RESEARCH ARTICLE

The Multidimensional Livelihood Vulnerability Index – an instrument to measure livelihood vulnerability to change in the Hindu Kush Himalayas

Jean-Yves Gerlitz[a*], Mirjam Macchi[b], Nick Brooks[c], Rajiv Pandey[d], Soumyadeep Banerjee[a] and Shashidhar Kumar Jha[e]

[a]*International Centre for Integrated Mountain Development (ICIMOD), GPO Box 3226, Kathmandu, Nepal;* [b]*Swiss Agency for Development and Cooperation, Former Climate Change Adaptation Specialist at ICIMOD, Freiburgstr. 130, 3003 Berne, Switzerland;* [c]*Garama 3C: Climate Change Consultancy, Sackville Place Business Centre, 44-48 Magdalen Street, Norwich NR2 1JU, UK;* [d]*Department of Forestry and Natural Resources, Hemwati Nandan Bahuguna Garhwal University, Srinagar, Uttarakand 246174, India;* [e]*Indian Institute of Forest Management (IIFM), PO Box 357, Nehru Nagar, Bhopal, MP 462003, India*

(*Received 26 March 2014; final version received 28 September 2015*)

In recent years the population of the Hindu Kush Himalayas (HKH) has been confronted with rapid social, economic, demographic, and political changes. In addition, the region is particularly vulnerable to climate change. However, there is a scarcity of cohesive information on the state of the environment and on the socio-economic situation of the approximately 210 million people who reside in the HKH. Specifically, data on livelihood vulnerability are lacking. As part of the Himalaya Climate Change Adaptation Programme, the International Centre for Integrated Mountain Development, in consultation with regional and international partners, has developed the Multidimensional Livelihood Vulnerability Index (MLVI), a measure to explore and describe livelihood vulnerability to climatic, environmental, and socio-economic change in the HKH region. This paper documents how the MLVI was developed and demonstrates the utility of this approach by using primary household survey data of 16 selected districts of three sub-basins in the HKH region. The analysis gives important clues about differences in the intensity and composition of multidimensional livelihood vulnerability across these locations that should be useful to decision makers to identify areas of intervention and guide their measures to reduce vulnerability.

Keywords: South Asia; mountain specificities; sustainable livelihoods; sensitivity; exposure; adaptive capacity; decomposition; cross-country analysis

1. Introduction

The Hindu Kush Himalayas (HKH) region (Map 1) is particularly exposed to climate change, having experienced warming greater than the global average that has resulted in significant environmental impacts (Nogues-Bravo, Araujo, Erra, & Martinez-Rica, 2007; Yao et al., 2012). In particular, this warming has been associated with glacial retreat, area reduction, and negative mass balance (Lemke et al., 2007; Yao et al., 2012). These impacts are likely to intensify over time as global climate change accelerates, with implications for disaster risk through more frequent and severe floods and landslides and glacial lake outbursts due to greater melting rates in the short to medium term, and possible reductions in water availability due to reduced snow and ice cover in the longer term (Akhtar, Ahmad, & Booij, 2008; Immerzeel, van Beek, & Bierkens, 2010; Tse-ring, Sharma, Chettri, & Shrestha, 2010). Climate change may also have a variety of impacts on rainfall regimes and local agro-climatic and ecological conditions, with further implications for livelihoods, health, and other aspects of human wellbeing. However, environmental change is poorly monitored in the HKH region, and the precise nature and distribution of future impacts remain uncertain (Akhtar et al., 2008). In addition, the extent and distribution of human vulnerability to climate change and its impacts in the region are poorly known. On top of that, the HKH region is undergoing rapid socio-economic changes that are caused by economic globalization. Labour migration to urban centres and international destinations is thoroughly changing the social structure of rural communities (Hoermann, Banerjee, & Kollmair, 2010; Kollmair & Hoermann, 2011).

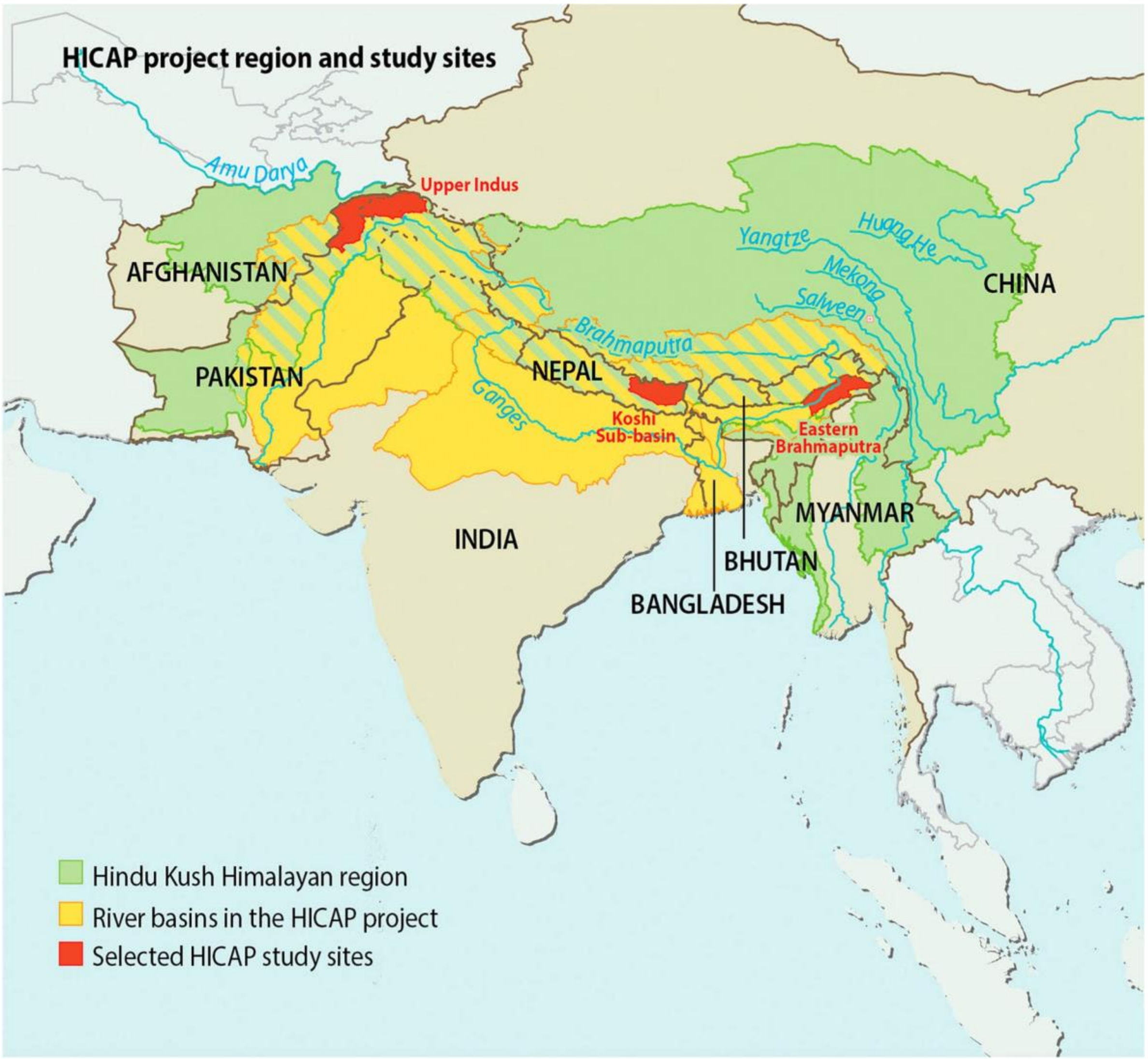
Under the *Himalaya Climate Change Adaptation Programme* (HICAP), the International Centre for Integrated Mountain Development (ICIMOD) and its regional partners have carried out the Vulnerability and Adaptive Capacity Assessment (VACA), a household survey that collects data on vulnerability to environmental and socio-economic change in

*Corresponding author. Email: jygerlitz@outlook.com

mountain contexts (see Gerlitz, Banerjee, Brooks, Hunzai, & Macchi, 2015). The VACA has been applied in three sub-basins in the HKH region (Upper Indus in Pakistan, Eastern Brahmaputra in India, and Koshi in Nepal) to gather data on livelihood vulnerabilities to climate, environmental, and socio-economic changes at district level (MAP 1).

This paper describes the development of a new index, the *Multidimensional Livelihood Vulnerability Index* (MLVI), using primary data gathered by the application of the VACA survey. The MLVI is designed to measure multi-dimensional livelihood vulnerability to climatic, environmental, and socio-economic change in a region that is predominantly rural, mountainous, and stretches across several of the least developed countries. It represents three dimensions of vulnerability: exposure, sensitivity, and adaptive capacity. Each of these dimensions is broken down into a number of components, and each component is represented by a number of indicators. The MLVI was developed using the Alkire-Foster approach of multidimensional index construction (AF method; Alkire & Foster, 2011) – a novel method which allows to decompose complex indices. Decomposition makes it possible to describe vulnerability in a more holistic, illustrative way, enables the user to identify location-specific components of livelihood vulnerability, and thus supports development planners and policy makers in developing policies and programmes that address location-specific needs. The MLVI can be used as a single-value index or decomposed into its three main dimensions, 12 components, and 25 vulnerability indicators.

The following sections describe the conceptual foundations and precursors of the MLVI, its development, and the results of its application in the Upper Indus,



Map 1. The HKH Region, showing the locations of the sub-basins that are the subject of this study.
Source: ICIMOD.

Eastern Brahmaputra, and Koshi sub-basins at district level.

2. Conceptual and methodological outline

2.1. The concept of vulnerability

While the term “vulnerability” is used widely in development and adaptation contexts, there is no standard definition of vulnerability, and usage of the term varies considerably. Nonetheless, definitions of vulnerability tend to fall into two categories. The first category draws on the natural hazards literature, and defines vulnerability as a function of the internal characteristics of a population or system that mediates the extent to which that population or system experiences harm as a result of exposure to an “external” *hazard* (Wisner, Blaikie, Cannon, & Davis, 2004). In this formulation, the risk of an undesirable outcome (e.g. a complex disaster) is a function of, and results from the interaction of, hazard and vulnerability. While this conceptualization of vulnerability may include local geographical and environmental factors that mediate risks/outcomes, it is strongly rooted in social and political processes and tends to take an actor-oriented approach (Cannon & Müller-Mahn, 2010; Miller et al., 2010; Wisner et al., 2004). The vulnerability of a system to hazards associated with environmental change is linked with the wider political economy of resource use (Adger, 2006). Generally, this approach tends to adopt socially defined scales, namely household, community, and region (Miller et al., 2010).

The second category is associated to a large extent with the Third and Fourth Assessment Reports (TAR and AR4, respectively) of the Intergovernmental Panel on Climate Change (IPCC, 2001, 2007). The IPCC definition views vulnerability as a function of *exposure*, *sensitivity*, and *adaptive capacity*. It differs from the natural hazards approach in viewing vulnerability as a function of both “internal” factors (sensitivity and adaptive capacity) and “external” factors (exposure to shocks and stresses). The latter are the various climate hazards associated with climate change and variability to which a system or population is exposed. The IPCC defines exposure as “ the nature and degree to which a system is exposed to significant climate variations” (IPCC, 2001, p. 987), and sensitivity as “the degree to which a system is affected, either adversely or beneficially, by climate related stimuli” (IPCC, 2001, p. 993). Adaptive capacity is defined as “the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences” (IPCC, 2001, p. 982).

In its recent SREX report, the IPCC (2012, p. 32) defines vulnerability as “the propensity or predisposition to be adversely affected”, and describes exposure and vulnerability as the determinants of risk. While the IPCC Fifth Assessment Report (AR5) has not been released at the time of writing, this suggests that the IPCC may be moving away from the definition of vulnerability in the glossaries of the previous two assessment reports, and towards the more established natural hazards definition of vulnerability as a component of risk. Nonetheless, this most recent IPCC definition of vulnerability is very vague. This may signify a desire on the part of the authors to accommodate multiple ways of defining and treating vulnerability, recognizing the diverse ways the concept has been used in the climate change literature, without contradicting the earlier IPCC glossary definition.

While recognizing the diverse and evolving definitions of vulnerability in the literature, the definition in the glossaries of the IPCC TAR and AR4 is used for the operationalization of the MLVI. This definition has been widely adopted, and has been used to frame a growing number of studies that range from local scale studies with the unit of analysis being the household (Eakin & Bojórquez-Tapia, 2008; Notenbaert, Nganga Karanja, Herrero, Felisberto, & Moyo, 2012; Pandey & Jha, 2011; Sonwa, Somorin, Jum, Bele, & Nkem, 2012), to global scale studies that examine the relative vulnerability of individual countries (Allison et al., 2009; Yohe et al., 2006a, 2006b). Other studies apply this approach at the national or sub-national scale, to analyse the relative vulnerability of individual states or districts (Allison et al., 2009; Brenkert & Malone, 2005; Malone & Brenkert, 2008; O’Brien et al., 2004). Common to all these definitions are the key concepts of exposure, sensitivity, and adaptive capacity (Miller et al., 2010).

2.2. Conceptual framework of the MLVI

The MLVI combines a modified version of a Livelihood Vulnerability Index framework (LVI, Hahn, Riederer, & Foster, 2009) with the AF method of multidimensional index construction (Alkire & Foster, 2011). For the purposes of the MLVI, the unit of analysis is the household. The aim is to measure the current livelihood vulnerability status of households, that is, to identify households that have a high potential to be negatively affected by climatic and other changes. Consequently, the identification is based on household-level characteristics (community or regional indicators would not vary at the household scale).

Underpinning the MLVI is the definition of vulnerability provided by the Intergovernmental Panel on Climate Change (IPCC, 2001, 2007). In the absence of small-scale data on past and future climate change, the exposure dimension captures the extent to which a household experiences potential harmful “external” hazards associated with climate variability (that will change in frequency, severity, and perhaps nature as a result of climate change), such as droughts and changes in temperature or precipitation. The MLVI specifically looks at severe losses at household level (severity as defined by the household's perception and in monetary terms) that were caused by environmental shocks over the past twelve months. These past losses provide information about the current stress level that a household is facing, and, under the assumption that impacts will intensify over time as global climate change accelerates, can be used as proxies for future shocks and the ability of the household to cope with them. As climate change will not act in isolation, the MLVI also incorporates an element that addresses exposure to socio-economic shocks, which have the potential to increase a household's sensitivity to climate hazards, and undermine its adaptive capacity. Sensitivity is defined in the framework as the degree to which a household can be adversely affected by the hazards to which it is exposed. The adaptive capacity dimension captures the ability of a household to make adjustments to its behaviour in order to moderate potential damages, to take advantage of opportunities, or to cope with the consequences of exposure to these hazards.

To implement the above livelihood vulnerability definition for the household level, we built on the approach of Hahn et al. (2009), who developed a Livelihood Vulnerability Index (LVI) that combines the IPCC vulnerability framework with the sustainable livelihoods approach (Chambers & Conway, 1992; Scoones, 1998). The LVI uses data from household surveys to assess households across eight major vulnerability components: *socio-demographic profile*, *livelihood strategies*, *social networks*, *health*, *food*, *water*, *natural disasters*, and *climate variability*. Each component is associated with one of the three dimensions of vulnerability (*exposure*, *sensitivity*, and *adaptive capacity*), and is represented by a number of indicators.

The MLVI has been developed by modifying the LVI approach so that it addresses factors that are relevant in the HKH region. Mountain regions are characterized by a variety of specific features. These "mountain specificities" on the one hand enable human activities and on the other constrain such activities (Jodha, 1992, 1997, 2001; Körner et al., 2005). "Constraining factors" include environmental and social fragility, marginality, and limited accessibility. Inaccessibility captures all elements of distance and mobility as well as the availability of risk management options. Marginality is defined as the lack of social and political capital, which often results in difficulties in securing tenancy rights over land and in gaining access to social services such as credit, education, and health. Fragility is understood as the diminished capacity of a social or ecological system to manage shocks. The social dimensions of fragility in the mountains occur due to scarce, scattered, and periodically unavailable livelihood resources. Ecological fragility is linked with low carrying capacities coupled with topography (slope and relief). Within the MLVI, the components *physical accessibility*, *resources and energy*, *social networks*, and *environmental stability* are closely related to the nature of the terrain in mountain regions.

The MLVI modifies and augments the eight components of the LVI, resulting in 12 vulnerability *components*, each of which is associated with one of the three main dimensions of vulnerability. As in the original LVI, each component is represented by a number of specific, measurable vulnerability *indicators* (Table 1). Overall, the MLVI covers 25 vulnerability indicators that were identified in two steps: Based on extensive literature review of existing vulnerability indicators and survey instruments and discussions with regional and international experts, there was a pre-selection of 60 potential indicators that were integrated in the VACA questionnaire. After the data collection was completed, conceptual considerations and statistical correlation analysis narrowed down the pre-selection to 25 indicators. To keep the MLVI manageable and avoid over-complexity, it was decided that there would not be more than three indicators per dimension. As double-counting should be avoided when using the AF method, indicators that showed very high correlations were either combined or dropped (e.g. the indicator "dwelling" of the component "environmental stability" is a combination of the three indicators "wall", "roof", and "stability"). For a detailed discussion of the indicators see Gerlitz et al. (2014); a tetrachoric correlation matrix for the 25 indicators is presented in Table A1 in the appendix.

While a detailed discussion of components and indicators is beyond the scope of this paper, two comments regarding the use of "subjective" indicators and the absence of an income-based indicator will be made: Besides "objective" indicators which measure physical goods or observable behaviour, the MLVI also incorporates "subjective" indicators that are based on perceptions. The use of "subjective" indicators has a long tradition in social sciences. Diener and Suh (1997) provided evidence that "subjective" indicators are relevant and valid measures in the quality of life measurement, as they shed a light on a different angle of wellbeing and add substantially to "objective" wellbeing measures. A prominent example for the combination of "objective" and "subjective" indicators in a quality of life measure is the Gross National Happiness Index of Bhutan (Ura, Alkire, Zangmo, & Wangdi, 2012).

Income is a relevant and widely used wellbeing measure. Nevertheless, consumption-based measures are preferred over income-based measures in most developing countries. The collection of accurate income data is difficult in societies where self-employment, including subsistence agriculture and small business, is common. Bhutan even refrained from including income measures in its Living Standards Survey after a pilot did not result in reliable income data (see Royal Government of Bhutan, 2007). The wellbeing indicator "per capita consumption" links the MLVI to official poverty measures in the HKH region

Table 1. MLVI – Dimensions, components, indicators, weights, and cut-offs.

Dimension	Component	Indicator	Weight	Vulnerability cut-offs (HH is vulnerable if …)/justification
Adaptive capacity	Socio-demographic status	Dependency ratio	.042	Its dependency ration >1.5 – a person of labour force who solely has to care for more than 1 dependant has a relatively high work load
		Education	.042	its HH head has no primary education – lack of education decreases the ability to understand, accept, and properly utilize new technologies and innovations (Asfaw & Admassie, 2004)
	Resources & energy	Agricultural land	.028	less than .07 ha per person – this is the absolute minimum of arable land to support one person (Myers, 1999)
		Electricity	.028	the primary source of lighting is not electricity – lack of electricity has negative implications on the health, education, communication, use of technologies, and income (Kanagawa & Nakata, 2008)
		Cooking fuel	.028	the primary source of cooking are solid cooking fuels – the use of solid cooking fuels has serious implications on the health and the economic development of households and causes serious environmental damage in the form of deforestation and degradation (IEA, 2006)
	Livelihood strategies	Non-agricultural livelihood diversity	.042	No. of secondary or tertiary livelihood strategies <1 – there is no non-agricultural livelihood strategies on which to fall back on if primary livelihoods are affected; broader livelihood portfolio spreads risk
		Agricultural livelihood diversity	.042	No. of primary livelihood strategies <2 or No. of crops <4 – there is no other primary sector strategy on which to fall back on if one primary livelihood is affected; monocropping increases the risk of yield loss from extreme weather events and changes in temperature and precipitation (Abramovitz et al., 2001); broader livelihood portfolio spreads risk decreases vulnerability
	Social networks	Access to loans	.042	it is difficult to borrow money – proxy for inadequate potential social support in times of stress with money being an easily convertible resource; linked to social inclusion (Sen, 2000) and wellbeing (Grootaert & van Bastelaer, 2001; OECD, 2001; UNESCO, 2002)
		Political voice	.042	it is difficult to influence decisions on community level – proxy for inadequate social inclusion that reflects the possibility of communicating and influencing one's own situation; linked to social inclusion (Sen, 2000) and wellbeing (Grootaert & van Bastelaer, 2001; OECD, 2001; UNESCO, 2002)
	Physical accessibility	Market	.042	it takes > 2 hours one way to reach the next market centre – a round-trip within one day is becomes difficult and travel time impacts adversely on other HH activities; reflects feasibility of basic coping strategy "exchange" to promote specialization and increase revenue flows (Agrawal & Perrin, 2009) and is linked to wellbeing (Ali & Pernia, 2003; Gerlitz, Hunzai, & Hoermann, 2012)
		Bus stop	.042	it takes > 2 hours one way to reach the next bus stop – a round-trip within one day is difficult and travel time impacts adversely on other HH activities; reflects feasibility of basic coping strategy "mobility" to pool or avoid risks across space (Agrawal & Perrin, 2009) and is linked to wellbeing (Ali & Pernia, 2003; Gerlitz et al., 2012)

(*Continued*)

Table 1. Continued.

Dimension	Component	Indicator	Weight	Vulnerability cut-offs (HH is vulnerable if …)/justification
Sensitivity	Wellbeing	Consumption	.042	the total per head consumption <70% of average national (rural /urban) total per head consumption (without rent) – relative poverty line that also includes households who are at risk to become poor if affected by change
		Indebtedness	.042	it is moderately in debt – an already relatively tense financial situation that might become critical if affected by change
	Health & sanitation	Illness	.028	at least once a month a member is seriously ill, i.e. not able to work – sensitivity to health issues related to climatic environmental events is higher for those people already affected by pre-existing illnesses (Hales, Edwards, & Kovats, 2003)
		Sanitation	.028	has no improved toilet facility (WHO definition), i.e. no facility at all or an open pit – has negative impact on health status of household and community (WHO and UNICEF, 2006) and increases sensitivity to water-related diseases because of inadequate sanitation (Hales et al., 2003)
		Drinking water	.028	has no access to improved source of drinking water (WHO definition), perceived water quality is poor, or cannot be collected within 30 min – has negative impact on health status of household and community (WHO and UNICEF, 2006) and increases sensitivity to water-related diseases because of inadequate drinking water supply (Hales et al., 2003)
	Food security	Food self-sufficiency	.042	it is not food self-sufficient or if No. of months HH had sufficient food < 12 – HH that are already unable to maintain food security are the ones who are most sensitive to environmental and climatic changes (Maxwell & Smith, 1992)
		Diet diversity	.042	it has consumed < 4 food categories (at least 1.25 U$ 2011 PPP per food category per head per month) – malnutrition if diet does not cover at least 4 food categories
	Water security	Water sufficiency	.042	No. of months HH had sufficient water for HH needs < 12 or No. of months HH had sufficient water for agriculture < 12 HH that are already facing water shortages are more sensitive to changes in temperatures and precipitation
		Water conflicts	.042	there are sometimes water conflicts within the community or between communities – scarcity of water brings with it the risk of human conflict, a risk that will increase with climate change (Barnett & Adger, 2007)
	Environmental stability	Slope	.028	the majority of its land is sloping – sensitivity for soil erosion and landslides (Jodha, 2001)
		Soil	.028	majority of the soil stony-gravy, sandy, or wet – less productive soil adversely influences the variety of crops that can be planted, the yield, and the erodibility of land and is more sensitive to adverse climate conditions (O'Brien et al., 2004)
		Dwelling	.028	the wall material is grass, leaves, bamboo, plastic, metal, or asbestos, or if roof material is straw, leaves, thatch, bamboo, plastic, or fabric, or house can only withstand extreme weather events with significant damage – linked to human right of adequate dwelling, i.e. a permanent structure that provide shelter from weather and climate (HREA, 2012)
Exposure	Environmental shocks	Environmental shocks	.083	during last 12 months at least one highly severe environmental shock experienced or if combined environmental damage > 25% of total yearly per head consumption – HH is already to a high extent adversely affected by environmental and climatic events
	Socio-economic shocks	Socio-economic shocks	.083	during last 12 months at least one highly severe socio-economic shock experienced or if combined socio-economic damage > 25% of total yearly per head consumption – HH is already to a high extent adversely affected by socio-economic events

which are based on the "cost of basic needs" approach (Morduch, 2006; Ravallion, 1994).

2.3. Methodological outline

The MLVI was constructed using the AF method (Alkire & Foster, 2011), the groundbreaking approach that was used to develop the Multidimensional Poverty Index (MPI, Alkire & Santos, 2010), a global measure for human development that has replaced the Human Poverty Index (HPI). While the LVI and other vulnerability and poverty measures are "multidimensional" in the sense that they are based on several underlying indicators or components, "multidimensional" in the context of the AF method signifies a certain process of identification and aggregation and the facility of decomposition: The MLVI identifies vulnerable households by counting vulnerabilities across dimensions (identification), answers the question how vulnerable a given population is (aggregation), and – its main advantage – is able to describe in which way people are vulnerable (decomposition). While single figures (index values, indicators like the GDP etc.) might give an idea about the level of vulnerability, decomposition actually allows to describe manifestations of vulnerability in an illustrative way and thus directly suggests components to focus interventions. The decomposition feature is one of the main reasons that the AF method has become popular, which is reflected in a growing number of multidimensional indices for measuring abstract concepts like poverty, happiness (Ura et al., 2012), and resilience (Hughes, 2013).

First, in a dual identification process, the multidimensionally vulnerable households are identified by (a) *determining a cut-off point for each vulnerability indicator* and then, (b) *deciding on the number of indicators* in which the household has to be vulnerable in order to be considered multidimensionally vulnerable. In the next step, the information on the multidimensionally vulnerable households is aggregated by *censoring the data on the non-vulnerable* and calculating the vulnerability *headcount*, *vulnerability intensity*, and the actual *vulnerability index*. A vital step in the aggregation of the 25 vulnerability indicators is the assigning of weights to individual indicators, and it is this weighting process that represents the transformation of the framework into an actual measure.

The definition of weights and cut-off points was obtained by literature review, data analysis, various bilateral and multilateral discussions with regional and international experts, and a technical workshop held at ICIMOD. Table 1 presents the results of all the analysis, discussions, and consultations: the main dimensions, components, indicators, weights, and vulnerability cut-offs of the MLVI. Regarding the weighting of indicators and dimensions, the MLVI has replicated the weighting approach of the global MPI (see Alkire & Santos, 2010, p. 16), giving equal weights to all components and equal weights to all indicators within a certain component since this is more comprehensible and easier to interpret for statistical laymen. This decision was supported by expert ratings that showed that all indicators and components were perceived as almost equally important. Overall, equal weights for all components meant that the dimensions *sensitivity* and *adaptive capacity* (each 41.6%) were much higher rated than the dimension *exposure* (16.6%). This is justifiable for an index that focuses on the system "household" and aims to address policy makers and development planners: The "internal" characteristics are sensitive to policy change and indicate how well a household will be able to cope with "external" features (hazards), which are very difficult to influence. Regarding the aggregated vulnerability cut-off it was again decided to follow the approach of the MPI and choose an aggregated vulnerability cut-off of 33% (see Alkire & Santos, 2013, p. 19f): A household is multidimensionally vulnerable to change if it is vulnerable in regard to 33% or more of the weighted indicators. This equals vulnerabilities in regard to at least 6 out of 25 indicators or 4 out of 12 components.

3. Methodology

3.1. Index calculation

The MLVI framework presented above provided the basis for the calculation of the actual vulnerability measure following the AF method. Based on the cut-offs for each vulnerability indicator, it was determined in which regard a household was vulnerable to change; that is the first stage of the two-staged counting approach. The second stage consists of adding up the number of vulnerabilities each household faces. Based on the predefined weights and the second cut-off point – the aggregated vulnerability cut-off – it was then determined if a household is considered to be multidimensionally vulnerable to change. To aggregate the information and construct the index the focus was solely on the multidimensionally vulnerable households. Data on the non-vulnerable households were censored, that is, vulnerabilities of those households were ignored during further analysis (compare raw and censored vulnerability headcounts in Tables A2 and A3 in the appendix). Now, the multidimensional vulnerability *headcount* (H; the proportion of vulnerable people in the population) and *intensity* (A; the average vulnerability share among the vulnerable people) could be calculated. The MLVI – the actual vulnerability index – is the product of the vulnerability headcount and the vulnerability intensity (MLVI = H × A) and ranges from "0" (nobody is vulnerable in regard to any indicator) to "1" (everyone is vulnerable in regard to all indicators). The index decomposition is presented in the form of the absolute and relative contribution of components to the index value and in the form of censored vulnerability headcounts, that is, the part of population that is multidimensionally vulnerable and vulnerable in regard to a specific vulnerability indicator. The results on the MLVI presented in the following are findings weighted with population weights, that is, the inverse selection probability of a household multiplied with its household size.

3.2. Data

The MLVI was computed using data collected by the VACA survey 2011/2012. The VACA survey is a standardized quantitative household survey on livelihood vulnerability to environmental and socio-economic change that was carried out in the selected districts of three sub-basins in the HKH region. The selection of districts within the sub-basins was based on the following seven criteria: (1) a substantial proportion of land that can be characterized as hilly or mountainous (some plain and foothill districts were selected as a control group), (2) prior environmental hazards such as floods, flash floods, or droughts, (3) representativity in terms of ecological, ethnic, livelihoods, and socio-economic aspects, (4) expected vulnerability to future climate change impacts, (5) being part of the HICAP feasibility study (2009–2010), (6) availability of operational partners to conduct the VACA survey, and (7) the security situation and accessibility. The dataset contains information on 6098 households: 2648 households from the Eastern Brahmaputra sub-basin in |||India, 2311 households from the Koshi sub-basin in Nepal, and 1139 households from the Upper Indus sub-basin in Pakistan. The data are representative at the district level and were collected in a three-stage random sampling stratified by urban and rural areas. The VACA questionnaire covers the thematic areas of household consumption, food security, water security, health and healthcare, access to basic facilities, accessibility, housing, education, assets, gender inequality, and exposure and resilience to shocks and medium-term climatic and environmental changes, representing the 12 components of vulnerability described in Table 1.

4. Findings

The following section presents the findings on multidimensional livelihood vulnerability in the 16 surveyed districts of the three sub-basins. While the MLVI index value and its constituent parts (vulnerability headcount and intensity) are shown, special focus will be put on the special feature of multidimensional measures developed following the AF method that makes them useful for the targeting: the decomposition which allows the user to see which components and indicators are the dominant determinants of livelihood vulnerability and thus supports the development of interventions to improve people's situation with respect to those characteristics. First, the MLVI and decompositions by dimensions and components for the 16 districts are presented. Then, the decomposition by single vulnerability indicators in the form of censored vulnerability headcounts for one district is showcased to demonstrate how district-level findings can help to identify areas of intervention and assist to fine-tune policies and development programmes to mitigate vulnerability to change.

4.1. MLVI – findings for all 16 districts

Figure 1 presents the MLVI index value, the vulnerability headcount, and the vulnerability intensity for the 16 districts of the three sub-basins, sorted in descending order by the index value for each sub-basin. Among the 16 surveyed districts, the district Khotang of the Koshi sub-basin showed the highest multidimensional livelihood vulnerability: here, 96% of the population were multidimensionally vulnerable to change and on average vulnerable in regard to 52% of the 25 vulnerability indicators, resulting in an index value of .50. In the Eastern Brahmaputra sub-basin, Lakhimpur was the most vulnerable among the seven surveyed districts with an index value of .46, a headcount of 92%, and an intensity of 50%, while in the Upper Indus sub-basin, Chitral showed the highest livelihood vulnerability among the three surveyed districts with an index value of .28, a headcount of 65%, and an intensity of 42%. It becomes apparent that the overall level of livelihood vulnerability was considerably lower in the districts of the Upper Indus sub-basin than in those of the Koshi sub-basin and the Eastern Brahmaputra sub-basin, with the exception of East Siang and Lower Dibang.

Figure 2 shows the decomposition of MLVI index value of the 16 surveyed districts in the form of the absolute and relative contributions of the main vulnerability dimensions' adaptive capacity, sensitivity, and exposure. While the districts Lohit and Udayapur showed the highest absolute contribution of lack of adaptive capacity to livelihood vulnerability (.17 and .16 respectively), in Chitral this dimension made up 50% of the MLVI and thus was the main contributor in relative terms. Likewise, the highest absolute contribution of sensitivity could be observed in Khotang and Lakhimpur (each .20), with Lakhimpur also showing the highest relative impact of sensitivity with 43%. Regarding the dimension exposure, the highest absolute contribution was found in Khotang (.15) and the highest relative contribution in Hunza-Nagar (38%).

In Figure 3, the relative contribution of the 12 components for the 16 surveyed districts is presented. In all districts, vulnerabilities related to a high exposure to environmental and socio-economic shocks were the most influential ones with values that range from 12% to 20% (with the exception of environmental shocks in Siraha and socio-economic shocks in Gilgit). This reconfirms the relevance of the study and indicates the strong need for relief measures throughout the districts. Regarding the

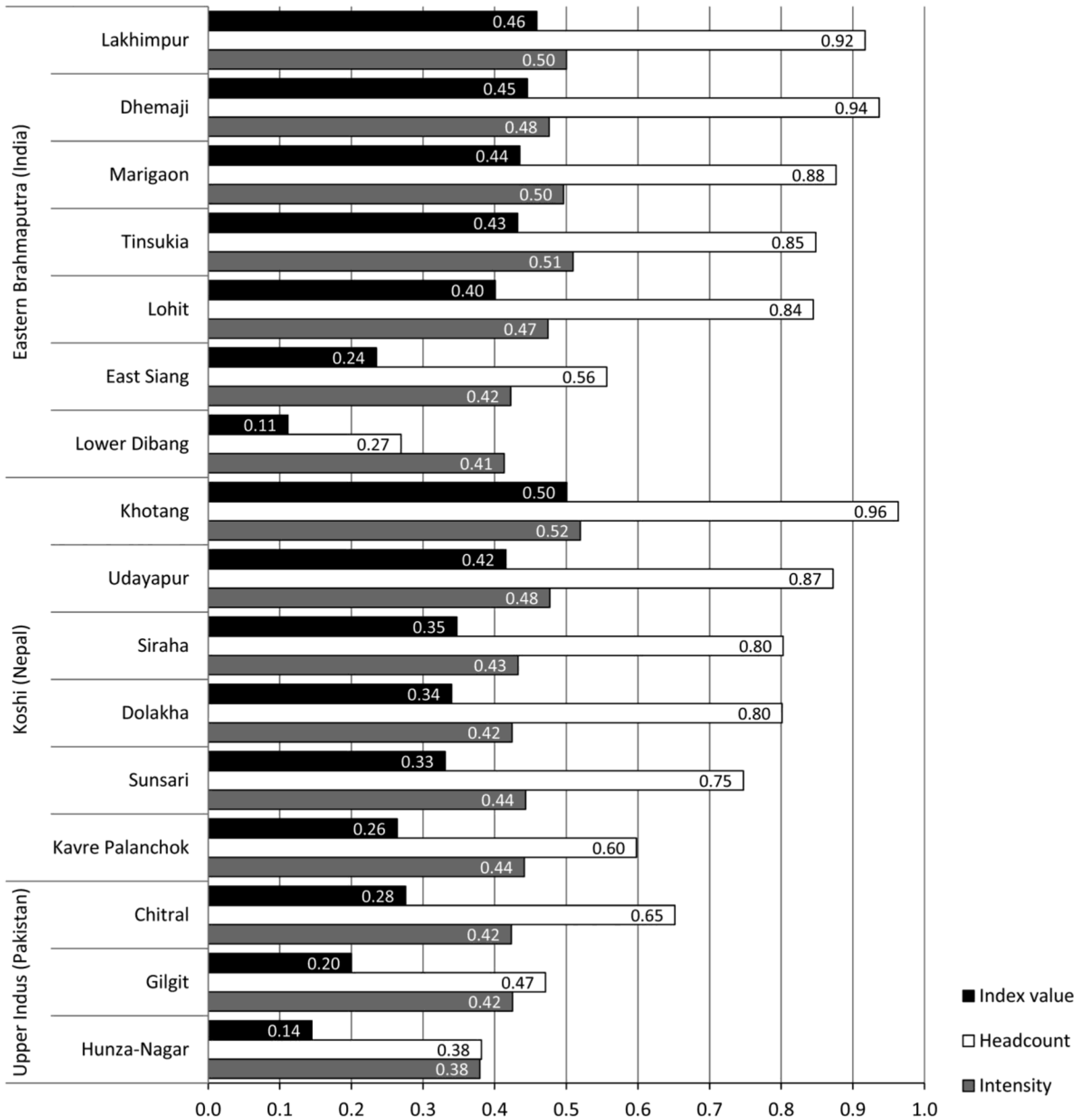


Figure 1. MLVI index value, headcount, and intensity by district. N = 5918 HH; own analysis, weighted; Data: VACA 2011/12.

other components, a lot of variation could be observed: in Hunza-Nagar for example vulnerabilities related to resources and energy had a relatively strong impact (13%), whereas in Sunsari and Chitral inadequate livelihood strategies (12%), and in Lakhimpur insufficient food security (11%) were quite influential.

While the MLVI index value, headcount, and intensity help to identify the most vulnerable locations, the decomposition in the form of the absolute and relative contributions can be very useful to determine areas of intervention. To reduce livelihood vulnerability to change in Chitral, one might concentrate first and foremost on measures that improve the adaptive capacity of the population (50% relative contribution to the MLVI), with a special focus on the improvement of resources and energy (12%), livelihood strategies (12%), and social networks (11%) that have a combined impact of 35%.

4.2. MLVI – livelihood vulnerability profile of Khotang

Figure 4 showcases the decomposition of the MLVI by the 25 vulnerability indicators in the form of censored vulnerability headcounts for Khotang, a rural, mountainous district located in the Koshi sub-basin of Nepal that showed the highest multidimensional livelihood vulnerability to change among the 16 surveyed districts. Censored vulnerability headcounts represent the proportion of the

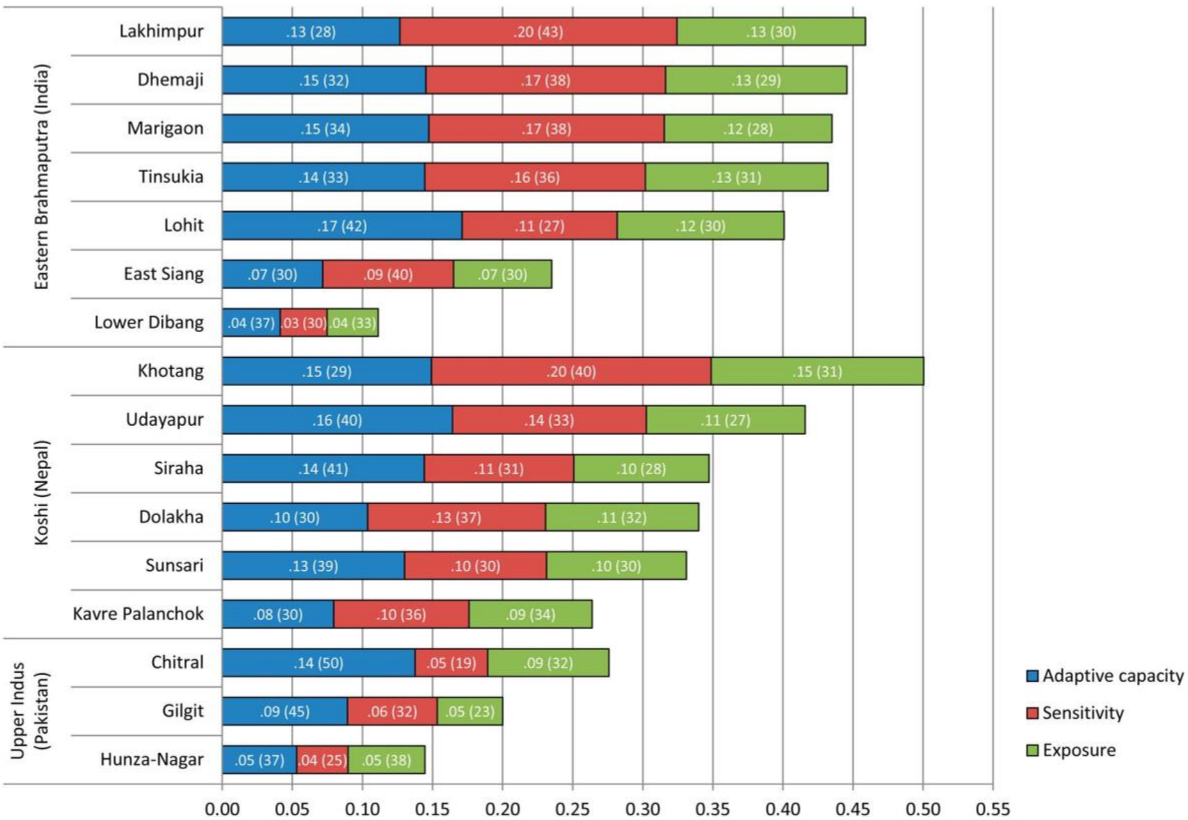


Figure 2. MLVI – Absolute and relative contribution of vulnerability dimensions by district. $N = 5918$ HH; own analysis, weighted, absolute contribution values without brackets, relative contribution in % in brackets; Data: VACA 2011/12.

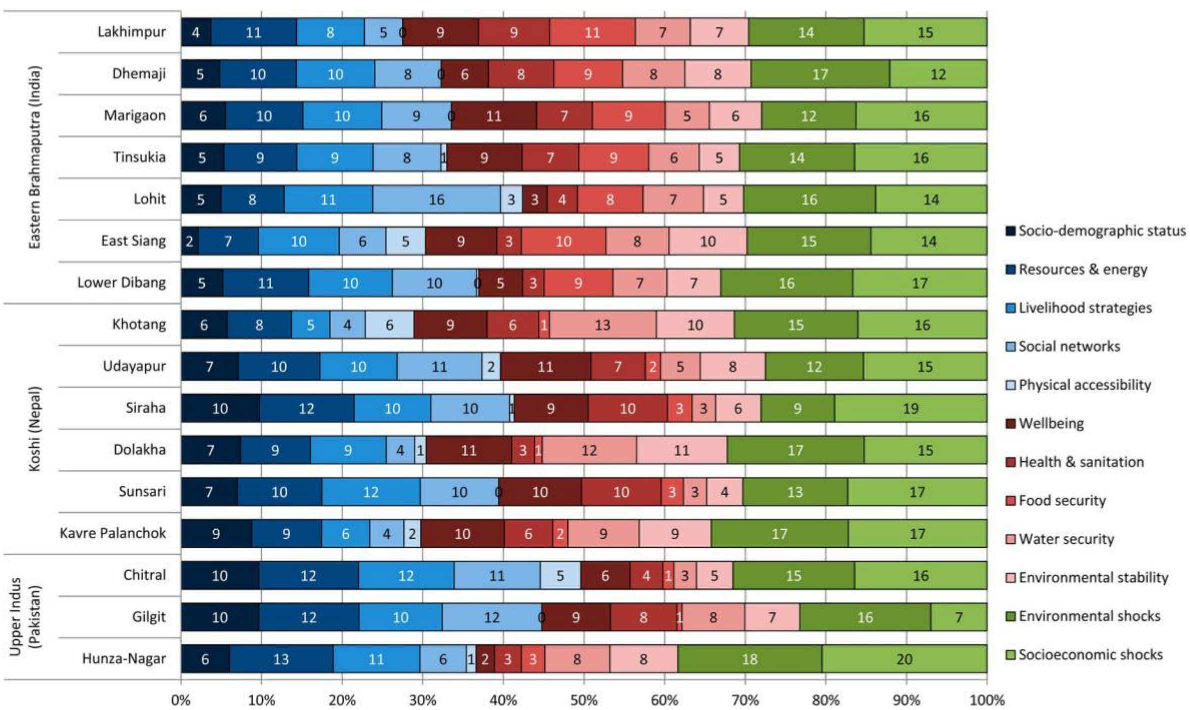


Figure 3. MLVI – Relative contribution of vulnerability components by district in %. $N = 5918$ HH; own analysis, weighted; Data: VACA 2011/12.

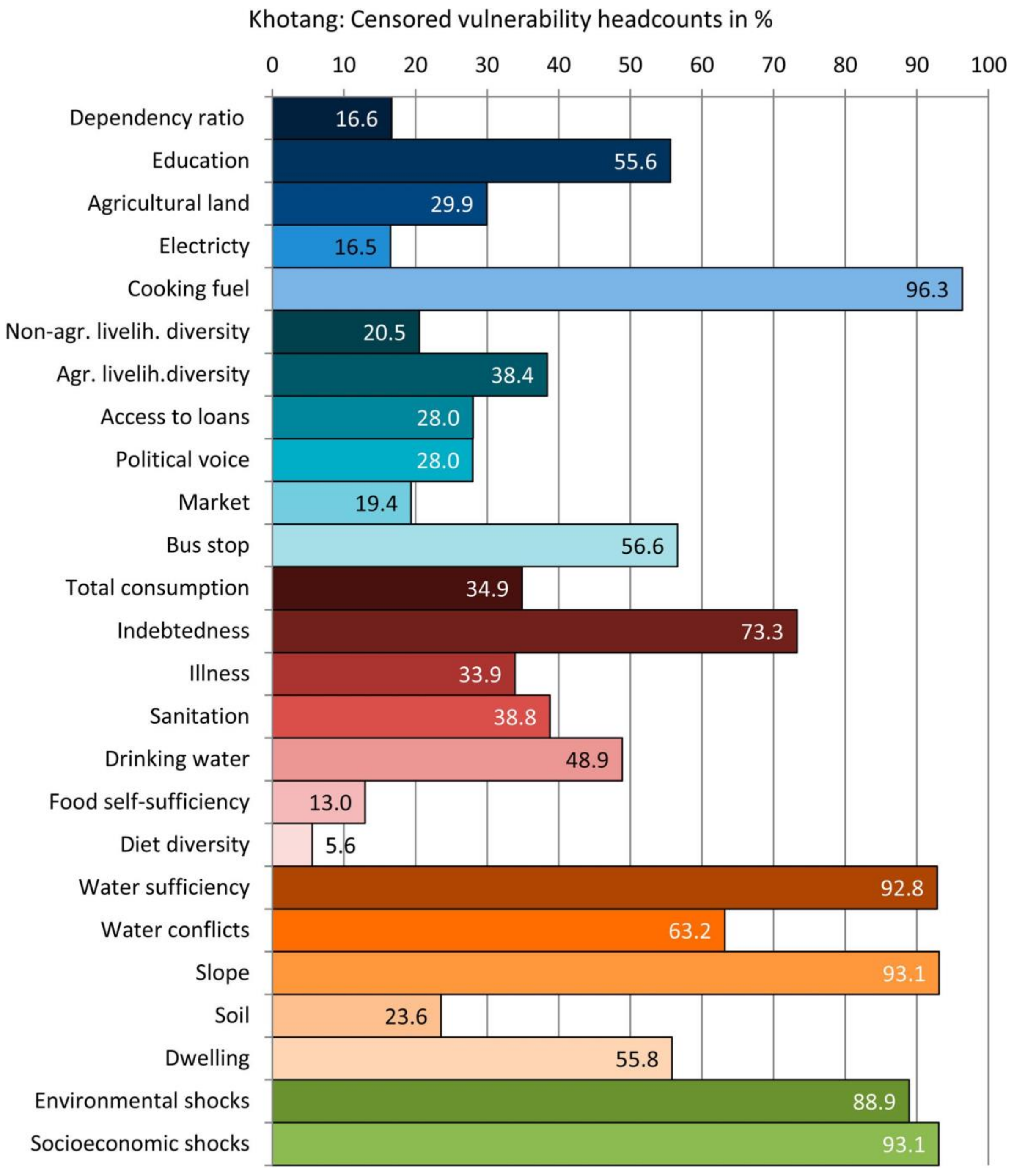


Figure 4. Khotang – Censored vulnerability headcounts of vulnerability indicators in %. *N* = 326 HH; own analysis, 100%, weighted; Data: VACA 2011/12.

population that is multidimensionally vulnerable and vulnerable in regard to a specific vulnerability indicator. 96% of the population of Khotang were multidimensionally vulnerable and vulnerable in regard to the lack of improved cooking fuels. Likewise, 93% of the population were multidimensionally vulnerable and showed vulnerabilities caused by water insufficiency and slope of agricultural land, and the majority of the population were vulnerable and were highly affected by environmental (90%) and socio-economic (93%) shocks during the last 12 months. The findings suggest that measures that aim to reduce the livelihood vulnerability of Khotang's population should first and foremost focus on the relief of these issues.

Vulnerabilities related to indebtedness, water conflicts, physical accessibility to public transport, quality of dwelling, and education were of second-order importance: Here, the respective censored headcounts ranged from 56% to 73%, which indicates that the majority of Khotang's population was multidimensionally vulnerable and vulnerable in these regards. Compared to the already mentioned vulnerabilities, issues like inadequate sources of drinking water (49%), inadequate sanitation (39%), and insufficient agricultural livelihood diversity (38%) seemed to be of lower importance, although they still affected considerable proportions of the population.

The decomposition of the MLVI by single vulnerability indicators in the form of censored vulnerability headcounts shows the livelihood vulnerability status in absolute figures and allows one to be very specific in the recommendation of components to focus interventions. Censored vulnerability headcounts for the remaining 15 districts can be found in Table A3 in the appendix and can be interpreted in the same way.

5. Conclusion

People in the HKH face an increasing challenge in adapting to impacts of climate and environmental change. Surveys in specific areas of the region show that the vast majority of households already perceive change in climate and environment (Colom & Pradhan, 2013; Gambhir & Kumar, 2013; Gerlitz et al., 2015; Zaheer and Colom 2013), and according to climate predictions these changes are likely to intensify over time (Akhtar et al., 2008; Immerzeel et al., 2010; Tse-ring et al., 2010). Decision makers and development planners are mandated to address this challenge, but have limited empirical evidence-based information on where the vulnerability pockets are and, more importantly, on the dimensions along which people are vulnerable to change.

ICIMOD, in cooperation with regional and international partners, addressed this lack of knowledge and initiated extensive primary research in three sub-basins to identify the most vulnerable areas and to understand the composition of their livelihood vulnerability. The research reported here uses data collected in the Upper Indus sub-basin in Pakistan, the Eastern Brahmaputra sub-basin in India, and the Koshi sub-basin in Nepal to demonstrate a Multidimensional Livelihood Vulnerability Index (MLVI) that can be applied throughout the HKH. It is specifically designed to measure livelihood vulnerability to change in a region that is predominantly rural, mountainous, and stretches across several of the least developed countries.

In an increasing body of literature, the development of vulnerability indicators has been criticized, there has been confusion about what "measuring vulnerability" means and doubts on whether the concept can actually be measured (Hinkel, 2011). By applying the AF method of multidimensional index construction (Alkire & Foster, 2011) to the issue of vulnerability, the MLVI avoids being an over-simplistic and over-generalized representation of the concept. The MLVI allows us to examine livelihood vulnerability as a complex phenomenon that has many dimensions. The MLVI provides decision makers with a fuller picture of vulnerability that supports the identification of areas and groups that can be targeted by measures aimed at enhancing adaptive capacity and reducing sensitivity, for example through standard development assistance, government adaptation, disaster risk reduction (DRR) initiatives etc.

With the intention of assisting local governments, development agencies, and NGOs to use funds in ways that will address the most pressing local problems, we have analysed 16 surveyed districts of the three sub-basins in terms of multidimensional livelihood vulnerability and also explored differences in the prominence of various dimensions of vulnerability across these districts. The MLVI shows how the contribution of 12 dimensions and 25 indicators of livelihood vulnerability such as physical accessibility to markets, water sufficiency, and slope of agricultural land varies in different locations. The measure allows to describe the specific multidimensional profile of livelihood vulnerability in a particular district and thus illustrates the importance of location-specific data in the development of effective relief measures. Blanket approaches for entire countries or regions might ignore crucial local manifestations of livelihood vulnerability and thus may not be very effective.

Multidimensional poverty and vulnerability measures are based on normative decisions, and findings are influenced to a great extent by these decisions. There is always the possibility that the reader might wish to add components or indicators, or disagree with some of the existing ones. Accordingly, there is always a scope for refinements and adjustments. The research framework of the MLVI is the result of a process of consultations and discussions that took place over a period of three years. In the end, the concept represents a compromise between a variety of ideas and opinions, the objective of the study, and data availability. In this regard, the MLVI is the first prototype of a multidimensional livelihood vulnerability measure for the HKH.

Acknowledgments

This study is a part of the Himalayan Climate Change Adaptation Programme (HICAP). HICAP is implemented jointly by ICIMOD, CICERO, and UNEP/Grid-Arendal in collaboration with local partners and is funded by the Ministry of Foreign Affairs, Norway and Swedish International Development Agency (Sida). The authors express their gratitude to the colleagues of ICIMOD, CICERO, and UNEP for their guidance and comments. Particular appreciation goes to Petra Tschakert, Michael Kollmair, Valdemar Holmgren, Yukta Kumar, Riccardo Pravettoni, and Sabarnee Tuladhar. Particular appreciation also goes to the partner organizations of ICIMOD that supported the implementation and refinement of this survey instrument and the development of the index: the Aga Khan Rural Support Programme (AKRSP), Pakistan; Aaranyak, India; the Nepal Development and Research Institute (NDRI), Nepal; and the Koshi Victims' Society (KVS), Nepal.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Abramovitz, J., Banuri, T., Girot, P. O., Orlando, B., Schneider, N., Spanger-Siegfried, E., … Hammill, A. (2001). *Adapting to climate change: Natural resource management and vulnerability reduction. Background Paper to the Task Force on Climate Change, Adaptation and Vulnerable Communities*. IUCN/Worldwatch Institute/IISD/SEI-B, Gland, Switzerland/Washington, DC, USA/Geneva, Switzerland/Stockholm, Sweden/Boston, USA. Retrieved April 23, 2013, from http://www.iisd.org/pdf/2002/envsec_cc_bkgd_paper.pdf

Adger, W. N. (2006). Vulnerability. *Global Environmental Change*, *16*(3), 268–281.

Agrawal, A. & Perrin, N. (2009). Climate adaptation, local institutions and rural livelihoods. In W. N. Adger, I. Lorenzoni, & K. L. O'Brien (Eds.), *Adapting to climate change* (pp. 350–367). Cambridge: Cambridge University Press.

Akhtar, M., Ahmad, N., & Booij, M. J. (2008). The impact of climate change on the water resources of Hindukush–Karakorum–Himalaya region under different glacier coverage scenarios. *Journal of Hydrology*, *355*, 148–163.

Ali, I. & Pernia, E. M. (2003). *Infrastructure and poverty reduction. What is the connection*? ERD Policy Brief Series No.13. Asian Development Bank, Manila, Philippines.

Alkire, S. & Foster, J. (2011). Counting and multidimensional poverty measurement. *Journal of Public Economics*, *95*(7), 476–487.

Alkire, S. & Santos, M. E. (2010). *Acute multidimensional poverty: A new index for developing countries*. UNDP Human Development Research Paper 2010/11, New York, USA.

Alkire, S. & Santos, M. E. (2013). *Measuring acute poverty in the developing world: Robustness and scope of the multidimensional poverty index*. OPHI Working Paper No. 59, Oxford, UK.

Allison, E. H., Perry, A. L., Badjeck, M. C., Adger, W. N., Brown, K., Conway, D., … Dulvy, N. K. (2009). Vulnerability of national economies to the impact of climate change on fisheries. *Fish and Fisheries*. doi:10.1111/j.1467-2979.2008.00310.x

Asfaw, A. & Admassie, A. (2004). The role of education on the adoption of chemical fertiliser under different socioeconomic environments in Ethiopia. *Agricultural Economics*, *30*, 215–228.

Barnett, J. & Adger, W. N. (2007). Climate change, human security and violent conflict. *Political Geography*, *26*, 639–655.

Brenkert, A. L., & Malone, E. L. (2005). Modeling vulnerability and resilience to climate change: A case study of India and Indian States. *Climatic Change*, *72*, 57–102.

Cannon, T., & Müller-Mahn, D. (2010). Vulnerability, resilience and development discourses in context of climate change. *Natural Hazards*, *55*, 621–635.

Chambers, R., & Conway, G. (1992). *Sustainable rural livelihoods: Practical concepts for the 21st century*. IDS Discussion Paper 296, Brighton, UK.

Colom, A. & Pradhan, S. (2013). *Nepal – How the people of Nepal live with climate change and what communication can do*. BBC Media Action, London, UK.

Diener, E., & Suh, E. (1997). Measuring quality of life: Economic, social, and subjective indicators. *Social Indicators Research*, *40*, 189–216.

Eakin, H., & Bojórquez-Tapia, L. A. (2008). Insights into the composition of household vulnerability from multicriteria decision analysis. *Global Environmental Change*, *18*, 112–127.

Gambhir, V., & Kumar, P. (2013). *India – How the people of India live with climate change and what communication can do.* BBC Media Action, London, UK.

Gerlitz, J.-Y., Banerjee, S., Brooks, N., Hunzai, K., & Macchi, M. (2015). Vulnerability and adaptive capacity assessment: An approach to measure vulnerability and adaptation to climate change. In W. Leal Filho (Ed.), *Handbook of climate change adaptation* (pp. 151–176). Berlin/Heidelberg: Springer

Gerlitz, J-Y., Banerjee, S., Hoermann, B., Hunzai, K., Macchi, M., & Tuladhar, S. (2014). *Poverty and Vulnerability Assessment (PVA): A survey instrument for the Hindu Kush Himalayas.* ICIMOD, Kathmandu, Nepal.

Gerlitz, J.-Y., Hunzai, K., & Hoermann, B. (2012). Mountain poverty in the Hindu-Kush Himalayas. *Canadian Journal of Development Studies*, *33*, 250–265.

Grootaert, C., & van Bastelaer, T. (2001). *Understanding and measuring social capital: A synthesis of findings and recommendations from the social capital initiative*. Social Capital Initiative Working Paper No. 24. The World Bank, Washington/DC, USA.

Hahn, M. B., Riederer, A. M., & Foster, S. O. (2009). The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change. *Global Environmental Change*, *19*, 74–88.

Hales, S., Edwards, S. J., & Kovats, R. S. (2003). Impacts on health of climate extremes. In A- J. McMicheal, D. H. Campell-Lendrum, C. F. Corvalán, K. L. Ebi, A. K. Githeko, J. D. Scheraga, & A. Woodward (Eds.), *Climate change and human health – Risks and responses* (pp. 79–102). Geneva: WHO.

Hinkel, J. (2011). Indicators of vulnerability and adaptive capacity: Towards a clarification of the science-policy interface. *Global Environmental Change*, *21*, 198–208.

Hoermann, B., Banerjee, S., & Kollmair, M. (2010). *Labour migration for development in the Western Hindu Kush-Himalayas: Understanding a livelihood strategy in the context of socioeconomic and environmental change*. Kathmandu: ICIMOD.

HREA. (2012). *The right to housing – Study guide*. Amsterdam: Human Rights Education Associates. Retrieved February 23, 2012, from http://www.hrea.org/index.php?doc_id=411

Hughes, K. (2013). *A multidimensional approach for measuring resilience*. Oxfam GB Working Paper, Oxford, GB.

IEA. (2006). *World energy outlook 2006*. Paris: OECD/IEA.

Immerzeel, W. W., van Beek, L. P. H., & Bierkens, M. F. P. (2010). Climate change will affect the Asian water towers. *Science*, *328*(5984), 1382–1385.

IPCC. (2001). *Climate change 2001: Impacts, adaptation and vulnerability. Working Group II contribution to the intergovernmental panel on climate change third assessment report*. Cambridge: Cambridge University Press.

IPCC. (2007). *Climate change 2007: Impacts, adaptation and vulnerability. Working Group II contribution to the intergovernmental panel on climate change fourth assessment report*. Cambridge: Cambridge University Press.

IPCC. (2012). *Managing the risks of extreme events and disasters to advance climate change adaptation. Special report of the intergovernmental panel on climate change*. Cambridge: Cambridge University Press.

Jodha, N. S. (1992). Mountain perspective and sustainability: A framework for development strategies. In N. S. Jodha, M.

Banskota, & T. Partap (Eds.), *Sustainable mountain agriculture, Volume 1: Perspectives and issues* (pp. 41–82). New Delhi: Oxford and IBH.

Jodha, N. S. (1997). Mountain agriculture. In B. Messerli & J. D. Ives (Eds.), *Mountains of the World: A global priority* (pp. 313–335). New York: The Parthenon.

Jodha, N. S. (2001). Global change and environmental risks in mountain ecosystems. In J. X. Kasperson & R. Kasperson (Eds.), *Global environmental risks* (pp. 306–342). Tokyo: Earth Scan, United Nations University and London.

Kanagawa, M., & Nakata, T. (2008). Assessment of access to electricity and the socio-economic impacts in rural areas of developing countries. *Energy Policy, 36*, 2016–2029.

Kollmair, M., & Hoermann, B. (2011). *Labour migration in the Himalayas: Opportunities and challenges*. Labour Migration - Opportunities and challenges for mountain livelihoods. Sustainable Mountain Development No. 59, Summer 2011, ICIMOD, Kathmandu, Nepal. 3–8.

Körner, C. & Ohsawa, M. et al. (2005). Mountain systems. In R. Hassan, R. Scholes & N. Ash (Eds.), *Ecosystems and human well-being. Current state and trends: Findings of the condition and trends working group. Millennium ecosystem assessment* (Vol. 1, pp. 681–716). Washington/DC: Island Press.

Lemke, P., Ren, J., Alley, R. B., Allison, I., Carrasco, J., Flato, G., … Zhang, T. (2007). Observations: Changes in snow, ice and frozen ground. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, & H.L. Miller (Eds.), *Climate change 2007: The physical science basis. contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change* (pp. 337–383). Cambridge: Cambridge University Press.

Malone, E. L., & Brenkert, A. L. (2008). Uncertainty in resilience to climate change in India and Indian states. *Climatic Change*, *91*, 451–476.

Maxwell, S. & Smith, M. (1992). Household food security: A conceptual review. In S. Maxwell & T. Frankenberger (Eds.), *Household food security: Concepts, indicators, and measurements* (pp. 1–71). Rome: UNICEF and IFAD.

Miller, F., Osbahr, H., Boyd, E., Thomalla, F., Bharwani, S., Ziervogel, G., … Nelson, D. (2010). Resilience and vulnerability: Complementary or conflicting concepts? *Ecology and Society*, *15*(3), 11. Retrieved March 03, 2013, from http://www.ecologyandsociety.org/vol15/iss3/art11/ES-2010-3378.pdf

Morduch, J. (2006). Concepts of poverty. In *Handbook on poverty statistics: Concepts, methods and policy use* (pp. 23–50). United Nations: United Nations Statistics Division. Retrieved 17 July, 2011, from http://unstats.un.org/unsd/methods/poverty/pdf/UN_Book%20FINAL%2030%20Dec%2005.pdf

Myers, N. (1999). The next green revolution: Its environmental underpinnings. *Current Science, 76*, 507–513.

Nogues-Bravo, D., Araujo, M. B., Erra, M. P., & Martinez-Rica, J. P. (2007). Exposure of global mountain systems to climate warming during the 21st Century. *Global Environmental Change*, *17*, 420–428.

Notenbaert, A., Nganga Karanja, S., Herrero, M., Felisberto, M., & Moyo, S. (2012). Derivation of a household-level vulnerability index for empirically testing measures of adaptive capacity and vulnerability. *Regional Environmental Change*. doi:10.1007/s10113-012-0368-4

O'Brien, K., Leichenko, R., Kelkar, U., Venema, H., Aandahl, G., Tompkins, H., … West, J. (2004). Mapping vulnerability to multiple stressors: Climate change and globalization in India. *Global Environmental Change*, *14*, 303–313.

OECD. (2001). *The well-being of nations. The role of human and social capital*. Paris: OECD.

Pandey, R., & Jha, S. K. (2011). Climate vulnerability index – measure of climate change vulnerability to communities: A case of rural Lower Himalaya, India. *Mitigation and Adaption Strategies for Global Change*. doi:10.1007/s11027-011-9338-2

Ravallion, M. (1994). *Poverty comparisons*. Chur: Harwood Academic.

Royal Government of Bhutan. 2007. *Poverty Analysis Report 2007*. National Statistics Bureau, Thimphu, Bhutan.

Scoones, I. (1998). *Sustainable rural livelihoods: A framework for analysis*. IDS Working Paper 72, Brighton, UK.

Sen, A. (2000). *Social exclusion: Concept, application, and scrutiny*. Social Development Papers No. 1. Asian Development Bank, Manila, Philippines.

Sonwa, D. J., Somorin, O. A., Jum, C., Bele, M. Y., & Nkem, J. N. (2012). Vulnerability, forest-related sectors and climate change adaptation: The case of Cameroon. *Forest Policy and Economics*, *23*, 1–9.

Tse-ring, K., Sharma, E., Chettri, N., & Shrestha, A. (2010). *Climate change vulnerability of mountain ecosystems in the Eastern Himalayas: Climate change impact and vulnerability in the Eastern Himalayas – Synthesis Report*. Kathmandu: ICIMOD.

UNESCO. (2002). *Social capital and poverty reduction*. Paris: UNESCO.

Ura, K., Alkire, S., Zangmo, T. & Wangdi, K. (2012). *A short guide to gross national happiness index*. Timphu: The Centre for Bhutan Studies.

WHO and UNICEF. (2006). *Meeting the MDG drinking and sanitation target: The urban and rural challenge of the decade*. Geneva: WHO.

Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2004). *At risk: Natural hazards, people's vulnerability and disasters*. London: Routledge.

Yao, T., Thompson, L., Yang, W., Yu, W., Gao, Y., Guo, X., … Joswiak, D. (2012). Different glacier status with atmospheric circulations in Tibetan Plateau and surroundings. *Nature Climate Change*. doi:10.1038/NCLIMATE1580

Yohe, G., Malone, E., Brenkert, A., Schlesinger, M., Meij, H., Xing, X. & Lee, D. (2006a). *A synthetic assessment of the global distribution of vulnerability to climate change from the IPCC perspective that reflects exposure and adaptive capacity*. New York: CIESIN, Columbia University.

Yohe, G., Malone, E., Brenkert, A., Schlesinger, M., Meij, H., & Xing, X. (2006b). Global distributions of vulnerability to climate change. *Integrated Assessment Journal*, *6*, 35–44.

Zaheer, K. & Colom, A. (2013). *Pakistan – How the people of India live with climate change and what communication can do*. London: BBC Media Action.

138 *J.-Y. Gerlitz* et al.

Appendix

Table A1. Tetrachoric correlations of MLVI vulnerability indicators.

	DR	ED	AL	E	CF	NALD	ALD	ATL	PV	M	BS	TC	ID	I	SA	DW	FSS	DD	WS	WC	SL	S	D	ES	SS
Dependency ratio (DR)	1.00																								
Education (ED)	0.05	1.00																							
Agricultural land (AL)	0.16*	0.12*	1.00																						
Electricity (E)	0.06	0.11*	−0.05	1.00																					
Cooking fuel (CF)	0.23*	0.42*	−0.12*	0.35*	1.00																				
Non-agr. livelih. Diversity (NALD)	0.01	0.05*	−0.17*	0.23*	0.27*	1.00																			
Agr. livelih.diversity (ALD)	0.04	0.07*	0.47*	−0.01	−0.17*	−0.27*	1.00																		
Access to loans (ATL)	0.01	0.06*	0.08*	0.27*	−0.02	0.14*	0.17*	1.00																	
Political voice (PV)	0.05	0.23*	0.17*	0.11*	0.10*	0.09*	0.22*	0.44*	1.00																
Market (M)	0.09*	0.15*	−0.15*	−0.08*	0.40*	0.11*	−0.08*	−0.11*	0.02	1.00															
Bus stop (BS)	0.10*	0.13*	−0.17*	0.06	0.57*	0.17*	−0.24*	−0.08*	0.04	0.77*	1.00														
Total consumption (TC)	0.13*	0.09*	0.13*	0.16*	0.12*	0.14*	0.00	0.02	0.06*	0.01	0.05	1.00													
Indebtedness (ID)	0.06*	0.17*	0.11*	0.13*	0.09*	−0.11*	0.11*	−0.02	−0.02	0.00	0.14*	−0.06*	1.00												
Illness (I)	−0.01	0.14*	0.04	0.10*	0.02	0.04	0.06*	−0.02	−0.05*	−0.09*	−0.01	−0.11*	0.20*	1.00											
Sanitation (SA)	0.07*	0.27*	0.03	0.42*	0.55*	0.26*	0.08*	0.10*	0.19*	0.15*	0.22*	0.17*	0.25*	0.08*	1.00										
Drinking water (DW)	0.07*	0.11*	0.10*	0.26*	0.16*	−0.01	0.15*	0.10*	0.02	−0.20*	−0.05	−0.05*	0.36*	0.17*	0.25*	1.00									
Food self-sufficiency (FSS)	−0.06*	−0.12*	−0.04	0.43*	−0.24*	0.13*	0.22*	0.25*	0.04	−0.28*	−0.36*	0.10*	−0.06*	0.23*	0.05*	0.06*	1.00								
Diet diversity (DD)	0.09*	0.00	−0.09*	0.16*	0.26*	0.18*	−0.24*	0.07*	0.00	0.15*	0.21*	0.69*	−0.14*	−0.01	0.23*	−0.09*/0.18*	1.00								
Water sufficiency (WS)	−0.06*	−0.06*	−0.65*	0.28*	0.16*	0.12*	−0.35*	0.05*	−0.06*	0.27*	0.43*	0.10*	0.06*	0.09*	0.04	0.03	0.19*	0.29*	1.00						
Water conflict (WC)	0.06	0.15*	0.02	−0.08*	0.29*	−0.16*	−0.13*	−0.04	−0.01	0.16*	0.34*	−0.18*	0.26*	0.03	0.03	0.26*	−0.46*	−0.25*	0.08*	1.00					
Slope (SL)	0.07*	0.13*	−0.24*	−0.31*	0.33*	−0.06*	−0.29*	−0.36*	−0.18*	0.52*	0.54*	−0.11*	0.06*	−0.08*	−0.17*	−0.19*	−0.48*	−0.08*	0.28*	0.45*	1.00				
Soil (S)	0.03	0.11*	−0.24*	0.21*	0.16*	−0.05	−0.12*	0.08*	−0.14*	0.14*	0.12*	−0.07*	0.13*	−0.01	0.07*	0.03	−0.05	−0.08*	0.29*	0.10*	0.26*	1.00			
Dwelling (D)	0.04	0.11*	−0.07*	0.63*	0.28*	0.31*	−0.01	0.24*	0.09*	−0.01	0.15*	0.22*	0.09*	0.13*	0.49*	0.16*	0.39*	0.27*	0.25*	−0.11*	−0.26*	0.09*	1.00		
Environmental shocks (ES)	0.00	0.09*	−0.29*	0.18*	0.25*	0.06*	−0.17*	0.08*	−0.05*	0.15*	0.12*	0.07*	0.08*	0.04	0.04	0.09*	0.14*	0.06*	0.41*	0.07*	0.16*	0.22*	0.13*	1.00	
socio-economic shocks (SS)	−0.04	0.08*	0.02*	0.20*	0.03	0.03	0.07*	−0.04	0.12*	−0.01	0.10*	0.09*	0.30*	0.35*	0.22*	0.06*	0.19*	−0.08*/0.01		−0.01	−0.10*	−0.05	0.10*	−0.07*	1.00

N = 5918 HH; own analysis, tetrachoric correlation coefficients; *p < =.05; Data: VACA 2011/2012.

Table A2. MLVI – raw vulnerability headcounts by district in %.

	Eastern Brahmaputra (India)							Koshi (Nepal)						Upper Indus (Pakistan)		
	Dhemaji	East Siang	Lakhimpur	Lohit	Lower Dibang	Marigaon	Tinsukia	Dolakha	Kavre Palanchok	Khotang	Siraha	Sunsari	Udayapur	Chitral	Gilgit	Hunza-Nagar
Dependency ratio	13.5	8.3	9.4	8.9	10.5	7.6	16.3	5.6	7.6	16.6	15.4	10.0	12.3	17.1	20.8	13.6
Education	41.2	7.2	34.7	42.1	12.7	54.3	42.2	64.8	66.7	55.6	74.6	51.9	63.8	65.5	53.3	32.7
Agricultural land	21.2	36.4	37.3	32.1	69.8	57.2	54.6	29.6	56.2	31.9	64.2	60.1	49.7	81.0	69.7	49.6
Electricity	48.8	2.5	57.5	17.1	11.8	28.3	26.8	0.0	2.5	16.5	9.8	7.5	18.3	0.1	0.5	6.0
Cooking fuel	90.8	59.6	86.8	74.7	43.8	74.9	75.9	99.6	66.2	100.0	97.4	82.8	95.8	99.6	96.9	98.6
Non-agr. livelih. diversity	34.6	31.5	17.1	30.4	16.1	16.3	39.8	9.1	8.5	20.5	20.6	31.3	13.0	25.6	15.2	12.6
Agric. livelih.diversity	74.3	61.8	80.5	90.2	81.0	97.5	73.9	82.1	51.1	41.4	75.5	89.7	92.8	88.3	76.3	70.3
Access to loans	72.6	26.5	41.1	84.1	71.6	52.2	42.4	5.5	15.0	28.6	31.8	37.1	63.3	46.0	52.4	13.6
Political voice	18.6	23.5	13.1	81.6	21.0	48.3	53.0	26.4	23.8	28.0	59.8	58.2	52.1	37.1	35.7	20.6
Market	0.0	15.4	0.0	12.2	0.9	0.0	8.2	10.6	16.1	19.5	4.7	0.0	19.9	19.5	0.0	6.9
Bus stop	0.0	13.4	0.0	18.3	0.0	0.0	0.0	2.8	0.0	56.7	1.5	0.0	6.3	19.5	0.0	0.0
Consumption	27.9	74.5	64.2	29.0	28.6	61.2	67.9	68.8	49.5	35.5	54.5	37.8	53.2	37.0	29.5	2.5
Indebtedness	37.8	1.9	45.5	3.6	0.2	53.9	35.8	28.9	40.8	75.9	32.7	57.1	69.0	17.3	28.8	11.0
Illness	32.3	11.3	45.7	32.8	3.7	51.3	35.5	29.2	24.2	33.9	24.4	15.8	8.2	23.2	36.3	17.7
Sanitation	31.8	18.3	58.8	21.0	6.8	30.6	57.1	7.4	23.5	38.8	82.0	42.8	59.8	14.2	8.5	1.7
Drinking water	71.1	4.8	48.9	4.7	3.6	32.3	26.0	5.1	23.9	48.9	38.6	85.4	37.8	12.9	57.4	10.7
Food self-sufficiency	81.7	41.0	89.2	63.6	28.5	70.7	76.1	4.3	4.7	13.0	4.2	19.7	1.7	3.4	3.8	28.5
Diet diversity	13.4	54.2	35.6	24.5	10.1	31.3	24.0	7.2	11.9	5.6	23.1	5.4	20.8	7.0	0.2	0.0
Water sufficiency	85.6	65.4	71.5	76.5	25.5	61.6	64.2	76.7	51.8	94.5	13.3	12.5	29.9	9.0	18.7	20.6
Water conflicts	0.0	0.2	8.2	2.0	1.4	1.5	3.3	30.2	21.1	63.3	14.4	15.0	24.5	11.9	44.4	36.2
Slope	0.0	44.2	9.2	0.8	5.0	10.9	5.9	99.0	56.8	94.8	0.6	1.4	35.9	37.8	46.0	81.1
Soil	53.0	7.1	26.8	0.3	1.4	19.2	1.3	18.8	28.9	23.7	5.7	4.9	38.2	13.3	14.4	6.9
Dwelling	85.0	55.2	86.5	77.0	55.1	74.6	73.7	44.8	25.5	55.9	76.1	55.0	57.2	7.9	41.5	17.4
Environmental shocks	95.3	62.8	83.5	86.7	29.8	64.9	79.8	81.0	68.2	90.0	45.4	58.0	63.7	70.4	56.4	56.5
socio-economic shocks	65.9	61.4	87.7	72.2	34.5	92.5	95.3	70.0	79.4	96.1	89.0	86.9	82.2	70.7	24.1	70.0

N = 5918 HH; own analysis, 100%, weighted; Data: VACA 2011/2012.

Table A3. MLVI − censored vulnerability headcounts by district in %

	Eastern Brahmaputra (India)							Koshi (Nepal)						Upper Indus (Pakistan)		
	Dhemaji	East Siang	Lakhimpur	Lohit	Lower Dibang	Marigaon	Tinsukia	Dolakha	Kavre Palanchok	Khotang	Siraha	Sunsari	Udayapur	Chitral	Gilgit	Hunza-Nagar
Dependency ratio	13.5	7.1	8.9	8.2	2.4	7.3	16.3	5.3	4.2	16.6	14.2	9.0	11.8	13.0	15.2	6.9
Education	40.8	5.0	34.4	41.4	12.1	53.1	41.9	55.4	50.2	55.6	66.6	47.7	59.1	50.7	32.3	13.8
Agricultural land	19.7	18.4	35.6	25.5	9.6	51.8	44.1	24.0	31.6	29.9	56.0	48.2	46.5	55.5	40.7	25.5
Electricity	47.0	2.5	55.9	16.9	6.5	27.6	26.6	0.0	1.9	16.5	9.8	7.5	17.0	0.1	0.5	3.3
Cooking fuel	86.5	40.1	83.7	71.6	25.8	72.3	71.5	80.0	48.6	96.3	79.5	68.6	85.1	65.2	46.7	38.1
Non-agr. livelih. diversity	34.2	25.7	15.9	29.9	11.2	15.6	38.7	6.4	6.1	20.5	18.8	28.4	10.9	19.2	8.5	6.9
Agric. livelih. diversity	69.6	31.6	76.0	76.5	16.5	85.7	60.3	69.2	32.2	38.4	60.4	67.7	81.4	58.4	40.5	30.1
Access to loans	70.0	16.9	39.4	77.2	16.6	44.8	37.5	5.3	12.0	28.0	30.5	32.0	56.7	39.2	34.4	8.3
Political voice	18.6	16.6	12.6	71.8	11.8	46.1	49.1	25.0	17.8	28.0	53.5	44.5	49.3	34.4	25.1	12.7
Market	0.0	15.2	0.0	12.2	0.7	0.0	8.2	10.1	13.9	19.4	3.7	0.0	19.6	17.4	0.0	4.2
Bus stop	0.0	13.2	0.0	17.7	0.0	0.0	0.0	2.8	0.0	56.6	1.5	0.0	6.3	17.4	0.0	0.0
Consumption	27.8	48.4	61.7	29.0	14.4	59.7	62.5	59.2	35.4	34.9	49.4	32.3	48.4	25.7	18.1	2.5
Indebtedness	36.9	0.6	43.8	3.2	0.2	51.0	34.7	26.5	29.2	73.3	28.1	49.8	61.1	14.2	23.0	5.7
Illness	32.2	8.8	43.5	30.4	3.3	49.3	33.0	25.8	17.8	33.9	18.6	12.9	8.2	21.4	20.9	11.3
Sanitation	31.1	15.0	58.0	21.0	5.6	29.4	55.2	6.2	20.9	38.8	70.4	39.6	58.4	10.2	7.0	1.1
Drinking water	67.2	2.3	47.7	4.6	2.3	30.0	24.5	4.9	20.2	48.9	31.2	66.0	34.0	8.9	32.0	6.0
Food self-sufficiency	77.1	22.3	82.3	54.1	14.3	66.4	66.4	2.3	3.3	13.0	4.2	17.4	1.5	2.4	3.3	9.8
Diet diversity	13.4	36.6	35.1	24.0	8.8	30.7	24.0	7.1	9.8	5.6	22.1	5.4	18.3	7.0	0.2	0.0
Water sufficiency	80.9	43.6	65.4	68.6	17.1	54.6	60.0	67.6	39.6	92.8	11.4	11.8	29.3	9.0	10.1	10.3
Water conflicts	0.0	0.1	8.2	1.8	0.4	1.0	3.3	26.3	18.4	63.2	13.7	11.3	22.0	9.3	27.1	18.3
Slope	0.0	35.8	9.0	0.8	3.6	10.7	5.6	79.6	42.9	93.1	0.4	1.3	34.4	29.5	19.2	31.8
Soil	50.2	5.4	25.2	0.3	0.2	17.7	1.3	16.6	20.7	23.6	3.1	4.3	37.7	9.2	5.6	3.8
Dwelling	81.1	40.9	83.4	70.0	22.6	72.5	70.6	40.2	21.4	55.8	66.7	48.5	53.9	6.1	23.2	7.9
Environmental shocks	89.8	42.9	78.0	77.0	21.6	61.5	73.9	68.8	52.7	88.9	38.3	51.5	61.5	50.2	38.6	30.9
socio-economic shocks	65.4	41.1	83.5	65.8	22.1	82.2	82.3	62.3	52.6	93.1	77.4	68.1	74.7	53.4	17.4	34.9

N = 5918 HH; own analysis, 100%, weighted; Data: VACA 2011/2012.