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Contextual vulnerability of the communal forests and population of Totonicapán, Guatemala

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Abstract

The risk of climate change impacts occurring is a function of a socioecological system's exposure and vulnerability to climate-related hazards. Vulnerability itself is the result of a system's sensitivity and adaptive capacity. The potential climate change driven biophysical impacts on the municipality Totonicapán in the western highlands of Guatemala are well documented in outcome vulnerability studies and projected to be severe. They include droughts, frosts, forest fires and life zone changes which also represent important hazards to the municipality's population. Yet, recent detailed socioeconomic information on the municipality's contextual vulnerability is scarce. Moreover, social capital which is central to the yet successful management of the unique communal coniferous forests is poorly understood. The present study evaluates the contextual vulnerability of the municipality's population and communal forests using 5 interviews and 167 household surveys from 3 communities for 15 socioeconomic indicators. Qualitative analysis of the interviews urges for further investigation into the link between emigration to the USA, the loss of social capital and communal forest management. Quantitative analysis of the indicators and their aggregation into a vulnerability index by Principal Component Analysis demonstrates that education is the most important vulnerability factor, followed by income which was negatively related to natural resource dependency. An overarching theme was gender inequality. The study is a plea for location and population specific research and adaptation strategies as it identifies significant differences even between communities of the same municipality.

Keywords: Social capital, Vulnerability Indicator, Vulnerability Index, Principal Component Analysis

Vulnerabilidad contextual de los bosques comunales y de la población de Totonicapán, Guatemala

Resumen

El riesgo de que ocurran impactos climáticos es la función de la exposición y vulnerabilidad de un sistema socioecológico frente a peligros. La vulnerabilidad es el resultado de la sensibilidad y capacidad adaptativa de un sistema. Los posibles impactos biofísicos debido al cambio climático en el municipio de Totonicapán en el Altiplano de Guatemala son bien documentados en estudios de vulnerabilidad resultante y proyectados a ser severos. Se tratan de sequías, heladas, incendios forestales y cambios en las zonas de vida, que también representan peligros importantes para la población del municipio. Sin embargo, información socioeconómica actualizada y detallada sobre la vulnerabilidad contextual del municipio es escasa. Además, el capital social del municipio que es clave para el manejo exitoso de sus bosques comunales es poco entendido. El presente estudio evalúa la vulnerabilidad contextual de la población del municipio y de los bosques comunales usando 5 entrevistas y 167 encuestas de hogares de 3 comunidades, analizando 15 indicadores socioeconómicos. El análisis cualitativo de las entrevistas resalta que la comprensión del vínculo entre la emigración a los Estados Unidos, la pérdida de capital social y el manejo de los bosques comunales requiere un mayor esfuerzo investigativo. El análisis cuantitativo de los indicadores y su agregación a un índice de vulnerabilidad mediante el Análisis de Componentes Principales demuestra que la educación es el factor más importante de la vulnerabilidad, seguido por el ingreso, que guarda una relación inversa con la dependencia en recursos naturales. Un tema transversal ha sido la desigualdad de género. Identificando diferencias significativas incluso entre comunidades de la misma municipalidad, el estudio es una súplica para investigaciones locales y estrategias de adaptación.

Palabras clave: capital social, Indicador de vulnerabilidad, índice de vulnerabilidad, análisis de componentes principales, índice

1. Introduction

1.1. Climate change vulnerability

The risk of climate change impacts occurring is a function of a socioecological system's exposure and vulnerability to climate-related hazards (IPCC, 2014). Vulnerability is a concept of both the natural and the social sciences (O'Brien, Eriksen, Schjolden and Nygaard, 2004a; O'Brien, Eriksen, Nygaard and Schjolden, 2007; Füssel, 2007). In the context of climate change and socioecological systems it is defined by a system's sensitivity and adaptive capacity. Sensitivity is the degree to which a system is directly or indirectly affected by climate-related hazards (IPCC, 2014). Adaptive capacity is the ability of the system to adjust to climate-related hazards and impacts (IPCC, 2014). Moreover, the IPCC's fifth assessment report distinguishes between contextual (starting-point) and outcome (end-point) vulnerability. Whilst contextual vulnerability is determined by the socioeconomic characteristics of a human or ecological system, outcome vulnerability is analyzed exclusively in natural systems by modelling climate change related hazards and biophysical impacts in the present or future (Kelly and Adger, 2000; O'Brien et al., 2004a and 2007; Füssel and Klein, 2006; IPCC, 2014). Although outcome vulnerability and its implications for mitigation have historically dominated science and politics, contextual vulnerability is becoming increasingly important due to the inevitability of considerable biophysical climate change impacts (O'Brien et al., 2004a; Füssel and Klein, 2006). It is the contextual vulnerability approach which can addresses location and population specific details omitted in small-scale outcome vulnerability studies, and offer adaptation strategies for the population (Cutter, Boruff and Shirley, 2003; Adger, 2003 and 2006; O'Brien et al., 2007).

1.2. The case of Totonicapán

Totonicapán is one of five departments which constitute the western highlands of Guatemala. It consists of eight municipalities, including the municipality Totonicapán, which has the most diverse forests in terms of coniferous genera and species of any location at 15° latitude on Earth. The forests are habitat to endemic mammals, birds and plants such as the endangered *Abies guatemalensis* (Rehd.) (Veblen, 1978; Parkswatch, 2003; IUCN, 2016). Although the western highlands of Guatemala have been densely populated since pre-Hispanic times, and high population densities often lead to agriculture-driven deforestation, the department Totonicapán benefited from a distinct historic development which favored forest conservation: Under Spanish rule, shepherding was the department's predominant economic activity. The Spanish strengthened common lands where only shepherding and the collection of forest products, but no agricultural activity were allowed. In consequence, agricultural land was seriously limited. Therefore, Totonicapán developed trade with other parts of the country, exchanging wooden handicrafts for food. A sustainable forest management was thus necessary to indirectly guarantee food supply (Veblen, 1978; Elías, Larson and Mendoza, 2009).

In the context of climate change, mixed pine-oak and coniferous forests above 1,000 meters above sea level (m asl.) are regarded to be moderately resilient and gain net primary productivity with changes in their composition and structure. Coniferous forests above 1,800 m asl. are regarded to lose net primary productivity, biodiversity and endemic species. In a projection of Holdridge's life zones to the year 2050 using the WorldClim database and the general circulation model HADCM3, the extension of mixed pine-oak and coniferous forests above 1,000 m asl. decreased by 30-50%, and that of coniferous forests above 1,800 m asl. by 50-55% across the IPCC low and high emissions SRES scenarios B2 and A2 (IARNA-URL, 2011).

With 0.04% per year, compared to a national average of 1.54% per year, the department Totonicapán had Guatemala's lowest deforestation rate between 2006 and 2010 (INAB, 2015). It is therefore legitimate to assume that climate change is an important driver of forest degradation, directly in the form of lower species habitat suitability, and indirectly through forest fires, plagues, storms, droughts and invasions. Nevertheless, a mere analysis of the forests' outcome vulnerability falls short on the human dimension, the population's livelihoods and social capital in the form of organizations, intangible social relations and norms which conserved Totonicapán's unique forests in the first place and determine their present contextual vulnerability (Putnam, 1995; Katz, 2000; Busso, 2001; Rubin and Rossing, 2012).

In 2014, Biota S.A. and The Nature Conservancy published vulnerability index scores for all of the western highlands' municipalities. In line with previous IPCC assessment reports, vulnerability was defined as a function of exposure (to climate-related hazards), sensitivity and adaptive capacity (IPCC, 2001 and 2007). Exposure was analyzed in the form of droughts, frosts, floods, forest fires, landslides and erosion. The department Totonicapán particularly suffers from droughts, frosts and forest fires. At the moment 12.5% of Totonicapán's municipalities face very severe droughts, seven out of eight municipalities are affected by frosts and 62.5% of municipalities are very frequently exposed to forest fires. For 2050, using the general circulation model PRECIS and the IPCC's SRES scenario B1, the authors projected a persistence of forest fires and a worsening of droughts and frosts. In 2050, very severe droughts are projected to affect 62.5% of the municipalities and frosts could affect all municipalities. Sensitivity was measured by analyzing water scarcity, defined as the difference between water demand and supply, and agricultural sensitivity to El Niño Southern Oscillation (ENSO) anomalies. All of Totonicapán's municipalities were very strongly affected by water scarcity in the present and in the 2050 projection. Adaptive capacity was evaluated by population density, ecosystem services (forest cover), food security, illiteracy, extreme poverty, job insecurity, education, sanitation, crowding and waste burning. The department Totonicapán benefited from the most ecosystem services despite having the highest population density. Overall, the study classified six of Totonicapán's eight municipalities as currently extremely vulnerable, and three of them, including the municipality Totonicapán, scored among the four most vulnerable municipalities of the entire region. For 2050, the municipality Totonicapán is projected to be the 23rd most vulnerable municipality of the western highlands, but the other two municipalities remain among the four most vulnerable.

Yet, the study, which focused mostly on outcome vulnerability, did not analyze any socioeconomic indicators as part of sensitivity and only few in the context of adaptive capacity. Moreover, the study's indicators on extreme poverty, job insecurity, sanitation, crowding and waste burning were based on outdated data from the last census in 2002, likely overestimating the households' current vulnerability as the standard of living has improved since then. It is further questionable whether the basic needs indicators on sanitation, crowding and waste burning are at all relevant to climate change vulnerability.

Therefore, the aim of the present study was to complement and contrast previous scientific outcome vulnerability studies of Totonicapán's population and forests with a detailed location and population specific contextual vulnerability study

- of one of the most vulnerable municipalities;
- based on recent and robust socioeconomic survey data from three communities;
- in the form of a one-by-one indicator and vulnerability index comparison between communities;
- identifying the municipality's most important socioeconomic drivers of vulnerability by Principal Component Analysis (PCA) and suggesting adaptation strategies;
- and taking into consideration the municipality's socioecological context by interviewing key informants on social capital, the sustainability of communal forest management and forest reliance.

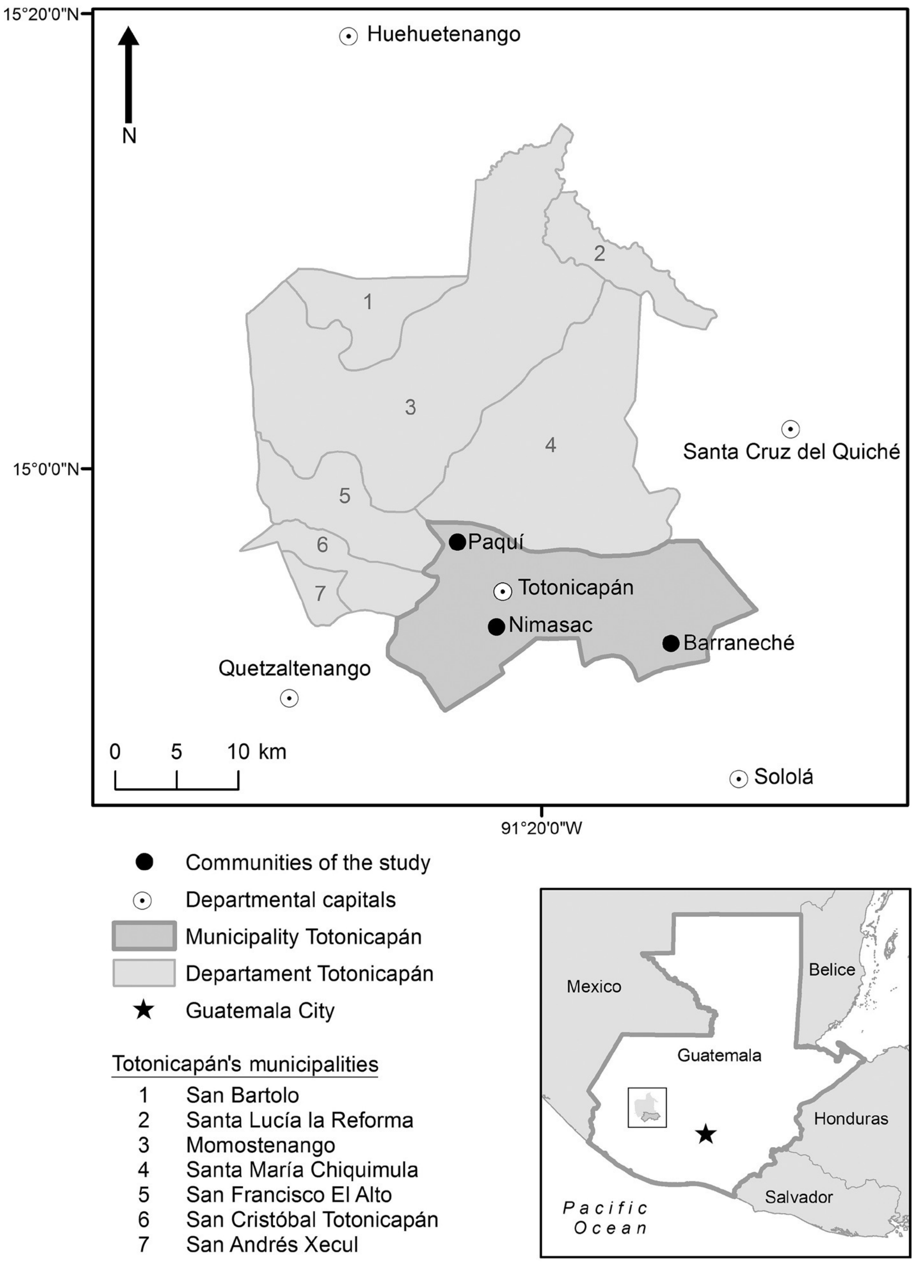
2. Materials and methods

2.1. The study area

The department Totonicapán is located at 14° 54' 45" N latitude and 91° 21' 36" W longitude at altitudes between 1,890 and 3,400 meters above sea level (map 1). The department is divided into the eight municipalities Totonicapán, Momostenango, Santa Lucía la Reforma, Santa María Chiquimula, San Bartolo, San Francisco El Alto, San Andrés Xecul and San Cristóbal Totonicapán. 98% of the population belong to the ethnic group Maya k'iche' (Consejo Departamental de Desarrollo del departamento de Totonicapán, 2011). In 2014, 77.5% of the department's population classified as poor, and 41.1% as extremely poor (INE, 2015). Especially the municipalities Santa María Chiquimula, Santa Lucía la Reforma, San Bartolo and areas of Momostenango, which are furthest away from the departmental capital, are socioeconomically disadvantaged (Consejo Departamental de Desarrollo del departamento de Totonicapán, 2011).

The three communities Nimasac, Paquí and Barraneché in the municipality Totonicapán were selected for the study due to their accessibility, willingness to participate, population size and distance to the departmental capital representative of the majority of communities in the municipality (figure 1, table 1).

Figure 1. The study area. Geographical location of the study's three communities in the municipality and department Totonicapán.



Sources: DIVA-GIS, Instituto Geográfico Nacional de Guatemala

Table 1. The study's three communities' sizes, compositions and distances from the departmental capital

Community	Distance from departmental capital Totonicapán	Extension	Forest cover	Population	Year	Source
Nimasac	3 km	6.5 km²	2.0 km² (30%)	3,872 2,870	2008 2016	Mejía, Choxom, Aguilar and Calijau, unpublished results Estimation based on this study's household surveys
Paquí	9 km	4.5 km²	3.6 km² (80%)	2,774 3,850	2002 2016	INE, 2003 Estimation based on this study's household surveys
Barraneché	65 km	8.8 km²	5.3 km² (60%)	3,317 3,684	2012 2016	Tzaj, unpublished results Estimation based on this study's household surveys

2.2. Interviews

Due to the scarcity of recent coherent quality information on the communal forests of the municipality Totonicapán five key informants from the intercooperation Helvetas, the local Cooperation for the Rural Development of the West (CDRO), the National Forestry Institute (INAB), the association of community forestry Utz Che' and a local leader were interviewed one by one following a set of 18 questions. The questions addressed the property type of the forests, forest management, people's livelihoods and forest reliance, and the municipality's vulnerability to climate change. The interviews were recorded and transcribed.

2.3. Surveys

The indicators were based on Busso (2001), Cutter et al. (2003) and Adger, Brooks, Bentham, Agnew and Eriksen (2004) (table 2). The survey questions were based on the last National Census XI of Population and VI of Housing, and the National Survey on Living Conditions (INE, 2003 and 2011). A household was defined as each person or group of people who lived and ate together (INE, 2003).

Table 2. The study's sensitivity and adaptive capacity indicators and the units they were analyzed in.

		Indicator	Measurement unit
Sensitivity	1.	Income diversification	Number of income-generating activities per household
	2.	Income instability	Standard deviation of the monthly income of twelve months expressed as percentage of the annual household income
	3.	Dependency	Percentage of household members without an income-generating activity
	4.	Extreme ages of the household	Percentage of household members older than 65 years and younger than 5 years
	5.	Robust infrastructure	Household house of adobe, cement blocks or mixed material (adobe and cement blocks)
	6.	Food security	Secure, mildly insecure, moderately insecure, severely insecure (using the Latin American and Caribbean Scale of Food Security)
	7.	Agriculture and livestock dependency	Household estimation of the annual value of self-consumed and sold agricultural and livestock products, and remunerated work in the agricultural sector, expressed as percentage of annual income
	8.	Forest reliance	Household estimation of the annual value of fuelwood, mushrooms, *broza*[*] and medicinal plants expressed as percentage of annual income
Adaptive capacity	1.	Income	Annual total household income
	2.	Financial and physical capital	Sum of the household's savings, debts and physical assets including land, housing and animals
	3.	Age of the head of household	Years
	4.	Education of the head of household	Years of primary, secondary and higher education
	5.	Education of the household	Average years of primary, secondary and higher education received by those household members who had finished their studies
	6.	Illiteracy of the household	Percentage of household members older than 6 who cannot read and write
	7.	Bilingualism of the household	Percentage of household members older than 3 who speak the indigenous language k'iche' and Spanish

[*] Fertilizer in the form of a) pine foliage having been used in animal stables and mixed with animal waste, or b) decomposed broadleaf foliage collected during the rainy season.

Each community was split into sectors of equal size and population. From each community four sectors were chosen at random or on purpose to stratify the sample. Of each sector 15 households were selected based on a random walk or drawing them at random from a satellite image. Unoccupied houses were substituted, but occupied houses unable or unwilling to participate were not. The survey was conducted verbally in company of bilingual locals. 55 households were surveyed in Nimasac, 57 in Paquí and 51 in Barraneché. The survey took place in February 2016.

2.4. Indicator quality control

- To reduce the subjectivity of estimations, the indicators of agriculture and livestock dependency and forest reliance were calculated using
- the price of a pound of maize based on each community's entire estimates' average;
- the price of a pound of beans based on all three communities' estimates' average;
- the price of fuelwood, *broza* and mushrooms based on all three communities' estimates' average.

The indicators were standardized and values $-3 > z > 3$ classified as extreme cases. By studying the questionnaires of each extreme case, extreme cases based on true data and extreme cases based on sub- or overestimated data were distinguished. If the extreme case was a sub- or overestimation, it was removed from analysis. If the extreme case was based on true data its value was adjusted to $z = +/- 3$ and it remained in the analysis.

2.5. Statistics

Categorical data were expressed as frequencies and compared between the communities using the chi-squared test. Ordinal and parametric data were analyzed by one-way ANOVA and LSD post-hoc tests if the data were normally distributed (Kolmogorov-Smirnov test and visual inspection of the histograms) and groups had an equal variance (Levene test). Otherwise Mann-Whitney and Kruskal-Wallis tests were used. Correlations between indicators were analyzed by two-tailed Spearman tests. Correlations between indices in the sensitivity analysis (see 2.6.4.) were analyzed by two-tailed Pearson tests. All tests and the PCA were performed in SPSS.

2.6. Vulnerability index calculation

The vulnerability index 1 was calculated following the guidelines set by Saisana and Tarantola (2002) and Nardo et al. (2005).

2.6.1. Indicator normalization

The indicators were minimum-maximum normalized to a scale of 0 to 1 to compare different measurement units. Indicators whose higher value corresponded to lower vulnerability were inverted by subtracting them from 1.

2.6.2. Assigning weights by PCA

PCA is a multivariate statistical method which resumes multiple indicators and their relationships through the creation of new variables called principal components (PCs). Especially when the indicators are correlated (scoring a minimum of 0.5-0.6 in the correlation matrix' Kaiser-Meyer-Olkin (KMO) index: 0.719 in the present study) a lower number of PCs than indicators can express a large amount of the original information (Saisana and Tarantola, 2002; Nardo et al., 2005; Velíz Capuñay, 2016). Importantly, PCA only provides descriptive results based on the correlation of the indicators and their impact on the variance and information of the original data, but not directly on their influence on vulnerability. Yet, it is a method for approximating real weights (Saisana and Tarantola, 2002; Nardo et al., 2005).

PCA is performed by establishing a correlation matrix from the indicators and by calculating the eigenvectors u_i and their eigenvalues λ_i from it. Each PC Y_i (for i = 1, 2, … p) is a linear combination of the original indicators X multiplied by the coordinates of the eigenvector (for i = 1, 2, … p), which form the coefficients of the indicators (Velíz Capuñay, 2016):

$$
\begin{gathered}
Y_1 = u_{11}X_1 + u_{12}X_2 + \dots + u_{1p}X_p \\
Y_2 = u_{21}X_1 + u_{22}X_2 + \dots + u_{2p}X_p \\
\dots \\
Y_p = u_{p1}X_1 + u_{p2}X_2 + \dots + u_{pp}X_p
\end{gathered}
$$

The eigenvalue λ_i of each eigenvector expresses the variance of Y_i. Of all PCs the first captures the largest variance or information contained in the distribution of the original data and therefore has the largest eigenvalue. The second PC captures the largest remaining variance and is based on the eigenvector with the second largest eigenvalue. This procedure is repeated until the same number of PCs as original indicators has been formed, reproducing the complete variability of the data (Saisana and Tarantola, 2002; Velíz Capuñay, 2016).

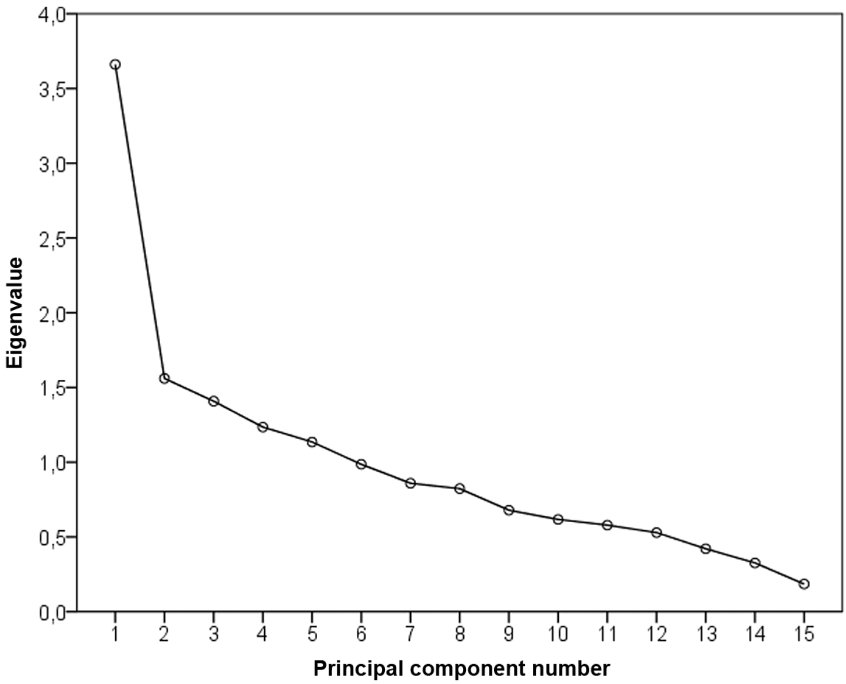
First, a PCA generating 15 PCs was performed. Three criteria were applied to determine that 8 PCs should be retained (Saisana and Tarantola, 2002; Nardo et al., 2005; Velíz Capuñay, 2016):

1. The Kaiser criterion, by which all PCs with an eigenvalue greater than 1 are retained. As the sum of all eigenvalues is equal to the number of indicators any PC with an eigenvalue greater than 1 scores above average and resumes information.

2. The accumulative variance of the retained PCs should represent between 70%-90% of the total variance (77.8% in the present study).

3. That number of PCs should be retained after which a significant drop in eigenvalue is visible on the scree plot (figure 2).

Figure 2. Scree plot. The PC ordered according to descending eigenvalues.



A second PCA with varimax rotation generating 8 PCs was performed. Varimax rotation maximizes the equal distribution of PCs and their eigenvalues to increase the comprehensibility of the results. It is the most common rotation and conserves orthogonality between the PCs, but may change the correlation between the PCs and the indicators.

The value of each PC was calculated for each of the 117 complete cases (Nimasac n=38, Paquí n=44, Barraneché n=35) and the PCs were minimum-maximum normalized.

2.6.3. Aggregation

The non-normalized PCs calculated for each of the 117 complete cases were multiplied by their eigenvalue, which represents the amount of information the PC resumes and its relative importance, and the weighted average was taken. The 117 indices were minimum-maximum normalized.

2.6.4. Sensitivity analysis

In a sensitivity analysis Index 1, constructed by PCA, was compared to two other indices based on the same set of data and indicators but constructed differently:

Index 2 was the weighted average of the 15 minimum-maximum normalized and inverted indicators (see 2.6.1). The 117 indices were minimum-maximum normalized.

Index 3 consisted of two sub-indices for adaptive capacity and sensitivity. Both sub-indices were the weighted average of the minimum-maximum normalized and inverted indicators (see 2.6.1). Special attention was paid to the concordance between the indicator values and the sub-indices. Adaptive capacity was subtracted from sensitivity and the results minimum-maximum normalized.

2.7. Ethical commitment

The data were collected with the participants' prior voluntary and informed consent. All participants were of legal age, informed about the study's aims, the confidentiality and use of their data, and the possibility to end participation at any time without any consequences.

3. Results

3.1. Social capital, communal forest management and forest reliance in the municipality Totonicapán

The five key informants agreed that the department and particularly the municipality Totonicapán are still renowned for trade and wooden handicrafts. Moreover, they specified that maize and beans subsistence agriculture is practiced ubiquitously, especially in rural and poor areas, although it is not sufficient to meet nutritional needs owing to the high population density and land fragmentation. According to the key informants, emigration to the USA is very frequent in the municipality and has important side effects such as the loss of communal knowledge, social coherence and traditional lifestyles.

Totonicapán's communal forests lack coherent terminology, as was evident during the interviews, and often legal titles. They can be distinguished into those owned by communities, those owned by extended kinships (*parcialidades*) and a large protected forest co-managed by the municipality and its communities, the communal municipal forest. Some private forest parcels also exist. Access to community forests and *parcialidades* is restricted to members, whilst all of the municipality's inhabitants have access to the communal municipal forest, although only the nearby communities tend to make use of that right. Only the collection of non-timber forest products (NTFP) and fuelwood for self-consumption is allowed. The extraction of wood other than fuelwood requires permission and usually incurs a cost, although members who have fulfilled their community service are entitled to some wood, e.g. for their housing. If possible, old, sick or fallen trees are used. All regimes have forest guards and sanctions such as community services and payments in place to minimize the unauthorized exploitation of forest resources.

With regards to forest reliance, the communities of the municipality Totonicapán protect their own forest resources whilst consuming those of other municipalities and departments. The municipality Santa María Chiquimula, which suffers from high levels of poverty and practices a more exploitative and commercial forest management, is one of Totonicapán's major providers of carpentry, construction and fuelwood. Therefore, the most important ecosystem service provided by the forests of the municipality Totonicapán is water, and water shortage due to high population densities and climate change is already affecting various communities, according to the five key informants.

3.2. Sensitivity indicators

3.2.1. Income diversification

Whilst households in Nimasac and Paquí had a median of two income-generating activities, households in Barraneché had a median of only one income-generating activity, as female economic activity was less frequent: Only 21.5% of the women aged 16 or older in Barraneché had an income, compared to 47.0% and 51.0% of those in Nimasac and Paquí, respectively. 31.8% of all economic activities in Barraneché were related to carpentry, in comparison to 5.1% and 4.0% of those in Paquí and Nimasac, respectively. Remittances were a more common source of income than trade across the three communities and only four households relied on agriculture as their sole source of income. In comparison to households with three economic activities, households with one and two economic activities had a significantly lower median income ($p<0.001$ and $p<0.01$, respectively) and median capital ($p<0.01$ and $p<0.01$, respectively).

3.2.2. Income instability

Across the three communities, 73.0% of all the income-generating activities registered provided a stable monthly income throughout the year. On the household level, 57.0%

of the three communities' households had a stable monthly income throughout the year without significant differences between the communities, but with a tendency towards more frequent income-stability in Barraneché (62.7%) than in Paquí (55.4%) or Nimasac (52.8%). The average levels of income instability also tended to be lower in Barraneché (1.4%) than in Paquí (1.8%) or Nimasac (1.7%). The results thus concurred with those of income diversification. The level of income instability was the only variable in the analysis that did not correlate with any other variable (table 3).

3.2.3. Dependency

The median dependency of households in Barraneché was significantly greater than that of households in Nimasac ($p<0.01$) and Paquí ($p<0.001$). Whilst in Nimasac and Paquí a median of half of the household members were economically active, in Barraneché only a median of a third of the household members generated an income. The results concurred with the frequencies of female economic activity in the three communities. Although households in Barraneché had the highest median dependency, they also had the highest income (see 3.3.1.), implying that the economic activities of the households in Barraneché, such as carpentry, are highly profitable.

3.2.4. Extreme ages

In Paquí a median of 20.0% of the household members were older than 65 years or younger than 5 years. This was significantly more than in Nimasac, where the median was 0% ($p<0.01$). In Barraneché a median of 9.1% of the household members were of extreme age. Assuming equal life expectancy and fertility across the communities, the elderly more frequently live on their own in Nimasac than in Paquí. The fraction of extreme-aged household members correlated positively with dependency ($p<0.01$), as the children or the elderly less frequently work, illiteracy ($p<0.01$), as children and the elderly are less likely to have learned how to read and write, and negatively with bilingualism ($p<0.001$), as the elderly are less likely to have learned Spanish and the new generations in Paquí grow up speaking only Spanish (see 3.3.4).

3.2.5. Robust infrastructure

Adobe was the most common building material in the three communities and 64.8% of the households' houses were built of adobe, especially in Nimasac (69.5%). 21.2% of the houses were made of concrete blocks, especially in Barraneché (28.6%). 13.9% of the houses consisted of both adobe and concrete blocks, with a significantly higher frequency of such houses in Paquí (21.1%) ($p<0.05$). Concrete block houses significantly more frequently had a female head of household (40.0%) than adobe houses (21.2%) or mixed-material houses (17.4%) ($p<0.01$). As houses made of concrete blocks require a comparably large financial investment they are usually commissioned by emigrants who send remittances from the USA to their wives who remain in Totonicapán. Households in concrete block houses also had a significantly higher median capital than households occupying adobe houses ($p<0.05$), as the value of the house was included in the estimation of the households' capital. Households in concrete block and mixed-material houses scored significantly better on a number of socioeconomic indicators than households in adobe houses: The head of household was of a younger median age ($p<0.01$ in case of concrete block and mixed-material houses) and had had a longer median education ($p<0.05$ in case of concrete block houses and $p<0.01$ in case of mixed-material houses), and the household members had benefited from a longer median education ($p<0.01$ in case of concrete block and mixed-material houses).

3.2.6. Food security

There was no significant difference between the levels of food insecurity in the three communities. 22.2% of the households counted as food secure, 52.1% of the households suffered from mild food insecurity, 16.8% and 9.0% of the households were in condition of moderate and severe food insecurity, respectively. Households headed by women were less frequently food secure (15.0%) and more frequently severely food insecure (15.0%) due to their lack of income and education (see 3.3.3.). Nimasac had the lowest frequencies of food secure (16.9%) and mildly food insecure (47.5%) households, and the highest frequencies of moderately (22.0%) and severely (13.6%) food insecure households. Paquí had the highest proportion of food secure households (26.3%). Barraneché had the highest fraction of mildly food insecure (56.9%) and the lowest fraction of severely food insecure (3.9%) households. Therefore, Nimasac was nutritionally speaking in the worst condition.

The category of food insecurity determined the median of various other socioeconomic indicators, which directly (as in the case of income and purchasing power) and indirectly (as in the case of education and the opportunity to provide a better income) influence food security: The median income of severely food insecure households was significantly lower than that of food secure ($p<0.001$), mildly food insecure ($p<0.001$) and moderately food insecure ($p<0.01$) households. The heads of food secure households had had a significantly longer median education than those of moderately food insecure ($p<0.001$) and severely food insecure ($p<0.05$) households. The heads of mildly food insecure households had benefited from a significantly longer median education than those of moderately food insecure households ($p<0.01$). In addition, the median maize production per year of food secure households was significantly greater than that of moderately and severely food insecure households ($p<0.05$).

Table 3. Two-tailed Spearman correlations r between the indicators and their p-value. Bold values indicate statistical significance (p<0.05).

		Income instability	Income	Age of the head of household	Education oft he head of household	Dependency	Financial and physical capital	Bilingualism oft he household	Illiteracy oft he household	Education oft he household	Extreme ages	Forest reliance	Agriculture and livestock dependency
Income instability	r	1.000	0.026	-0.116	0.106	-0.125	-0.065	0.054	-0.121	0.093	-0.127	0.134	0.021
	p		0.744	0.145	0.187	0.123	0.440	0.497	0.127	0.240	0.108	0.099	0.804
Income	r	0.026	1.000	-0.087	**0.240**	-0.007	**0.296**	0.079	**-0.216**	**0.352**	-0.154	**-0.437**	**-0.174**
	p	0.744		0.274	**0.002**	0.932	**0.000**	0.321	**0.006**	**0.000**	0.050	**0.000**	**0.034**
Age of the head of household	r	-0.116	-0.087	1.000	**-0.509**	**-0.167**	-0.053	-0.138	**0.515**	**-0.396**	0.086	**0.255**	**0.386**
	p	0.145	0.274		**0.000**	**0.039**	0.526	0.080	**0.000**	**0.000**	0.273	**0.001**	**0.000**
Education of the head of household	r	0.106	**0.240**	**-0.509**	1.000	0.093	**0.180**	**0.156**	**-0.574**	**0.718**	-0.001	**-0.302**	**-0.246**
	p	0.187	**0.002**	**0.000**		0.250	**0.028**	**0.047**	**0.000**	**0.000**	0.994	**0.000**	**0.003**
Depedency	r	-0.125	-0.007	**-0.167**	0.093	1.000	0.031	-0.086	0.068	-0.047	**0.248**	-0.075	0.126
	p	0.123	0.932	**0.039**	0.250		0.718	0.288	0.397	0.562	**0.002**	0.367	0.135
Financial and physical capital	r	-0.065	**0.296**	-0.053	**0.180**	0.031	1.000	**0.179**	-0.126	**0.208**	-0.055	-0.146	-0.014
	p	0.440	**0.000**	0.526	**0.028**	0.718		**0.028**	0.126	**0.010**	0.500	0.083	0.875
Bilingualism of the household	r	0.054	0.079	-0.138	**0.156**	-0.086	**0.179**	1.000	-0.126	0.095	**-0.308**	-0.127	-0.108
	p	0.497	0.321	0.080	**0.047**	0.288	**0.028**		0.105	0.222	**0.000**	0.114	0.189
Illiteracy of the household	r	-0.121	**-0.216**	**0.515**	**-0.574**	0.068	-0.126	-0.126	1.000	**-0.673**	**0.220**	**0.249**	**0.335**
	p	0.127	**0.006**	**0.000**	**0.000**	0.397	0.126	0.105		**0.000**	**0.004**	**0.002**	**0.000**
Education of the household	r	0.093	**0.352**	**-0.396**	**0.718**	-0.047	**0.208**	0.095	**-0.673**	1.000	-0.148	**-0.352**	**-0.388**
	p	0.240	**0.000**	**0.000**	**0.000**	0.562	**0.010**	0.222	**0.000**		0.056	**0.000**	**0.000**
Extreme ages	r	-0.127	-0.154	0.086	-0.001	**0.248**	-0.055	**-0.308**	**0.220**	-0.148	1.000	0.013	0.077
	p	0.108	0.050	0.273	0.994	**0.002**	0.500	**0.000**	**0.004**	0.056		0.875	0.351
Forest reliance	r	0.134	**-0.437**	**0.255**	**-0.302**	-0.075	-0.146	-0.127	**0.249**	**-0.352**	0.013	1.000	**0.172**
	p	0.099	**0.000**	**0.001**	**0.000**	0.367	0.083	0.114	**0.002**	**0.000**	0.875		**0.040**
Agriculture and livestock dependency	r	0.021	**-0.174**	**0.386**	**-0.246**	0.126	-0.014	-0.108	**0.335**	**-0.388**	0.077	**0.172**	1.000
	p	0.804	**0.034**	**0.000**	**0.003**	0.135	0.875	0.189	**0.000**	**0.000**	0.351	0.040	

3.2.7. Agriculture and livestock dependency

The prevalence of agriculture concurred with the distance of the communities from the departmental capital and in part with the proportion of households that possessed land: 67.8% of the households in Nimasac, 70.2% of the households in Paquí and 76.0% of the households in Barraneché practiced agriculture. Accordingly, 66.1% of the households in Nimasac, 64.9% of the households in Paquí and 78.4% of the households in Barraneché possessed agricultural land.

The degree of agricultural intensification was determined by the communities' proximity to the departmental capital, the pricing and shortage of land. The median maize production per area was significantly higher in Nimasac than in Paquí ($p<0.05$) and Barraneché ($p<0.01$). On the other hand, land in fallow or out of use was significantly more common in Barraneché than in the other communities ($p<0.05$). Nevertheless, production per household was highest in Barraneché due to employing greater areas of land. The median price of land was significantly higher in Nimasac than in Paquí ($p<0.01$) and Barraneché ($p<0.001$), and the median price of land was significantly higher in Paquí than in Barraneché ($p<0.05$).

Agricultural production almost exclusively served self-consumption and only 9.5% of all farmers sold part of their production. In Nimasac, Paquí and Barraneché the median dependency on remunerated work in agriculture, self-consumption and sales of agricultural products represented 3.2%, 1.8% and 4.6% of the household income, respectively. Besides agriculture 53.4% of the households owned farm animals. In Nimasac and Paquí the median dependency on self-consumed or sold animal products was 0% of the household income. In Barraneché the median dependency represented 0.6% of the household income. The results demonstrate that agriculture is far more important for nutrition and income than are animal products, despite their higher market value. The median dependency on agriculture and livestock was estimated at 5.2% of the income of households in Barraneché, 3.8% of the income of households in Nimasac and 2.7% of the income of households in Paquí.

Agriculture and livestock dependency was positively correlated with socioeconomic indicators such as the age of the head of household ($p<0.001$), and negatively correlated with the education of the head of household ($p<0.01$), the education and literacy of the household members ($p<0.001$) and household income ($p<0.05$).

3.2.8. Forest reliance

Fuelwood was used by 94.0% of the households in the three communities. A considerable number of households also used gas, especially in Paquí (50.9%) and Nimasac (46.7%), but less so in Barraneché (37.3%). 93.0% of the households that used fuelwood bought it, and 31.8% also collected it. In Barraneché households that collected fuelwood supplied an average of 60.1% of their demand with it, more than in Paquí, where collection covered on average 47.1% of the consumption, and significantly more than in Nimasac, where collection accounted for an average of 37.1% of the households' fuelwood ($p<0.05$). 78.9% of the households asserted that fuelwood was more expensive and 87.7% that it was scarcer than five years ago. In addition to fuelwood, 33.3% of the communities' households collected *broza*, 16.8% collected medicinal plants and and 31.7% collected mushrooms from the nearby forests. The median forest reliance of households on self-collected NTFP and fuelwood from the nearby forests represented 2.1% of the households' income in Nimasac, 2.5% of the households' income in Paquí and 1.6% of the households' income in Barraneché. Taking into consideration purchased fuelwood, median forest reliance ascended to 12.0% of the households' income in Nimasac, 11.5% of the households' income in Paquí and 10.2% of the households' income in Barraneché. Therefore, purchased fuelwood represented the main forest product consumed by the households and a major expense. Households with gas had a significantly lower median forest reliance (7.0%) than households without gas (14.2%) ($p<0.01$).

As in the case of agriculture and livestock dependency, forest reliance correlated positively with the age of the head of household ($p<0.01$), and negatively with the education of the head of household ($p<0.001$), the education of the household members ($p<0.001$) and their literacy ($p<0.01$), but most of all household income ($p<0.001$).

3.3. Adaptive capacity indicators

3.3.1. Income

Households in Paquí had the lowest median income of 21,950 Quetzales per year. Households in Nimasac had a slightly higher median income of 22,800 Quetzales per year. Despite having the least diversified income and the highest median dependency of the three communities, households in Barraneché had the highest median income of 29,600 Quetzales per year, significantly more than the median income of households in Nimasac ($p<0.05$). Income correlated positively with the education of the head of household ($p<0.01$), of the household members ($p<0.001$), their literacy ($p<0.001$), the households' capital ($p<0.001$), and correlated negatively with dependency on agriculture and livestock ($p<0.05$) and forest reliance ($p<0.001$).

3.3.2. Financial and physical capital

Median household capital was significantly different between the three communities and reflected the cost of land and cement block housing included in the estimation of the indicator. Households in Nimasac had a greater median capital than households in Barraneché, and a significantly greater median capital than households in Paquí ($p<0.01$). Capital correlated positively with income ($p<0.001$), household education and bilingualism ($p<0.05$) and the education of the head of household ($p<0.05$).

3.3.3. The heads of household

The median age of the heads of household was not significantly different between the three communities, although Paquí had the heads of household with the highest median age (46 years), and Barraneché those with the lowest median age (42 years). Nimasac's heads of household were of a median age of 45 years. The age of the head of household correlated negatively with their education ($p<0.001$), the education and literacy of the household members ($p<0.001$), and positively with dependency on agriculture and livestock ($p<0.001$) and forest reliance ($p<0.01$).

The median education of the heads of household was also not significantly different between the three communities, although Paquí had the heads of household with the highest median education (5 years), followed by those of Barraneché (4 years) and Nimasac (3 years). Female heads of household had received a median of 2.5 years fewer education than male heads of household, a significant difference ($p<0.01$). Households headed by women also obtained a significantly lower income than those headed by men ($p<0.05$). The education of the head of household correlated positively with the households' education and literacy ($p<0.001$), income ($p<0.01$), capital ($p<0.05$), and negatively with their dependency on agriculture and livestock ($p<0.01$) and forest reliance ($p<0.001$).

With respect to the sex of the heads of household, 86.3%, 72.4% and 72.7% of them were men in Barraneché, Nimasac and Paquí, respectively. The result concurred with Barraneché's pronounced labor division.

3.3.4. The household members

The median household education was highest in Paquí (6.0 years), reproducing the results of the education of the heads of household, followed by the median household education in Nimasac (4.5 years) and that in Barraneché (4.4 years). The difference between the medians of household education in Paquí and Barraneché was significant ($p<0.05$).

Whilst households in Nimasac and Paquí had a median of 0% illiterate members, households in Barraneché had a median of 24.2% illiterate members. Illiteracy was positively correlated with the percentage of extreme-aged household members ($p<0.01$) due to the elderly.

Household education and illiteracy were negatively correlated ($p<0.001$). Both household education and literacy were positively correlated with income ($p<0.001$

and $p<0.01$, respectively), education and age of the head of household (see above), and negatively correlated with dependency on agriculture and livestock ($p<0.001$) and forest reliance ($p<0.001$ and $p<0.01$, respectively).

With regards to bilingualism, households in all three communities had a median of 100% bilingual members, but the median percentage of bilingual household members in Nimasac was significantly greater than that in Paquí ($p<0.001$) and Barraneché ($p<0.05$). The median percentage of bilingual household members was also significantly greater in Barraneché than in Paquí ($p<0.05$). It should be noted that there are two types of monolinguals: The elderly k'iche'-monolinguals of Nimasac and Barraneché, and the younger generations of Spanish-monolinguals in Paquí. Bilingualism correlated positively with capital ($p<0.05$), education of the head of household ($p<0.05$), and negatively with the age of the head of household in case of the k'iche'-monolinguals ($p<0.001$).

3.4. The vulnerability index

3.4.1. The PC

The first PC had an eigenvalue considerably greater than that of the other seven PCs, because five sensitivity and adaptive capacity indicators loaded onto it: Lack of household education, household illiteracy, lack of education of the head of household, the age of the head of household and dependency on agriculture and livestock (table 4). The first three indicators are directly related to education and strongly correlated with the PC ($r=0.804$, $r= 0.776$ and $r=0.753$, respectively). The age of the head of household is indirectly related to education and therefore correlated less with the PC ($r=0.701$) and only 65.3% of its variance were reproduced by the eight PCs, the lowest value of all indicators. Of the five indicators that loaded onto the first PC, dependency on agriculture and livestock was the only sensitivity indicator, the indicator that correlated least with its PC ($r=0.637$), and the indicator with the second least variance (69.0%) reproduced by the eight PCs. Therefore, the first PC represented the theme lack of education.

The second PC had an eigenvalue half of that of the first PC. It resumed the indicators forest reliance (sensitivity) and lack of income (adaptive capacity). Between 70.5% and 77.6% of the indicators' information was reproduced by the eight PCs. Both indicators correlated strongly and equally with the second PC ($r=0.768$ and 0.765, respectively). Assuming that a lack of income causes high forest reliance, and taking the better reproduction of information of the lack of income indicator into consideration, the second PC represented the theme lack of income. The average value of the second PC was significantly higher in Paquí than in Barraneché, owing to the high income of households in Barraneché ($p<0.05$) (figure 2).

Table 4. Results of the PCA. Given are the eight extracted principal components (PCs) and their eigenvalues under varimax rotation. Each PC represents a theme defined by the indicators which most correlated with it (correlations given in bold). The indicators' concept (AC = adaptive capacity; S = sensitivity) and variance reproduced by the eight PCs are also given.

PC	Eigen-value	Theme	Concept	Indicator	Variance	Correlation Pearson r							
						PC1	PC2	PC3	PC4	**PC5**	**PC6**	**PC7**	**PC8**
1	2.901	Lack of education	AC	Lack of household education	79.9%	**0.804**	0.102	0.093	-0.103	0.189	0.102	-0.117	0.250
			AC	Illiteracy	73.1%	**0.776**	0.117	0.117	0.308	0.083	-0.020	0.005	0.000
			AC	Lack of education of the head of household	81.9%	**0.753**	0.099	-0.154	-0.201	0.191	0.143	-0.141	0.318
			AC	Age of the head of household	65.3%	**0.701**	0.129	-0.216	0.262	0.102	0.004	-0.007	-0.136
			S	Dependency on agriculture and livestock	69.0%	**0.637**	0.183	0.258	0.019	-0.273	-0.032	0.269	-0.187
2	1.469	Lack of income	S	Forest reliance	70.5%	0.195	**0.768**	-0.137	0.191	0.113	-0.065	0.012	0.073
			AC	Lack of income	77.6%	0.171	**0.765**	0.335	-0.034	-0.027	0.149	0.013	0.157
3	1.362	Division of labor	S	Lack of income diversification	79.1%	0.020	0.126	**0.849**	0.012	0.162	0.021	0.099	-0.128
			S	Dependency	83.1%	-0.052	-0.325	**0.535**	0.326	-0.215	-0.023	-0.341	0.408
4	1.260	Extreme ages	S	Extreme ages	78.6%	0.178	0.149	0.069	**0.814**	0.178	0.155	-0.067	-0.064
5	1.213	Lack of robust infrastructure	S	Lack of robust infrastructure	81.7%	0.179	0.072	0.096	0.182	**0.857**	-0.012	0.038	0.028
6	1.207	Sociocultural development	AC	Lack of bilingualism	85.8%	-0.004	0.000	-0.070	0.332	-0.149	**0.848**	-0.009	-0.022
			AC	Lack of capital	74.0%	0.183	0.091	0.180	-0.294	0.413	**0.635**	-0.020	0.070
7	1.145	Income instability	AC	Income instability	88.6%	-0.066	0.002	0.054	-0.051	0.023	-0.017	**0.918**	0.184
8	1.118	Food insecurity	S	Food insecurity	79.3%	0.121	0.228	-0.094	-0.077	0.055	0.009	0.254	**0.802**

The third PC loaded two sensitivity indicators, lack of income diversification and dependency, which information was well reproduced by the eight PCs. Previous results highlighted that female economic activity is an important determinant of income diversification and dependency. Therefore, the third PC represented the theme division of labor. Barraneché had a significantly greater average labor division than Nimasac (p<0.01) and Paquí (p<0.01), as less women were economically active (figure 3).

The fourth and fifth PC only represented two sensitivity indicators, extreme ages and lack of robust infrastructure. In both cases a high percentage of their original information was reproduced by the eight PCs (78.6% and 81.7%, respectively) and the indicators correlated significantly with their PC.

The sixth PC resumed two adaptive capacity indicators, lack of bilingualism and lack of capital. Lack of bilingualism correlated more with the PC (r=0.848) than lack of capital (r=0.635) and the eight PCs reproduced 11.8% more of the former's variance. In fact, lack of bilingualism was the second best reproduced indicator of the entire analysis (85.5%). The sixth PC therefore represented sociocultural development in Totonicapán and its average value was significantly higher in Paquí than in Nimasac (p<0.01) and Barraneché (p<0.05) due to more Spanish-monolinguals in Paquí. The seventh PC only loaded income insecurity. Of all indicators and PCs, this indicator correlated the most with its PC (r=0.918) and had the most information reproduced by the eight PCs (88.6%). Barraneché had a significantly smaller average income insecurity than Paquí (p<0.05), because of the community's traditional labor division. The seventh PC was therefore strongly related to the third PC.

The eighth PC represented food insecurity and had an eigenvalue of only a third of that of the first PC. The reproduction of the indicator's variance (79.3%) and its correlation with the PC (r=0.802) were adequate.

Each PC was calculated for 117 cases, minimum-maximum normalized and its average taken for each community (Nimasac n=38, Paquí n=44, Barraneché n=35). The average lack of income was significantly higher in Paquí than in Barraneché (p<0.05). The average division of labor was significantly greater in Barraneché than in Nimasac (p<0.01) and Paquí (p<0.01). Sociocultural development was significantly higher in Paquí than in Nimasac (p<0.01) and Barraneché (p<0.05).

3.4.2. The vulnerability index

Nimasac was the most vulnerable of the three communities with an average vulnerability index score of 43.01% +/- 3.92% SEM, followed by Paquí with an average vulnerability index of 42.77% +/- 2.24% SEM and Barraneché with the lowest average vulnerability index of 40.99% +/- 4.00% SEM (figure 4, index 1). The communities' averages were not significantly different from one another.

Figure 3. Average percentage of the PC +/- standard error of the mean (SEM) in the three communities

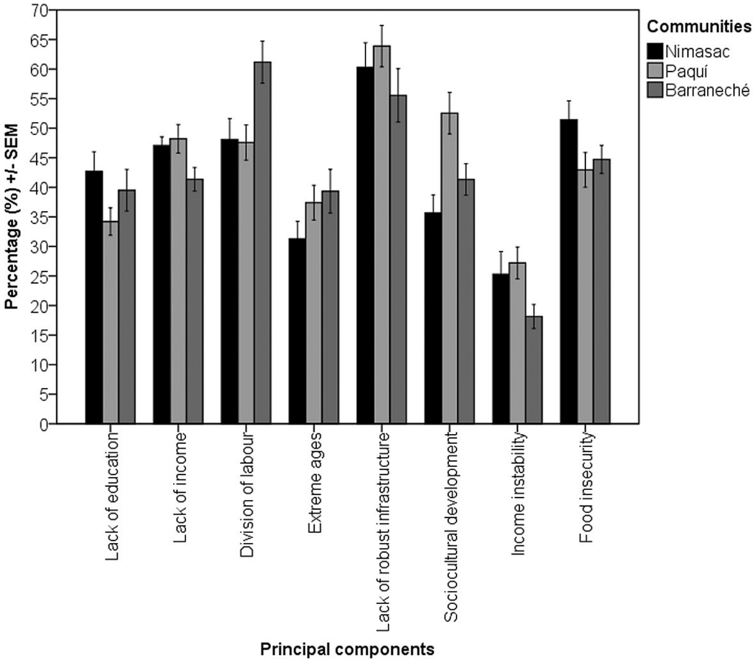
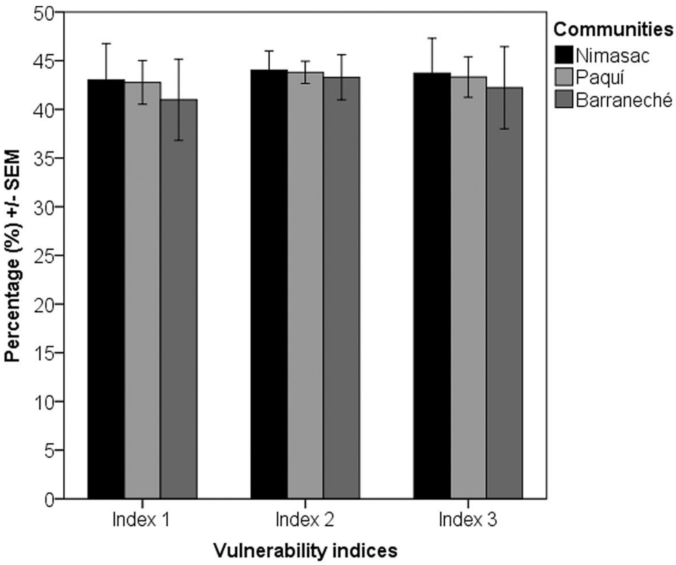


Figure 4. Average percentage of the three vulnerability indices +/- SEM in the three communities.



Each index was calculated for 117 cases, minimum-maximum normalized and its average taken for each community (Nimasac n=38, Paquí n=44, Barraneché n=35). Index 1 was constructed using PCA, index 2 using equal weights and index 3 using equal weights and two sub-indices for sensitivity and adaptive capacity. There were no significant differences between communities or indices.

3.4.3. Sensitivity analysis

In the two additional indices that were constructed to analyze the sensitivity of the results the communities adopted very similar average vulnerability index values and their order was maintained. In none of the additional vulnerability indices the differences between the communities' averages were significant (figure 3).

The similarity between the indices was reflected in the statistically significant correlation between the three indices ($p<0.001$) and the conservation of ranking amongst the 117 cases: Between index 1 and index 2, each case gained or lost an average of 6 positions (+30 and -19 positions in the most extreme cases). Between index 1 and index 3, each case also gained or lost an average of 6 positions (+34 and -18 positions in the most extreme cases). Between index 2 and index 3, both constructed using equal weights, each case gained or lost an average of only 2 positions (+6 and -10 in the most extreme cases).

Index 3 was composed of a sensitivity and an adaptive capacity sub-index. Paquí had the lowest sensitivity (35.28% +/- 1.34% SEM), followed by Nimasac (35.70% +/- 2.13% SEM) and Barraneché (36.28% +/- 2.09% SEM), which was the most sensitive community. Nevertheless, Barraneché was also the community with the highest adaptive capacity (48.70% +/- 2.91% SEM), followed by Paquí (46.47% +/- 1.76% SEM) and Nimasac (46.46% +/- 2.72% SEM). The communities' average sensitivities and adaptive capacities were not significantly different from one another.

4. Discussion

4.1. Contextual vulnerability of the communal forests of the municipality Totonicapán

Currently, Totonicapán's communal forests share many of the characteristics of sustainably managed commons, nevertheless some premises are at stake and the forests' contextual vulnerability is likely to increase in the future (Ostrom, 2009 and 2011):

Those who exploit the communal forests are also negatively affected by their overexploitation. Based on this premise, carpentry livelihoods used to guarantee the sustainable use of forest resources. Yet nowadays, it has led to the almost complete conservation of forests in Totonicapán and exploitation of those in poorer municipalities, possibly concealing a net ecosystemic degradation and unsustainable use of forest resources at the regional level.

The users culturally identify with the forests, which form an integral part of Mayan world view. They are familiar with their ecological characteristics and productivity, but lack complete information on the state of the resource, which is why rules ensure a sustainable use: Boundary rules which restrict forest access to local members of similar socioeconomic status; Position rules by which offices such as the forest guard rotate amongst members; Scope rules which delimit the forests' extension; Choice and aggregation rules which define that cutting wood requires permission, but NTFP and fuelwood collection for self-consumption does not; Payoff rules which guarantee that violations are reported and sanctioned. The members adhere to these rules as they consider relationships and their reputation within the community as part of the cost-benefit equation. Yet, globalization and widespread emigration to the USA degrade social capital and coherence, cultural identity and traditional knowledge of the ecological system (O'Brien et al., 2004b).

4.2. Contextual vulnerability of the population of the municipality Totonicapán

The PCA and its by far most important first PC demonstrate that education is Totonicapán's most promising opportunity to strengthen its adaptive capacity, nourish socioeconomic development and reduce its dependency on climate sensitive agriculture and livestock. In the context of the intense historic exploitation of soils in the region, current population growth, continuing plot fragmentation and agricultural intensification, Totonicapán's agriculture is extremely vulnerable to climate change, which is putting the municipality's food sovereignty and food security further at risk. Education directly influences the livelihood choices people make, and indirectly determines people's access to profitable income-generating activities that can substitute laborious farming with the purchase of its products. It thereby strongly contributes to the transition between traditional and modern livelihoods, which may come at the cost of social capital. The same is true for emigration to the USA and the sending of remittances, which economically transform the region, but disintegrate families and communities. Therefore, for education not to be a double-edged sword, it is important to complement modern knowhow with traditional knowledge and thereby foster cultural identity and ultimately social capital, which is crucial for a successful communal forest management. The indigenous language k'iche' is an important part of cultural identity and necessary to access much of the traditional knowledge, including adaptation strategies, especially in agriculture. Although the community with the best education spoke the least k'iche', bilingualism was not associated with education in the PCA and was far less important to the household's vulnerability in the form of the sixth PC of sociocultural development. Nevertheless, it is convenient for education to promote the indigenous language alongside traditional knowledge.

Moreover, the results confirm that there is a strong link between socioeconomic poverty and dependency on natural resources (MEA, 2005). Particularly lack of income and forest reliance are related as the two indicators were summarized by the second PC. For those households which are both poor and natural resource dependent climate change is a two-fold challenge. Lower crop and forest species suitability to the changing abiotic conditions, and exposure to droughts and extreme hydrometeorological events reduce farm yields and forest productivity and ultimately raise the price of basic grains and fuelwood, especially affecting those households most dependent on natural resources, which are the poorer ones least able to compensate for the losses. The transitional subsidized introduction of gas could be an ad-hoc measure to lower the forest reliance of low-income households and free up women's time otherwise caught up in the collection of fuelwood which can now be used for study or income-generating activities. Although not a sustainable solution, the transitional subsidized introduction of gas could quickly reduce the communities' sensitivity to a point where the households themselves can come forward with long-term adaptation strategies.

Considering sensitivity and the economic indicators analyzed, Barraneché stood out as the community with the least diversified income and highest dependency due to a lower rate of female economic activity. Nevertheless, Barraneché's households also profited from less income instability and surprisingly had the highest median annual income of all three communities. Barraneché's economic wellbeing is mostly based on carpentry, but climate change and forest degradation may decrease its profitability by raising the price of wood. This could promote more female economic activity and income diversification. The third PC underlines that the families themselves play an active part in shaping their sensitivity to climate change. It also reminds us that climate change vulnerability contains a complex human dimension that renders one-size-fits-all approaches insufficient, even at scales as large as the municipality Totonicapán. This is also true for the fourth PC, extreme ages, where distribution of the elderly varied significantly between households in Paquí and Nimasac. Whilst few households in Nimasac are very sensitive to climate change, more households in Paquí are moderately sensitive. The results imply different adaptation strategies in the two communities. An overarching theme has been the socioeconomic disadvantage of women. With emigration raising the female to male ratio, gender equality is becoming increasingly important for successful climate change adaptation. Households with female heads of household who do not receive remittances should be prioritized by public programmes aimed at climate change adaptation.

Despite differences between the communities on the single indicator level, they classified as almost equally vulnerable in all three indices, indicating that the result is robust. On one hand, this implies that no community's adaptation has priority over that of another, and on the other hand that community-tailored adaptation should be a priority to all. On a methodological note, the sensitivity analysis demonstrated that aggregation using equal weights, which is less laborious than PCA and does not require a statistical package, is just as legitimate under the study's protocol. Whether linear aggregation and compensation between indicators and sub-indices of sensitivity and adaptive capacity is true to life remains to be validated.

5. Conclusions

The present study is a plea for the contextual vulnerability approach. It has identified socioeconomic cause-effect relationships, adaptation strategies and significant location specific differences even on a scale as large as the municipality Totonicapán. It also has laid the groundwork for more systematic and quantitative research on the link between emigration, social capital and communal forest management. Future efforts should be directed towards analyzing the large and well-conserved communal municipal forest and its co-management by the municipality and association of the municipality's communities; and the contextual vulnerability of the surrounding municipalities' forests.

6. References

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