in general, lead to vulnerability (section 3.2). Because, the paper adapts an existing index deemed relevant to developing countries, it uses indicators in the index which have been highlighted in a table (Table 1).

   The issue of data quality is acknowledged and discussed as a limitation in the conclusion section.

3. The reviewer observed that the methodology section was not clear. Attempts have been made to make it clearer. One of the reasons for lack of clarity was the use of two spatial scales in the original manuscript. In response to reviewer no.2 comments, the revised paper has now focussed on only the community scale.

4. The reviewer also opined that the results section was too long. Attempts have been made to make the length reasonable

Response to reviewer #2

1. The reviewer opined that vulnerability should have been addressed alongside hazard characteristics, arguing that vulnerability is not generic. As earlier emphasised, this study draws from a disaster risk community perspective and it also focuses only on the vulnerability component. From this discipline,

vulnerability is independent of the hazard. If the hazard is considered, then what is being assessed is risk, an aspect not the focus in this paper.

Nonetheless, the authors agree that vulnerability has to be addressed with regard to a specific hazard. The specificity of vulnerability to a particular hazard is implicit in the vulnerability indicators chosen. For example, if one is measuring vulnerability with respect to droughts, the use of *quality of housing* as an indicator would be questionable.

2. The calculation of vulnerability with two different indices and subsequent comparison at two different scales was likened to comparing apples and pears. The authors acknowledge this gross mistake. In the revised manuscript, vulnerability has been limited to community (ADC) scale. The justification is given in section 3.1 of the methodology section. Consequently, there is no response to all concerns raised with respect to the sub-catchment index, the FVI.

3. The reviewer suggested that the contribution of each indicator to vulnerability be discussed. While the authors agree, 38 indicators have been used in this study and therefore a discussion of how each contributes to vulnerability is impractical within the space limits of this paper. Nonetheless, a citation has been provided to readers where the contribution of each to vulnerability is discussed comprehensively.

   The reviewer was also concerned with weighting. It has to be borne in mind that index development is a subjective area and subjectivity comes from different factors besides weighting. These include the actual indicators considered, the way they are aggregated, the thresholds sets, etc. Therefore, whether indicators are assumed to contribute equally or differentially to vulnerability is much the discretion of the index developer or author. There is no scientific basis. In fact, many authors e.g. Allison et al. (2009) using equal contribution have used this justification. On the other hand, those differentiating ‘feel ‘indicators contribute differently. In fact, the CBDRI does not assume equal contribution; a weight (w) is applied. This explanation is given in section 3.3 of the methodology section.

   The limitations of the approach, as is inherent is all index-based methods, has been highlighted in the conclusion section.

4. The reviewer pointed out that the paper was not transparent on the methodology and community response. The revised manuscript includes number of groups interviewed, number per group and is clearer that each group represented a community. Further, in the results section of the revised manuscript (section 4.1), raw data, actual scores and weights as they relate to some nine indicators have been included (Tables 3, 4, 5 and 6).

5. There was concern that similarity in vulnerability magnitudes calculated may be methodological other than situational. This is very true and has been acknowledged in the conclusion section and part of the discussion as possibly arising from a coarse spatial scale (ADC as may be opposed to villages or households) and the score scale (i.e. 1 or 2 or 3) used. On the other hand, vast heterogeneity in vulnerability is not expected from anecdotal evidence.

6. The reviewer was confused as to whether "a community scores higher on exposure the more households having piped water and the higher income they have" and if so, this was thought to be a mistake. By definition, exposure is what is in harm's way. Piped water is representative of infrastructure; income represents the size of the economy. So the more the community has, the higher is what is at stake – that is the higher the exposure. So, this is correct as it is.

   A community scoring high on capacity has high capacity or low incapacity (the complementary side of it)

7. The references have been corrected as pointed out.

8. Appendix 1 has been changed to appendix A.

9. It was observed that the authors go too quickly through concepts. Attempts have been to provide argumentation where required.

10. A spelling correction has been made to Loer Shire valley.

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Quantifying vulnerability of rural communities to flooding in SSA: a contemporary disaster management perspective applied to the Lower Shire Valley, Malawi

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Abstract

In response to the increasing frequency and economic damages of natural disasters globally, disaster management has evolved significantly to incorporate vulnerability assessments that are multi-dimensional, integrated and metric-based. This is to support knowledge-based decision making and hence sustainable disaster risk reduction. In Malawi and most of Sub-Saharan Africa (SSA), however, flood vulnerability assessments mainly focusing on social vulnerability, have been largely qualitative. The subjective nature of such qualitative assessments makes their use for identifying relative vulnerabilities of specific people and places, targeting of interventions, allocation of scarce resources and monitoring of benefits that may arise from interventions extremely problematic. Viewing vulnerability through exposure, susceptibility and capacity dimensions, all linked to social, economic, physical and environmental factors, this study has used an index-based approach to quantify and profile vulnerability to flooding of rural, subsistent communities in the Lower Shire Valley, Malawi. Results show that vulnerability to flooding is susceptibility-driven with susceptibility magnitudes manifesting as high to very high. In particular, socio-economic and to a large extent environmental susceptibilities are predominantly high to very high. Economic and physical capacities tend to be low but societal capacity tends to be high thereby attenuating overall capacity-induced vulnerability to medium levels. Physical exposure is medium. Except for environmental vulnerability, spatial differentiation in all forms of vulnerability across communities is in general marginal.

Keywords: flooding; integrated; index; multi-dimensional; rural communities; vulnerability.

1. Introduction

Vulnerability has generally been defined as the degree of susceptibility or fragility of communities, systems or elements at risk and their capacity to cope under hazardous conditions [1] although the term carries numerous and often contested definitions across disciplines. Over the years, there has been a shift in the analytical frameworks used in measuring vulnerability, from those that conceive vulnerability as solely a biophysical or social phenomenon, to those which emphasise its integrative nature. The frameworks further emphasize multi-dimensioning and the use of quantitative metrics [2-4]. Consequently, such frameworks are now seen as the pathway to sustainable disaster management [5].

In the literature of human vulnerability to natural hazards, the term 'social vulnerability' has been used to describe vulnerability arising from historical, cultural, socio, economic and political processes that make people vulnerable [4, 6]. Biophysical vulnerability on the other hand has related to characteristics of the stressor (e.g. frequency, duration) (external biophysical vulnerability) and the physical environment in which the human system resides (internal biophysical vulnerability) [7].

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However, such a definition of biophysical vulnerability is associated with the climate change discipline [7]. In the natural hazard discipline [2, 5, 8], external biophysical vulnerability is a hazard; vulnerability is independent of the hazard and is confined to the social system and its physical environment. Further, while both aspects constitute 'vulnerability' in the climate change discipline, their integration defines risk in the natural hazard discipline. This paper adopts a natural hazard discipline conceptualization of vulnerability. Either way, the aspect of integration of social and biophysical aspects is important for holistic interventions. Fussel [7], for example, observed that social vulnerability studies that define vulnerability as socially constructed are important only for the design of adaptation policies but limited in informing mitigation policy.

Dimensioning vulnerability or grouping vulnerability factors to some common bracket has followed several thematic areas. However, both the climate change and natural disaster risk communities have broadly viewed vulnerability through the *exposure*, *susceptibility, capacity/resilience* lens [1, 3]. *Exposure* has been defined as "the presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social and cultural assets in places that could be adversely affected"; *susceptibility* as "the predisposition of elements at risk to suffer harm" and *resilience,* also treated synonymously with *capacity* across vulnerability literature [1], as "the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event" [1, 9]. The natural hazard discipline has also emphasised thematic areas of sustainable development i.e. social, economic, environmental and physical [1, 2]. In this regard, *physical vulnerability* relates to factors of exposure and susceptibility of the built environment in terms of material and design, remoteness of the place etc. *Social vulnerability* refers to the level of individual, community and societal well-being in terms of such indicators as literacy levels, health, governance, institutions etc. *Economic vulnerability* also looks at the level of individual, community and society well-being but in terms of economic resource base including the diversity of such resources, and the availability of basic socio-economic infrastructure. *Environmental vulnerability* describes the state of the environment. An emphasis on dimensioning stems from the understanding that while a single aggregate metric for vulnerability may provide a useful tool for differential ranking of vulnerability of places, it does not reveal the relative importance of its constituent dimension and hence their trade-off possibilities. Thus, as observed by Cinner et al. [10], an aggregate vulnerability metric is limited in informing interventions that will be most effective for reducing vulnerability at a particular location.

Metric-based assessments of vulnerability have become important to decision-making and policy in that they allow comparison of vulnerabilities of specific people and specific places. This facilitates the targeting of interventions and allocation of scarce resources, an important aspect for resource strapped developing countries. Metrics further enable the monitoring of progress accruing from policy interventions made [11, 12].

The above attributes of multidimensional, integrated and metric-based vulnerability assessments are even more relevant in Sub-Saharan Africa (SSA) where droughts and floods alone account for 80% of disaster related mortality and 70% of the economic losses [13]. However, this approach has been confined to vulnerability to climate change studies [11, 14-16] but more recurrent and immediate hazards such as flooding that constantly erode the asset base of poor rural communities reducing their quality of life have not been so analysed. Rather, the assessment of vulnerability to flooding has been largely qualitative; describing, notably, causative factors, impacts, coping and adaptation capacities at hand [17-21]. While providing a rich insight into the vulnerability problem and therefore useful in the design of interventions, such studies offer very little in terms of decision making on aspects of comparisons across places, targeting of scarce resources and monitoring over time. Their social emphasis also provides a limited view of vulnerability thus undermining the effectiveness of vulnerability reduction measures.

Using this contemporary discourse on disaster management, this paper quantifies and profiles vulnerability to flooding of rural communities in the Lower Shire Valley, Malawi. In particular, vulnerability is examined within a coupled IPCC and Sustainable Development framework i.e. as exposure, susceptibility and capacity and as manifested through the social, economic, physical and environmental dimensions.

2. Case study area

The Lower Shire Valley lies at the southern tip of Malawi at an elevation of between 30 and 150 meters above sea level [22] (Figure 1). It is drained by the Shire River, the only outlet of Lake Malawi. Administratively, the Valley falls in two districts: Chikwawa and Nsanje.

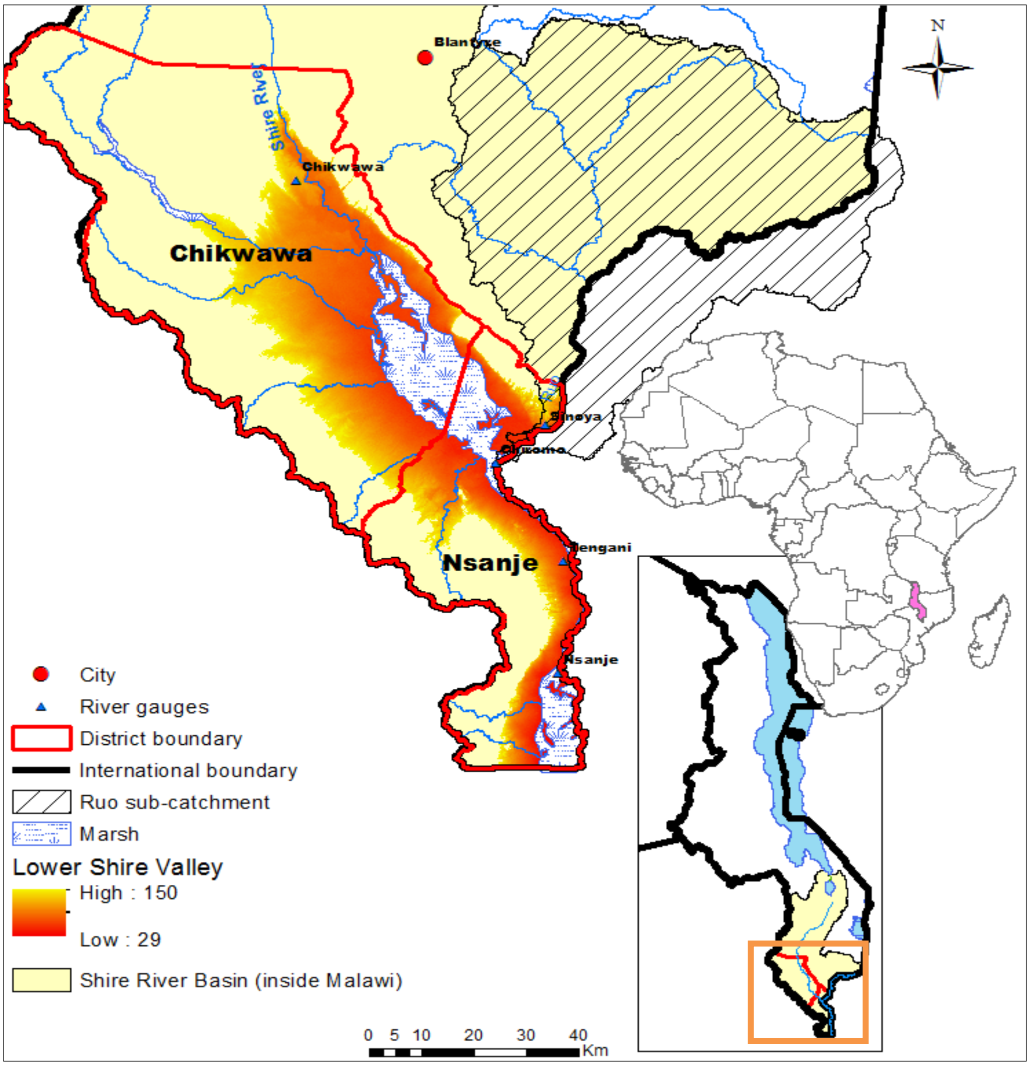


Figure 1: Geographical location of the study area

Rainfall in the Lower Shire Valley is low (600 – 750 mm annually). Nonetheless, its upper and middle catchments, dominated by the orographic influences of mountains, have annual rainfall around 900 mm and in excess of 2000 mm in the Ruo sub-catchment to the east on its main tributary. Although the Shire at Chiromo averages 450 m^3/s annually, and the Ruo at Sinoya averages 54 m^3/s, flows as high as 1430 m^3/s and 5400 m^3/s respectively have been recorded at these two stations [23]. Landuse and landcover studies in the Shire River basin [24] and in Lake Malawi basin upstream of the Shire River Basin [25], point to an increasing trend in cultivated/grazing area at the expense of woodlands. Poverty rates in the two districts (calculated with respect to 37,002 Malawi Kwacha poverty line which is equivalent to US$0.40 per person per day as of 2012) are over 80%, the highest in the country [26], significantly exceeding the national average of 50.7%. As the rest of the country, the population is predominantly rural and subsistence farming, more practised in the low lying wetlands in this region, is the main source of livelihood. Other forms of livelihoods are artisanal fishing, livestock rearing and casual labour popularly known as *ganyu*. These livelihoods, however, are fragile and productivity is very low given the multiplicity of stressors (floods, droughts, stock mortality and morbidity and stock theft) in the region [27].

3. Methods

3.1. Scale of analysis

Vulnerability is a scale-dependant variable determined by spatial scale (global to individual) and specificity of a place; as well as time scale (over a period of time or for a specific moment in time) [28]. As such vulnerability outcome at different scales serves different purpose. For example, while global, regional and national scales assessments allow comparisons across nations, which is useful for flagging to aid and development agencies, prioritization of resources at global scale and also for bench marking purposes the local scale is more important for the design of disaster risk reduction [29, 30]. Besides consideration of purpose, it is important that vulnerability assessments are linked to scale of decision-making as vulnerability reduction measures are developed, promulgated and implemented through institutions [6].

While vulnerability may operate at an individual or household scale, the policy scale i.e. the scale for which policies are valid and implemented [28] is the most pertinent in this study. Therefore, the study follows the institutional framework for disaster management in Malawi. Disaster management activities in Malawi are coordinated at national level in the Department of Disaster Management Affairs (DoDMA). The department is supported at the lower level through local government decentralised structures: the District Level, Area Development Level and Group Village Development Levels. The Lower Shire Valley falls into two district level units: Chikwawa with an area of 4755 km^2 and Nsanje with an area of 1942 km^2. Chikwawa District has 11 Area Development Committee levels (ADCs) and Nsanje 9, with each ADC level corresponding to the area under the jurisdiction of a chief (Traditional Authority, TA). Further Chikwawa comprises 79 Village Development Committees (VDC) and 593 villages. Nsanje on the other hand has 82 VDCs and 790 villages. The number of VDCs and villages in both districts are actually higher than these figures given the continual promotion of tradition leaders to chiefs and senior chiefs through political will. Each VDC level is a conglomerate of several villages. The basis for a number of villages making a VDC is elusive and explains the unexpected higher figures in Nsanje than Chikwawa despite Nsanje's size.

The district as a scale of analysis was adjudged too coarse to unmask risk at a local scale. Conversely, while the VDC and village scales would have provided a more representative picture of risk, the associated costs proved prohibitive. The ADC level, also referred to as *community* in this study, was therefore chosen as a scale of analysis. The ADC level has the added advantage of secondary data availability: socio-economic data gathered through government's nationwide surveys e.g. Population and Housing Census and Integrated Household Surveys are readily available at this scale. In furtherance, developmental work in Malawi through Non-Governmental Organizations (NGOs), donor community or government is also much tied to administrative boundaries of TAs [31].

In total, 14 communities (TAs) were initially assessed: Ngabu, Katunga, Chapananga, Maseya, Makhuwila, Ngowi and Lundu in Chikwawa District and Mbenje, Mlolo, Tengani, Ngabu, Malemia, Ndamela and Nyachikhadza in Nsanje District. Ngowi was subsequently dropped as it acted as a pilot ADC, leaving only 13 communities.

3.2. Vulnerability factors

Vulnerability has been linked to social, economic, cultural and institutional factors. A comprehensive review of the factors and their contribution to vulnerability can be found in Cutter et al. [32] and Collins et al. [33]. In particular, they identify such indicators as: age, gender, race; socioeconomic status (income, power, prestige); whether the population is rural or urban; special-needs population and minorities (the physically or mentally challenged, immigrants, the homeless, transients, and seasonal tourists); livelihoods, family structure, education, population growth and densities, access to medical services, access to information, institutional capacity, quality of human settlements in terms of housing type and construction and, infrastructure, and lifelines.

For SSA, HIV/AIDS has been another humanitarian crisis with its population accounting for 70% of global-wide infections [34]. The disease increases population susceptibility and reduces societal resilience through increase in widow-headed families and orphanhood and hence an increase in dependency; financial strain through medical bills, funerals and absenteeism from work; diminished access to resources due to stigmatization that limits social linkages and networks; lack of labour to maintain livelihoods and productive activities as the disease is debilitating; selling of productive assets which impairs future productivity; food insecurity, malnutrition and ultimately poverty [35].

In a recent study in Malawi, vulnerability to climate change was found to arise from a complex web of factors related to poverty, health, AIDS, mortality, livelihoods, food, water and environmental degradation [31].

It is evident that vulnerability arises from a multitude of factors. While some of these factors may be correlated, thus reducing the number of truly independent factors, the residual number of factors will still be large that incorporating all of them in one analysis will be impractical. As several authors point out [11, 12, 36], what factors ultimately go into measuring vulnerability is a function of several aspects: the objective of the assessment, the scale of analysis, the relative ease of measurement of an indicator, data availability, validity of the indicator and methodological approach in building the index. The factors used in measuring the vulnerability to flooding in this study are dictated by the index used, as described in the next section.

3.3. Index selection

The paper adapts the community-based disaster risk index (CBDRI) (Eqs. 1 and 2) developed by Bollin et al.[8].

$$CBDRI = v(H + E + S - C) \tag{1}$$

$$H = \sum_{i=1}^{h} w_i x_i \ , \qquad E = \sum_{j=1}^{q} w_j x_j \ , \qquad S = \sum_{k=1}^{r} w_k x_k \ , \qquad C = \sum_{y=1}^{z} w_y x_y \tag{2}$$

where *H*, *E*, *S* and *C* are the *hazard*, *exposure*, *susceptibility* and *capacities* (resilience) sub-components with a range from 0 to 100; $v = 0.33$. This factor keeps the final value of risk within 0 and 100. w is a weight reflecting indicator importance in the sub-component as elaborated in the next section. h, q, r, z are the total number of indicators in the hazard, exposure, susceptibility and capacity components respectively. x is a score allocated to the indicator in the sub-component and is equal to either 1 (low), 2 (medium) or 3 (high). The indicators used in the CBDRI are shown Table 1; their link to vulnerability has been exhaustively discussed in Bollin et al.[8].

Whether indicators contribute equally or differentially to vulnerability is much the discretion of the modeller. Allison et al. [37] for example argues that there is no scientific basis for differential contribution of exposure, susceptibility and capacity to vulnerability. Others e.g. Vincent [11] have used weights, the basis of which is sometimes not clear. The CBDRI is one index that uses a weighting scheme to reflect differential importance of indicators towards a sub-component. Therefore, besides measuring the indicator by a score of 1, 2 or 3, the community is also asked to weight (w) the indicator in the sub-component based on their perceived importance of the indicator in contributing to the sub-component in question i.e. the hazard, exposure, susceptibility or the capacities. The weights used in the study ranged from 1 to 10 with 10 being very important. For example, lack of *building codes* may get a score (x) of 1 signifying low levels of capacity with respect to this indicator. The community may feel nonetheless *building codes* is a very important indicator in contributing to the overall capacity in anticipating floods. In this case they would give the indicator *'building codes'* a weight (w) of 9. Similarly, incorporation of disaster studies in the school curriculum in all grades may attract a score of 3 showing high levels of capacity with respect to this variable. However, the community may weight the indicator with a 4 signifying it is not a very important indicator in contributing to their societal capacity.

Because 13 communities were assessed, there are 13 weights for a given indicator. To attach a common perception to a given indicator for comparison purposes, the weight used for a particular indicator is the mode of weights. Since the total sum of weights in each sub-component should equal 33 (so that the final sub-component value is between 0 and 100), in this study, a final weight *w* for the indicator in a given sub-component is calculated by a simple proportion on 33. For example, if the sum of weights on all indicators in the capacities sub-component is 80, then the weight of indicator *'building codes'* is 9/80*33 = 4 assuming 9 is the mode. For full details of the index, one is referred to Bollin et al. [8].

It should be noted that Bollin et al. [8] used the term *vulnerability* (V) in place of *susceptibility* (S) in Eqs. 1 and 2. However, a review of the factors that go into the evaluation of this component of the CBDRI (see Table 1) shows that they are more appropriate to susceptibility. Additionally, it is more generally accepted that exposure and capacity are important dimensions of vulnerability [3]. Consequently, including vulnerability, exposure and capacity as independent variables in the original CBDRI will be tantamount to double counting of the exposure and capacity components of vulnerability. For these reasons, the susceptibility term (instead of vulnerability) has been used in the adapted form of the CBDRI implemented in the current study.

Table 1: Vulnerability factors in the CBDRI

Component	Indicator Name	Indicator
EXPOSURE		
Structures	(E1) Number of housing units.	Number of housing units
	(E2) Lifelines	% of homes with piped drinking water
Population	(E3) Total resident population	Total resident population
Economy	(E4) Local gross domestic product	Total locally generated GDP in constant currency
SUSCEPTIBILITY		
Physical / Demographic	(S1) Density.	People per km2.
	(S2) Demographic pressure.	Population growth rate.
	(S3) Unsafe settlements.	Homes in hazard prone areas (ravines, river banks, etc).
	(S4) Access to basic services	% of homes with piped drinking water.
Social	(S5) Poverty level.	% of population below poverty level.
	(S6) Literacy rate.	% of adult population that can read and write.
	(S7) Attitude.	Priority of a population to protect against a hazard.
	(S8) Decentralisation.	Portion of self generated revenues of the total budget.
	(S9) Community participation	% of voter turn out at last commune elections.
Economic	(S10) Local resource base.	Total available local budget in US$.
	(S11) Diversification.	Economic sector mix for employment.
	(S12) Stability.	% of businesses with fewer than 20 employees.
	(S13) Accessibility	Number of interuption of road access in last 5 years
Environmental	(S14) Area under forest.	% Area of the commune covered with forest.
	(S15) Degraded land.	% Area that is degraded/eroded/desertified.
	(S16) Overused land	% of agricultural land that is overused.
CAPACITY & MEASURES		
Physical planning and engineering	(C1) Land use planning.	Enforced land use plan or zoning regulations.
	(C2) Building codes.	Applied building codes.
	(C3) Retrofitting/maintenance.	Applied retrofitting and regular maintenance.
	(C4) Preventive structures.	Expected effect of impact-limiting structures.
	(C5) Environmental management.	Measures that promote and enforce nature preservation.
Societal capacity	(C6) Public awareness programs.	Frequency of public awareness programmes.
	(C7) school curricula.	Scope of relevant topics taught at school.
	(C8) Emergency response drills.	Ongoing emergency response training and drills.
	(C9) Public participation.	Emergency committee with public representatives.
	(C10) Local risk management groups	Grade of organisation of local groups.
Economic capacity	(C11) Local emergency funds.	Local emergency funds as % of local budget.
	(C12) Access to local emergency funds.	Release period of national emergency funds.
	(C13) Access to international emergency funds.	Access to international emergency funds.
	(C14) Insurance market.	Availability of insurance for buildings.
	(C15) Mitigation loans.	Availability of loans for disaster risk reduction measures.
	(C16) Reconstruction loans.	Availability of construction credits.
	(C17) Public works.	Magnitude of local public works programmes.
Management and institutional capacity	(C18) Risk management committee.	Meeting frequency of a commune committee.
	(C19) Risk map.	Availability and circulation of risk maps.
	(C20) Emergency plan.	Availability and circulation of emergency plans.
	(C21) Early warning system.	Effectiveness of early warning systems.
	(C22) Institutional capacity building.	Frequency of training for local institutions.
	(C23) Communication.	Frequency of contact with district level risk institutions.

Also, as the name implies, CBDRI was developed to measure risk directly; however, its additive form as shown in Eq. (1) makes it possible to disaggregate the index into hazard and vulnerability components. Thus a further adaptation of the index carried out in the current study was to quantify the vulnerability from the E, S and C components. Thus, to measure vulnerability in this study, *E*, *S* and *C* were first calculated using equation (2). The aggregate vulnerability (V) was then estimated using the widely used arithmetic aggregation scheme [15, 37] as follows:

$$V = \frac{1}{3}\left[E + S + (1 - C)\right] \tag{3}$$

where $(1-C)$ represents the lack of capacity

Further, while exposure, susceptibility and capacities are directly measured through Eq. 2, the CBDRI does not provide a direct measure of vulnerability from a *social*, *economic*, *environment* and *physical* perspective although it classifies the indicators as such. To dimension vulnerability by the social, economic, environment and physical components in this study, indicators in the exposure, susceptibility and capacities sub-components (Table 1) are rearranged into social, economic, environment and physical sub-components as shown in Table 2.

Once classified, the estimation of social, economic, physical and environmental vulnerabilities used Eq. 3 with the weights determined as outlined earlier to ensure that the total weight in each of the exposure, susceptibility and capacities components of the new dimensions (social, economic, physical and environmental) does not also exceed 33.

To provide a degree of magnitude of vulnerability and its dimensions, quintiles, were used: *0 – 0.2 = very low, >0.2 – 0.4 = low, >0.4 – 0.6 = medium, >0.6 – 0.8 = high and >0.8 – 1.0 = very high.*

3.4. Data collection

For a given community, primary data were sourced through a structured questionnaire (appendix A) administered to a group of experts and knowledgeable people representing the community as recommended by Bollin et al. [8]. The group used was the ADC. The ADC draws membership from government extension workers from various institutions notably Forestry Department, Ministry of Agriculture, Ministry of Health, Ministry of Education, Community Development and Police. Other members are NGOs, Community Based Organizations (CBO), chiefs and some ordinary village people. People interviewed per group varied between 10 and 16. The score and weight allocated to a particular indicator by a community was one mutually agreed upon by group members without any coercion.

Secondary data unobtainable through the questionnaire such as *population density*, *population growth rate*, *access to water services, literacy levels* were obtained from the third Integrated Household Surveys [26] and the 2008 population and housing census data [38]. *Access to water services* followed the definition in the third Integrated Household Surveys [26] i.e. as access to piped water into dwelling, piped water into yard or plot, communal standpipe, protected well in the yard or plot, protected public well or borehole. The *percentage of forested area* for a community was derived with GIS from Malawi land cover database [39]. Some indicators originally included in the index were not used in this study due to the difficulty of thresholds, given the differences in community size. Such data include *number of housing units, total resident population* and *unsafe settlements*. *Total Gross Domestic Product* was replaced with *average per capita income per day*. *Degraded land* and *overused land* were also not included due to the difficulty of definitions. Thus environmental susceptibility was limited to *amount of forest cover*.

Table 2: Vulnerability by social, economic, environmental and physical dimensions

Factor component	Indicator Name	Indicator
PHYSICAL		
Exposure Structures	(E2) Lifelines	% of homes with piped drinking water
Economy	(E4) Economy	Total locally generated GDP in constant currency
Physical susceptibility	(S1) Density	People per km2.
	(S2) Demographic pressure	Population growth rate (%)
	(S4) Access to basic services	% of homes with piped drinking water.
Physical capacity	(C1) Landuse planning	Enforced land use plan or zoning regulations.
	(C2) Building codes	Applied building codes.
	(C3) Retrofitting/Maintenance	Applied retrofitting and regular maintenance.
	(C4) Preventive measures	Expected effect of impact-limiting structures.
	(C5) Environmental management	Measures that promote and enforce nature preservation.
SOCIAL		
Social susceptibility	(S5) Poverty level	% of population below poverty level
	(S6) Literacy	% of adult population that can read and write.
	(S7) Attitude	Priority of a population to protect against a hazard.
	(S8) Decentralization	Portion of self generated revenues of the total budget.
	(S9) Community participation	% of voter turn out at last commune elections.
Societal capacity	(C6) Public awareness programs	Frequency of public awareness programmes.
	(C7) School curriculum	Scope of relevant topics taught at school.
	(C8) Emergency response drills	Ongoing emergency response training and drills.
	(C9) Public participation	Emergency committee with public representatives.
	(C10) Local risk management/emergency groups	Grade of organisation of local groups.
Management and Institutional Capacity	(C18) Risk	Meeting frequency of a commune committee.
	(C19) Risk map	Availability and circulation of risk maps.
	(C20) Emergency plan	Availability and circulation of emergency plans.
	(C21) Early warning system	Effectiveness of early warning systems.
	(C22) Institutional capacity	Frequency of training for local institutions.
	(C23) Communication	Frequency of contact with district level risk institutions.
ECONOMIC		
Economic susceptibility	(S10) Local resource base	Total available local budget in US$.
	(S11) Diversification	Economic sector mix for employment.
	(S12) Stability	% of businesses with fewer than 20 employees.
	(S13) Accessibility	Number of interuption of road access in last 5 years
Economic capacity	(C11) Local emergency fund	Local emergency funds as % of local budget.
	(C12) Access to national	Access to international emergency funds.
	(C13) Access to international	Release period of national emergency funds.
	(C14) Insurance market	Availability of insurance for buildings.
	(C15) Mitigation loans	Availability of loans for disaster risk reduction measures.
	(C16) Reconstruction loans	Availability of reconstruction credits.
	(C17) Public works	Magnitude of local public works programmes.
ENVIRONMENTAL		
Environmental	(S14) Environmental	% Area of the commune covered with forest.

4. Results and discussion

4.1. Indicator scoring and weighting

Table 3 shows how communities perform with respect to indicators in the CBDRI. Only the first nine indicators are shown for the sake of space. The scores are shown in Table 4. Community perception on the importance of the indicators in contributing to vulnerability is shown in Table 5. Table 6 shows the adjusted weights allocated to indicators by the simple proportion approach explained in section 3.3. For example, the adjusted weight used for *lifeline* in Table 6 was 9. This was obtained by rebasing the modal weight from a total of 11 (3+8) to a total of 33 as explained earlier. Thus the adjusted weight for the lifeline factor becomes: $\frac{3}{11} \times 33 = 9$. This adjusted weight was applied to all the communities. All other adjusted weights reported in Table 6 were arrived at using the same procedure.

As expected, there are differences in weights accorded to the indicators by communities. (Table 5). However, for the majority of indicators, the differences between weights tend to be small, suggesting similar perceptions for a given indicator. Further, results suggest that communities perceive the indicators captured in the CBDRI as being very important in contributing to their vulnerability. Of the 38 indicators used, 34 had a mode in the range of 7-9.

4.2. Vulnerability in the Lower Shire valley – magnitudes and dimensional profile

Levels of exposure, susceptibility, lack of capacities are shown in Fig. 2. Fig. 3 shows magnitudes of aggregate vulnerability. In general, vulnerability to flooding of rural communities in the Lower Shire Valley, on the basis of these dimensions and aggregately falls in the low (0.2-0.4) to very high (0.8-1.0) categories but with a predominance of medium and high classes. In particular, exposure tends to be predominantly medium. Susceptibility, quite marked from exposure and capacities, manifests as high (0.6-0.8) to very high (0.8-1.0) with the predominance of high levels. Susceptibility has the greatest contribution to the vulnerability. Surprisingly, lack of capacity, falls in the medium range.

From a sustainable development perspective from which vulnerability is examined from a social, economic, environmental and physical perspective (Fig. 4), the economic sub-component emerges in general as a dominant component, manifesting as high to very high but predominantly very high. Social or physical vulnerability tends to follow in the medium and high ranges. Environmental vulnerability emerges in the low, high and very high classes but exhibits a predominance of high to very high categories.

In coupling exposure, susceptibility and lack of capacity to social, economic, physical and environmental dimensions (Fig. 5), it is evident that high susceptibility levels observed in the valley (Fig.2) are driven by economic and social susceptibilities and to a considerable extent by environmental susceptibility, all of which manifest predominantly on the high to very high end of the vulnerability spectrum. This highlights enormous limitations for rural communities in aspects of economic resources, diversification of economy and employments opportunities among other economic factors. It also underscores fragilities of communities in aspects of literacy, poverty and the environment. Capacity-related vulnerability from a societal perspective is low but predominantly high from an economic and physical perspective.

Table 3: Indicator values across communities in the Lower Shire Valley

Factor component	**Indicator Name**	**Indicator**	Mbenje	Mlolo	Tengani	Ngabu	Malemia	Ndamela	Nyachikhaza	Ngabu	Katunga	Chapananga	Maseya	Makhuwila	Lundu
EXPOSURE															
Structures	(E1) Lifelines	% of home with potable water	97.5	90.5	97.9	62.5	100	56.3	water sourced from swamp, no boleholes	89.8	100	34.4	71.9	96.9	100
Economy	(E2) Economy	average income per capita/day	<US$ 1	<US$ 1	<US$ 1	<US$ 1	<US$ 1	<US$ 1	<US$ 1	<US$ 1	<US$ 1	<US$ 1	<US$ 1	<US$ 1	<US$ 1
SUSCEPTIBILITY															
Physical	(S1) Density	People per km^2	136	169	100	189	125	141	47	138	153	103	183	135	232
	(S2) Demographic pressure	Population growth rate (%)	2.7	2.2	3.8	2.3	1.3	1.3	1.7	3.1	5.0	3.3	3.9	0.7	0.3
	(S3) Access to basic services	% of home with potable water	97.5	90.5	97.9	62.5	100	56.3	water sourced from swamp, no boleholes	89.8	100	34.4	71.9	96.9	100
Social	(S4) Poverty level	% of population below poevrty line	many	many	many	many	many	many	many	many	many	many	many	many	many
	(S5) Literacy	% of people that can aread and write	41.7	46.9	41.7	46.9	50.0	50.0	very few	50.0	46.9	40.6	46.9	42.0	79.2
	(S6) Attitude	priority of population to protect against a hazard	medium	high priority, people relocating at own will	High priority	concerned but mainly when disaster hits	concerned but mainly when disaster hits	concerned but mainly when disaster hits	concerned but mainly when disaster hits	not concerned, other issues very important	not concerned, other issues very important	not concerned, other issues very important	high priority	not concerned, other issues very important	high priority
	(S7) Decentralization	proportion of self geranated revenue of total budget	no budget	no budget	no budget	no budget	no budget	no budget	no budget	no budget	no budget	no budget	no budget	no budget	no budget

Table 4: Indicator scores

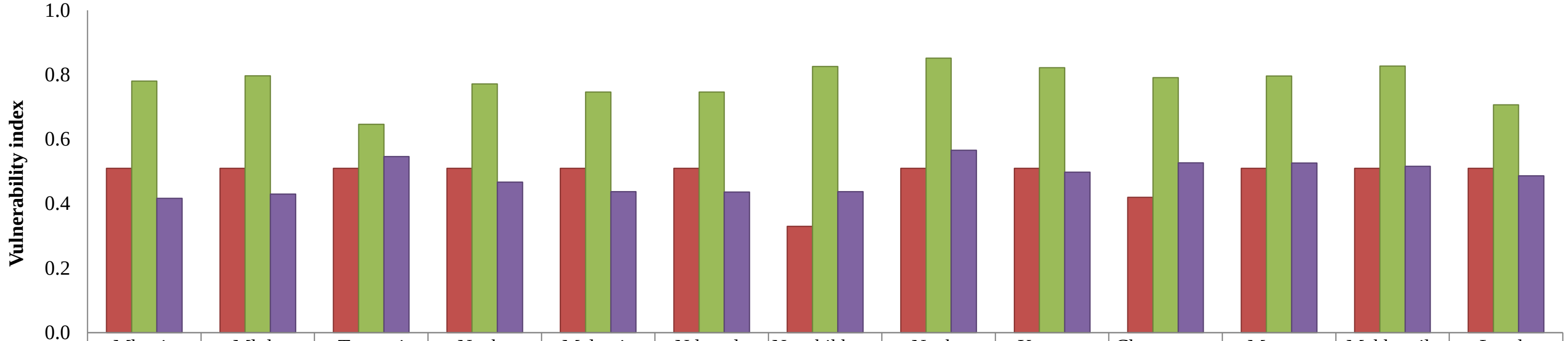
Factor component	**Indicator Name**	Mbenje	Mlolo	Tengani	Ngabu	Malemia	Ndamela	Nyachikhaza	Ngabu	Katunga	Chapananga	Maseya	Makhuwila	Lundu
EXPOSURE														
Structures	(E1) Lifelines	3	3	3	3	3	3	1	3	3	2	3	3	3
Economy	(E2) Economy	1	1	1	1	1	1	1	1	1	1	1	1	1
SUSCEPTIBILITY														
Physical	(S1) Density	2	2	1	2	2	2	1	2	2	2	2	2	2
	(S2) Demographic pressure	2	2	2	2	1	1	1	2	3	2	2	1	1
	(S3) Access to basic services	1	1	1	1	1	1	3	1	1	2	1	1	1
Social	(S4) Poverty level	3	3	3	3	3	3	3	3	3	3	3	3	3
	(S5) Literacy	2	2	2	2	2	2	3	2	2	2	2	2	1
	(S6) Attitude	2	1	1	2	2	2	2	3	3	3	3	3	1
	(S7) Decentralization	3	3	3	3	3	3	3	3	3	3	3	3	3

Table 5: Perceived importance of indicators in contributing to vulnerability

Factor component	Indicator Name	Indicator	Mbenje	Mlolo	Tengani	Ngabu	Malemia	Ndamela	Nyachikhaza	Ngabu	Katunga	Chapananga	Maseya	Makhuwila	Lundu	Mode
EXPOSURE																
Structures	(E1) Lifelines	% of home with potable water	3	7	7	8	5	2	2	3	2	3	5	4	7	3
Economy	(E2) Economy	average income per capita/day	8	8	8	8	8	7	8	7	8	7	6	7	10	8
SUSCEPTIBILITY																
Physical	(S1) Density	People per km^2	8	5	5	10	8	7	8	9	8	9	9	5	6	8
	(S2) Demographic pressure	Population growth rate	6	5	5	10	8	7	8	8	8	9	9	5	6	8
	(S3) Access to basic services	% of home with potable water	4	7	2	5	5	4	10	10	4	5	7	5	4	4
Social	(S4) Poverty level	% of population below poevrty line	7	9	7	10	8	9	9	9	8	8	7	3	9	9
	(S5) Literacy	% of people that can aread and write	5	9	7	8	7	7	8	10	8	8	8	6	9	8
	(S6) Attitude	priority of population to protect against a hazard	2	9	5	6	8	2	7	10	9	7	7	7	7	7
	(S7) Decentralization	proportion of self geranated revenue of total budget	9	10	9	9	8	6	7	9	9	9	8	8	9	9

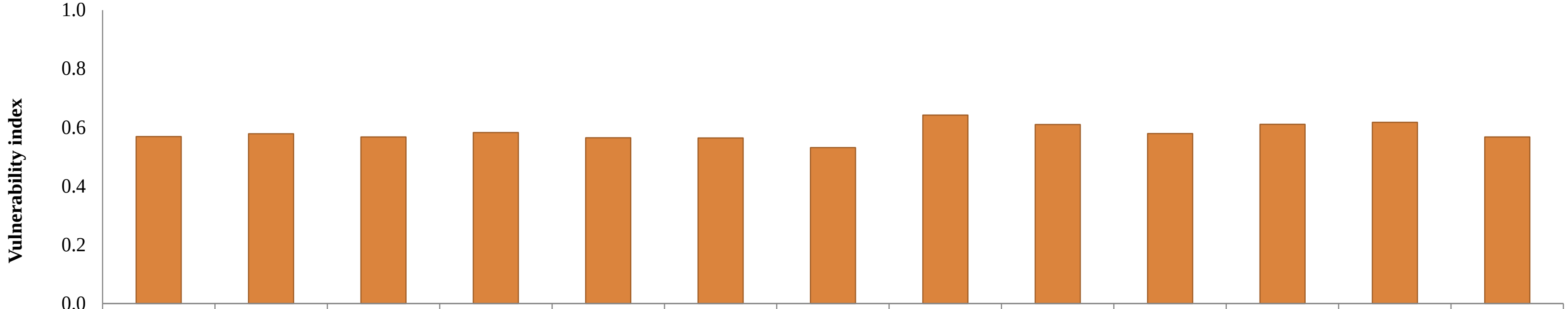
Table 6: Adjusted weights

Susceptibility			Exposure		
	Indicator	Adjusted weight		Indicator	Adjusted weight
Physical	(S1) Density	2	Structures	(E1) Lifelines	9
	(S2) Demographic	3	Economy	(E2) Economy	24
	(S3) Access to basic services	2			
Social	(S4) Poverty level	3			
	(S5) Literacy	3			
	(S6) Attitude	3			
	(S7) Decentralization	3			



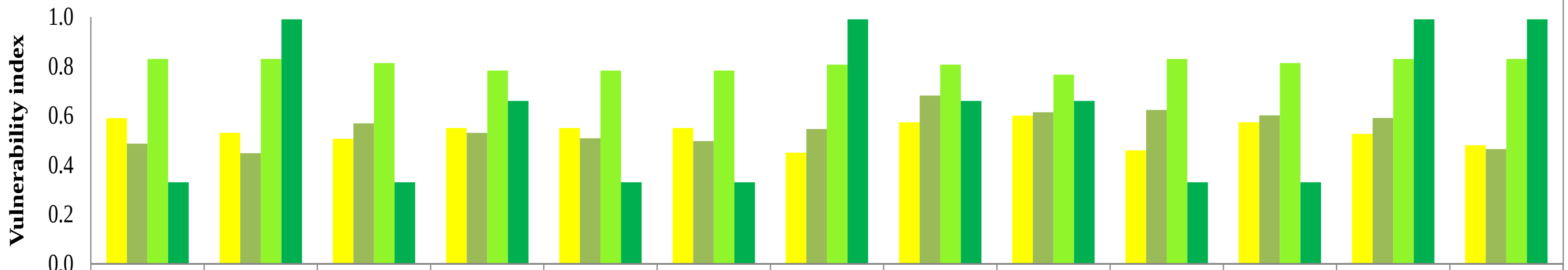
	Mbenje	Mlolo	Tengani	Ngabu	Malemia	Ndamela	Nyachikhaza	Ngabu	Katunga	Chapananga	Maseya	Makhuwila	Lundu
E	0.51	0.51	0.51	0.51	0.51	0.51	0.33	0.51	0.51	0.42	0.51	0.51	0.51
S	0.78	0.80	0.65	0.77	0.75	0.75	0.83	0.85	0.82	0.79	0.80	0.83	0.71
LoC	0.42	0.43	0.55	0.47	0.44	0.44	0.44	0.57	0.50	0.53	0.53	0.52	0.49

Figure 2: Vulnerability magnitudes from exposure, susceptibility and a lack of capacity across communities.
(LoC =Lack of capacity)



	Mbenje	Mlolo	Tengani	Ngabu	Malemia	Ndamela	Nyachikhaza	Ngabu	Katunga	Chapananga	Maseya	Makhuwila	Lundu
CoV	0.57	0.58	0.57	0.58	0.56	0.56	0.53	0.64	0.61	0.58	0.61	0.62	0.57

Figure 3: Aggregate vulnerability across communities in the Lower Shire Valley
(CoV= Community Vulnerability)



	Mbenje	Mlolo	Tengani	Ngabu	Malemia	Ndamela	Nyachikhaza	Ngabu	Katunga	Chapananga	Maseya	Makhuwila	Lundu
Physical	0.59	0.53	0.51	0.55	0.55	0.55	0.45	0.57	0.60	0.46	0.57	0.53	0.48
Social	0.49	0.45	0.57	0.53	0.51	0.50	0.55	0.68	0.61	0.62	0.60	0.59	0.47
Economic	0.83	0.83	0.81	0.78	0.78	0.78	0.81	0.81	0.77	0.83	0.81	0.83	0.83
Environmental	0.33	0.99	0.33	0.66	0.33	0.33	0.99	0.66	0.66	0.33	0.33	0.99	0.99

Figure 4: Vulnerability of the Lower Shire from Sustainable Development Framework

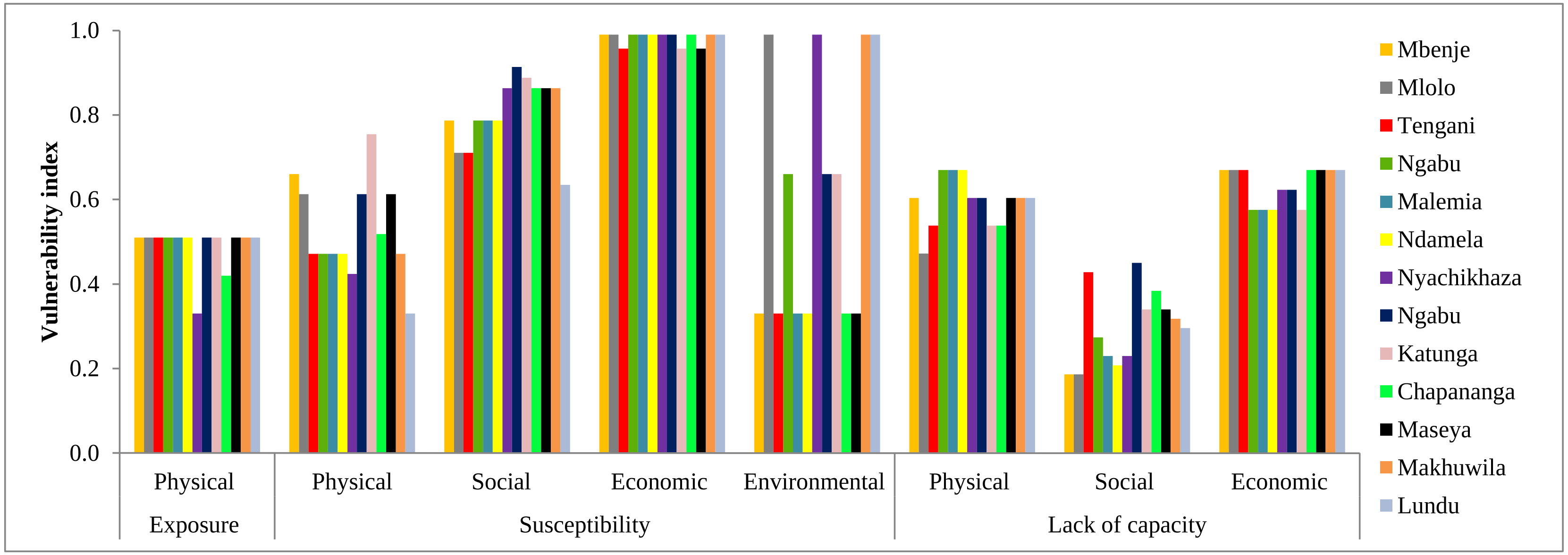


Figure 5: Vulnerability profile from a coupled IPCC-Sustainable Development Framework

Vulnerability of rural communities in SSA to flood hazard has not been quantified before from this contemporary perspective as far as the authors are aware; neither has its measurement with respect to other hazards from an exposure, susceptibility and capacity perspective been viewed through the lens of social, economic, environmental and physical factors. Nevertheless, the levels and profile of vulnerability to flooding found in the Lower Shire from this perspective, mirrors in several aspects, the degree of vulnerability of rural agrarian communities in SSA measured in other ways albeit to other climatological hazards, notably climate change. For example, in the Livelihood Vulnerability Index used by Hahn et al. [15] in Moma and Mabote districts of Mozambique, on account of the Socio-Demographic Profile, Livelihood Strategies, Social Networks, Health, Food and Water, five dimensions deemed describing vulnerability in the context of this study, the scores found, in general, did not reflect low vulnerability. On a scale of 0 - 0.5, aggregate vulnerability scores were 0.316 and 0.306 respectively. Except for the Socio-Demographic Profile in Moma and the Water component in Mabote that measured 0.175 and 0.099 respectively, all dimensions fell in the range of 0.25 – 0.48 suggesting a medium to high vulnerability.

Similarly, Gbetibouo and Ringler [17] found that predominantly rural provinces of the Republic of South Africa (Limpopo, KwaZulu Natal and Eastern Cape) registered high susceptibility and low capacity in their vulnerability to climate change. This was in contrast to economically developed provinces of Western Cape and Gauteng. As factors used in their exposure dimension amount to the hazard in this study, their exposure dimension is not discussed. In a recent study in Malawi, Malcomb et al. [31] measured vulnerability to climate change based on *Adaptive Capacity, Livelihood Sensitivity* and *Physical Exposure*, which was essentially risk. Discounting *Physical Exposure* whose indicators describe the hazard in the context of this study, the combination of *Adaptive Capacity* and *Livelihood Sensitivity* which Malcomb et al. [31] define as *resilience,* was predominantly low over the Lower Shire Valley.

The predominance of environmental susceptibility magnitudes in the high and very high categories is also consistent with the state of the environment not only in Malawi but in most of SSA. The dominant driver of landcover change in SSA has been agriculture and much of the changes have taken place in the Zambezia region, a region covering the study area [40]. In fact, in general, Malawi is a country in environmental distress with the southern region where the study area falls, being the most stressed [41]. Minde et al. [42] actually observed that in the southern region of Malawi, there is little forest left outside forest reserves.

Nevertheless, while Hahn et al. [15] and Gbetibouo and Ringler [16] find rural communities in SSA as predominantly exhibiting low capacity, this study finds that in the context of vulnerability to flooding, such low levels are mainly associated with economic and physical capacity. Capacity from a societal perspective is higher resulting in the unexpected medium levels in overall lack of capacity component.

4.3. Spatial trends

A spatial analysis across the valley shows that community vulnerability is relatively homogenous (Figs. 6 and 7) suggesting insubstantial differences between communities. The pattern is observed in aggregate community vulnerability, exposure, susceptibility and capacity related vulnerability. It also manifests when vulnerability is viewed as social, economic and physical. Environmental vulnerability however is the exception; it is the most spatially differentiated dimension of vulnerability.

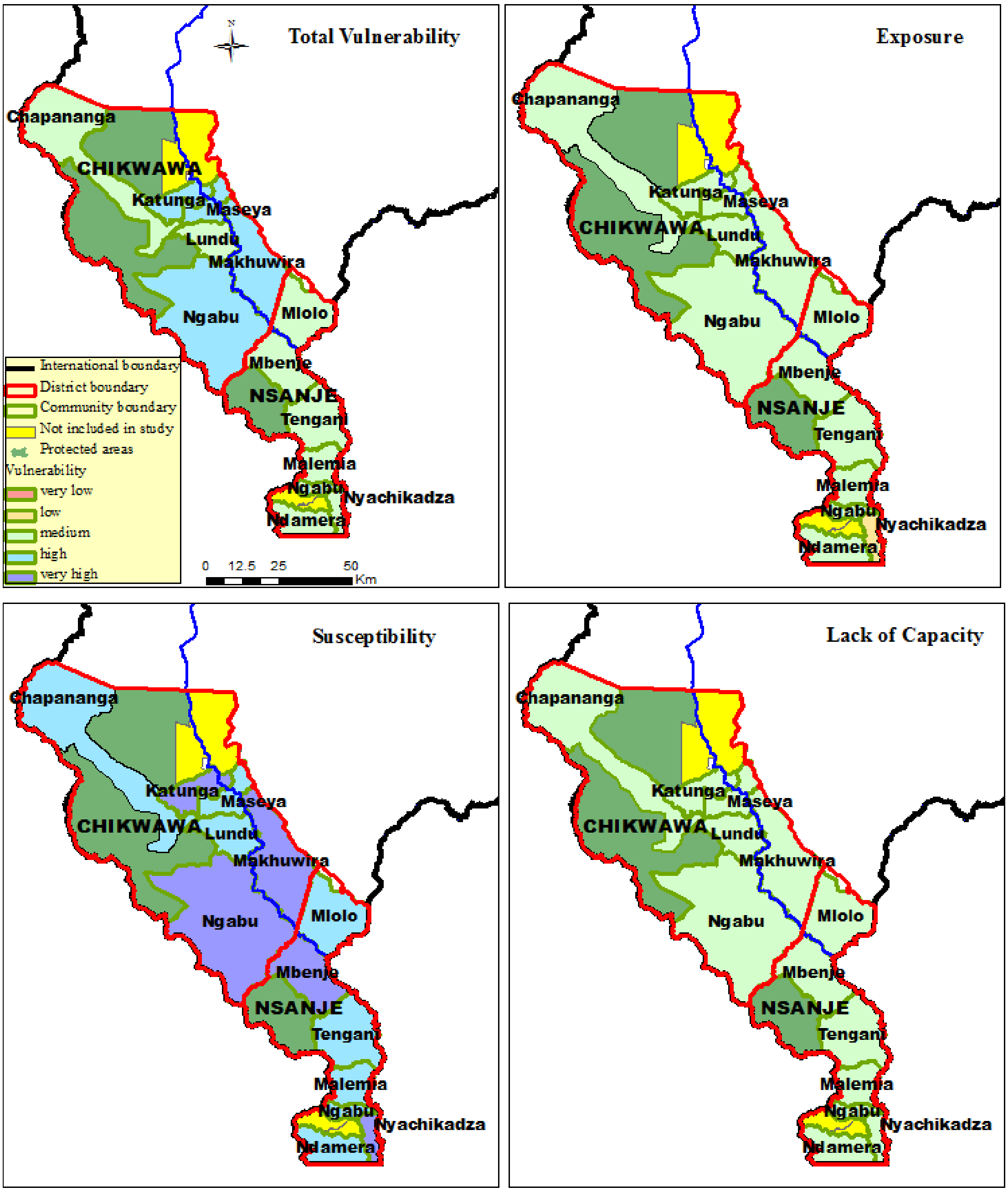


Figure 5: Spatial variation in community vulnerability arising from exposure, susceptibility and capacity

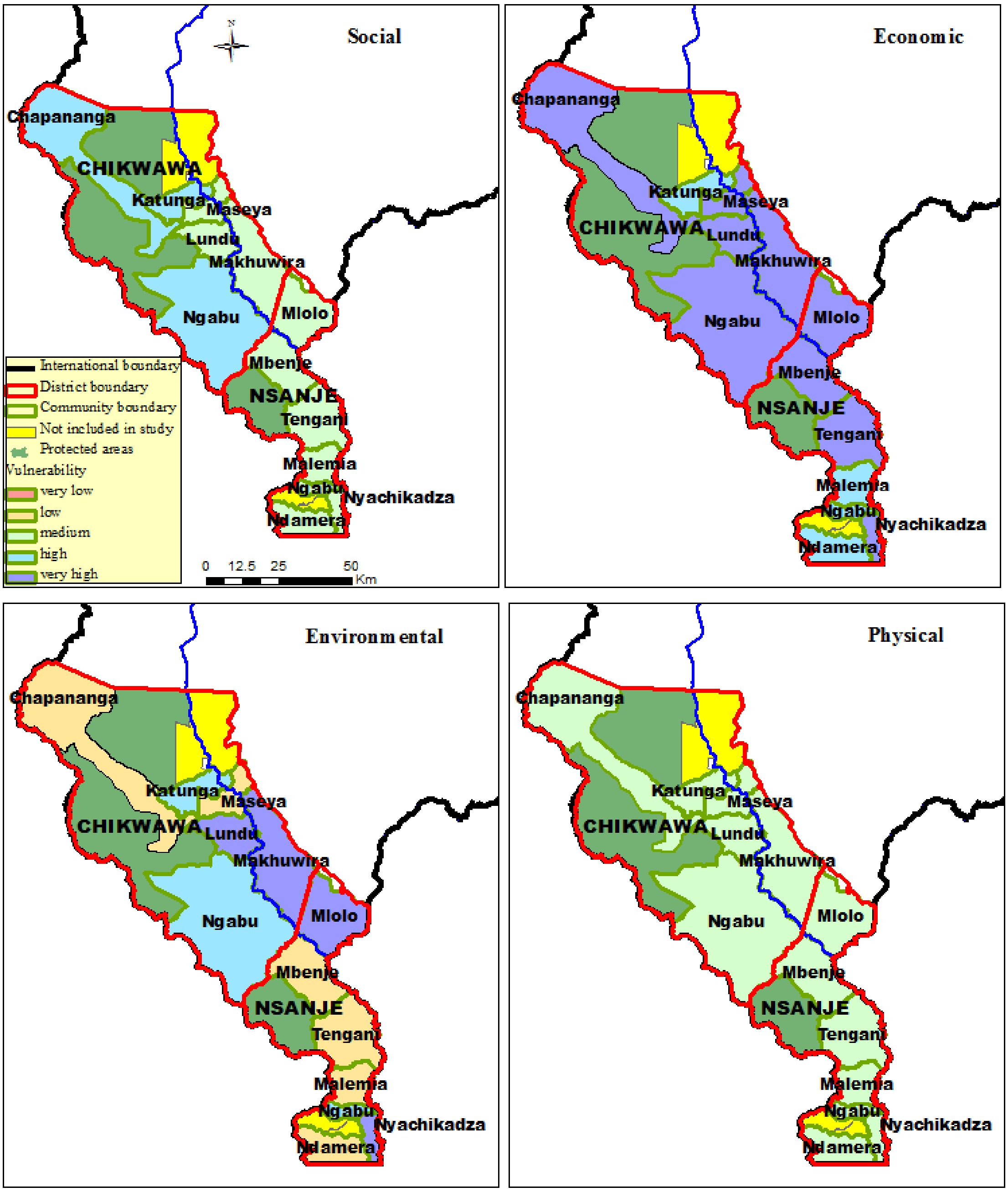


Figure 6: Spatial variability in community vulnerability - a social, economic, environment and physical perspective

In spite of a relative uniform degree of vulnerability for a given dimension, there is a clear trend in the Lower Shire Valley of extreme ends of susceptibility and consequently aggregate vulnerability being concentrated in Chikwawa. This may be explained by geographical concentrations of very high environmental vulnerability being more associated with Chikwawa than Nsanje, linked to its proximity to the city of Blantyre, a major factor of deforestation in the Shire River basin [24]. The city is a lucrative market for charcoal and wood for the energy needs of the urban poor and for the urban masses in general in the face of constant power cuts. The impact of household energy needs in cities on the deforestation of outskirt areas have been also reported in Masvingo city in Zimbabwe [43].

A general homogeneity in vulnerability magnitudes in the Lower Shire is not unexpected considering that Chikwawa and Nsanje districts are very similar districts in their social and economic profile as summed up in their poverty levels, which also tend to be the highest in the country [26, 38]. This is further evident in the raw data presented in Table 3 where it can be seen that in general, people in the communities are on below 1USD per day. Further, the economic capacity for disaster management of the two districts is similar: both are served with non-governmental organisations and like the rest of the country, with local government institutional structures. In this respect, vast diversity in vulnerability in the Lower Shire valley at this scale is unexpected. Lack of vast diversity in vulnerability amongst rural communities has also been observed in other parts of SSA though notably with respect to climate change e.g. in Mozambique [15] and South Africa [16]. Nonetheless, the findings herein do not offer conclusive evidence on lack of heterogeneity in the valley. Vulnerability is a scale-dependent variable that become more conspicuous with fineness in scale. Differences in vulnerability in the Lower Shire Valley may operate at a much smaller scale such as a village or at household level. The ADC level used in this study therefore may be too coarse to unmask heterogeneity in vulnerability across the valley. Besides, the scores used in the questionnaire i.e. 1 (low), 2 (medium) and 3 (high) may also be too coarse to reveal heterogeneity.

4.4. Policy implications

It emerges from implementing an index approach to measuring vulnerability of rural communities to the flood hazard in the Lower Shire Valley that their vulnerability is driven by high to very high levels of economic and social susceptibility and to a large extent by environmental susceptibility. The lack of capacity is mainly in the economic and physical dimensions both of which manifests as medium or high; societal capacity is high. Physical exposure, the only dimension of exposure measured in this study, tends to be medium. The Lower Shire Valley is one of the poorest parts of the country. However, it is also a region in Malawi substantially supported in conventional developmental projects notably by NGOs and donor partners [23]. The plethora of conventional developmental programs taking place offers a platform for susceptibility reduction by mainstreaming flood risk reduction measures into such programs. This, to some extent, will also address the issue of economic incapacity that arises from implementing lone flood risk reduction programs.

Despite a limited economic capacity, communities already demonstrate diverse societal capacity mechanisms. These include availability of decentralised institutions, considerable coordination amongst local institutional structures, public participation and awareness and to some extent, the existence of non-unconventional early warning systems such as drumming, whistling, and use of text messages. Therefore, programs that expand and strengthen this societal capacity will provide the much needed leverage for vulnerability reduction.

Further, the relative homogeneity in the vulnerability to flooding manifested across communities in the Lower Shire Valley calls for universally applied interventions to all flood-prone areas in the basin. Chikwawa in particular however, offers a leverage point in vulnerability reduction through environmental responses.

5. Conclusion

Measuring vulnerability, supported by metrics and dimensions provide important information for decision-making and policy in disaster risk management. The application of the method to the Lower Shire Valley with respect to the flood hazard demonstrates that the Lower Shire valley is a region predominantly in the medium to high vulnerability categories. Vulnerability magnitudes are driven by a high to very high level of susceptibility mainly arising from socio-economic and environmental susceptibility. Economic and physical capacities tend to be predominantly low but social capacity is significantly high, resulting in overall medium levels of capacity-induced vulnerability. Exposure manifests as medium. For a given vulnerability dimension, spatial variation tends to be marginal except, conspicuously, for environmental component.

This multi-dimensional and integrated approach coupled with metrics is an approach already applied in assessing vulnerability in SSA but notably to climate change and confined to exposure, susceptibility and capacity elements. However, equally critical are the most recurrent and immediate hazards that constantly erode community asset base and reduce overall quality of life. For SSA, flooding is one such hazard. This study quantifies associated vulnerability magnitudes and affirms the relatively high level of susceptibility of rural, subsistent communities in SSA even to the flood hazard. In coupling exposure, susceptibility and capacity to social, economic, physical and environmental components, the study highlights the dominant aspects of susceptibility and capacity driving vulnerability of rural subsistent communities to the flood hazard.

The results found nonetheless pertain to the index used. Therefore, results are much dependent on indicators used, the thresholds set, the aggregation process applied and the scale of application among other factors. Besides, there are no means for validation. Use of other indices may reveal different levels and profiles of vulnerabilities. These are problems nonetheless shared by all index-based vulnerability analyses. Further, data with different temporal scales have been combined in some cases which may affect the outcome as vulnerability is a dynamic phenomenon. Nevertheless, most factors in the index are structural and therefore significant changes for a period of two years around 2010 over which the data span, is likely to be marginal. For example, in the 5-year period between the second integrated household surveys (IHS-2) in 2005 and the third (IHS-2) in 2011, poverty levels in Malawi only declined by 1.4% over this period [26].

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Appendix A - The Community-Based Disaster Risk Index Questionnaire

2. EXPOSURE			
	STRUCTURES		
2.1	**(E1) Lifelines**		
	% of homes with piped drinking		
	<20%	Low	
	20%-50%	Medium	
	>50%	High	
2.2	**Economy**		
	(E2) average income per capita/day		
	<$2.8	Low	
	$2.8 - $11	Medium	
	>$11/capita/day	High	
3. SUSCEPTIBILITY			
3.1	**Physical/demographic**		
	(S1) Density		
	How many people per km^2 live in the		
	<100	Low	
	100-500	Medium	
	>500	High	
	(S2) Demographic pressure		
	Population growth rate		
	<2%	Low	
	2-4%	Medium	
	>4%	High	
	(S3) Access to basic services		
	% of homes with piped drinking water		
	>50	Low	
	20-50	Medium	
	<20	High	
3.2	**Social**		
	(S4) Poverty level		
	Percent of population below poverty level (1USD/day)		
	<10%	Low	
	10-30%	Medium	
	>30%	High	
	(S5) Literacy		
	Percentage of adult population able to read and write		
	>70%	Low	
	40-70%	Medium	
	<40	High	

	(S6) Attitude		
	What priority does the general population give the protection against a threat from a hazard		
	High priority. Protection against a hazard	Low	
	Concerned, but only if a disaster has hit.	Medium	
	Not concerned. Other issues (food, work etc are much more important)	High	
	(S7) Decentralization		
	What is the portion of self generated revenues of the total available budget		
	>50%	Low	
	20 - 50%	Medium	
	<20%	High	
	(S8) Community participation		
	% voter turnout on last commune elections		
	>70%	Low	
	50-70%	Medium	
	<20%	High	
3.3	**Economic**		
	(S9) Local resource base		
	Does the community have a budget	**yes/no**	
	Enough to help the most affected	Low	
	Insufficient	High	
	(S10) Diversification		
	Source of livelihood comes from one, two or three sectors?		
	Mix of 3 sectors	Low	
	Mix of 2 sectors	Medium	
	More than 80% in 1 sector (e.g. agriculture)	High	
	(S11) Small business		
	Percentage of businesses with fewer than 20 employees		
	<50%	Low	
	50-80%	Medium	
	>80%	High	
	(S12) Accessibility		
	How often in the last 5 years was the commune isolated through interruption of access roads for more than 2 days		
	0 - time	Low	
	1-5 times	Medium	
	>5 times	High	
3.4	**Environmental**		
	(S13) Area under forest		
	How much of the total territory of the commune is covered with forest?		
	>30%	Low	
	10-30%	Medium	
	<10%	High	

4. CAPACITIES AND MANAGEMENT				
4.1	**Physical planning and engineering**			
	(C1) Landuse planning		**Their enforcement is**	**Evaluation**
	Does a land use plan or zoning regulations exists that keeps local production and housing out of hazardous areas?	**YES/NO**	Low	Low
			High	High
	(C2) Building codes	**Percent of buildings in threatened area complying to code/standards**		
	Do building codes, design standards, and performance specifications for facilities exist that guarantee the use of flood resistant methods, techniques and material building codes?	**YES/NO**	<30%	Low
			30-70%	Medium
			>70%	High
	(C3) Retrofitting/Maintenance		**Measures implemented**	
	Are existing infrastructure (e.g. bridges, roads) and buildings (schools, hospitals etc) retrofitted to withstand flooding and /or are regular maintenance carried out (River dredging, flood canals etc)	**YES/NO**	Few	Low
			Some	Medium
			Many	High
	(C4) Preventive measures		**Expected effect on damage:**	
	Do flood exposure- limiting mechanisms/ structures exist (dykes, retaining walls, dams, barrages, rock fall barriers, terraces, drainage)?	**YES/NO**	Low	Low
			Medium	Medium
			High	High
	(C5) Environmental management		**Number of activities and projects**	
	Are there activities to promote and enforce conservation of natural resources in risk areas (e.g. protection of water reserves , natural resources, desertification control techniques, reafforestation)	**YES/NO**	Few	Low
			Some	Medium
			Many	High
4.2	**Societal measures**			
	(C6) Public awareness programs		**Frequency (annual)**	
	Are public awareness programs executed?	**YES/NO**	once	Low
			Sometimes	Medium
			regular	High
	(C7) School curriculum		**The topics are taught at:**	
	Are risk, disaster, environment and development topics part of taught lessons at school?	**YES/NO**	one grade only	Low
			2-3 grades	Medium
			all grades	High
	(C8) Emergency response drills		**Drills take place:**	
	Is emergency response training and drills at multiple levels ongoing?	**YES/NO**	One level	Low
			2 levels	Medium
			all levels	High
	Level 1: administration			
	Level 2: relevant response institutions (civil defence, police, fire brigade, emergence health)			
	Level 3: the public (hospitals, schools, large buildings etc			

	(C9) Public participation		**It is composed of**	
	Is the public represented as member in the risk management/emergency committee?	**YES/NO**	only level 1	Low
			2 levels	Medium
			mix of 3 levels	High
	Level 1: administration (mayor's office, planning department			
	Level 2: relevant response institutions (police, fire brigade, education, emergence health)			
	Level 3: the public (business, civil society, NGO'S)			
	(C10) Local risk management/emergency groups		**% of villages at risk with local emergency group.**	
	Do local groups exist, that have organized members with specific tasks (e.g. emergency response?	**YES/NO**	<30%	Low
			30 - 60%	Medium
			>60%	High
4.3	**Economic measures (Risk Transfer)**			
	(C11) Local emergency fund		**Fund as % of local budget:**	**Evaluation**
	Does a local fund for emergency exist?	**YES/NO**	<10%	Low
			10-50%	Medium
			>50%	High
	(C12) Access to national emergency fund		**How fast can it be released/received**	
	Is there access to a national/district emergency fund?	**YES/NO**	>7 days	Low
			3-5 days	Medium
			< 3 days	High
	(C13) Access to international emergency funds		**Access to funds is:**	
	Is there access to international emergency funds?	**YES/NO**	Difficult	Low
			Easy	High
	(C14) Insurance market		Use	
	Is disaster risk insurance coverage for buildings available?	**YES/NO**	Not common	Low
			common	High
	(C15) Mitigation loans		**Use**	
	Do private banks (including micro-credit institutes) or the government offer loans or subsidies for disaster risk reduction measures (relocation, retrofitting, protective structures etc.)	**YES/NO**	not common	Low
			common	High
	(C16) Reconstruction loans			
	Are there reconstruction credits for affected households?	**YES/NO**	With collateral	Low
			Without	High
	(C17) Public works		**Magnitude:**	
	Do local public works programs (e.g. food for work) exist to support risks reducing measures (retrofitting, preventive structures, reconstruction)?	**YES/NO**	Low	Low
			Medium	Medium
			High	High

4.4	**Management and institutional measures**			
	(C18) Risk management/emergency committee		**Meeting frequency:**	
	Does a community risk management or emergency committee exist, that deals with prevention, mitigation, preparedness and response?	**YES/NO**	only during emergency	Low
			once a year	Medium
			at least quarterly	High
	(C19) Risk map		**The map is available at different levels:**	
	Does a risk map exist?	**YES/NO**	only level 1	Low
			also at level 2	Medium
			also at level 3	High
	Level 1: administration (mayor's office, planning department)			
	Level 2: relevant response institutions (police, fire brigade, education, emergence health)			
	Level 3: the public (business, civil society, NGO'S)			
	(C20) Emergency plan		**Availability of maps at different levels:**	
	Is there a worked out and circulated emergency plan?	**YES/NO**	One	Low
			few	Medium
			many	High
	(C21) Early warning system		Does it work	
	Is an early warning system in place?	**YES/NO**	Low	Low
			Medium	Medium
			High	High
	(C22) Institutional capacity building			
	Do local institutions (administration, police, fire brigade, hospitals, building sector) receive training on risk management?	**YES/NO**	Sometimes	Low
			Often	Medium
			Constant	High
	(C23) Communication			
	Is there coordination with national level risk management organizations (national committees, government etc.)?	**YES/NO**	Sometimes	Low
			Often	Medium
			Constant	High

Shaded data were sourced from third Integrated Household Surveys [26], the 2008 population and housing census data [38] and the Malawi land cover database [39].