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Assessing Household Vulnerability to Climate Variability in Far-West Nepal

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Abstract

This study analyzed the trends of climatic parameters (temperature and precipitation) over the last three decades (1977-2008) and assessed vulnerability of households to climate variability, i.e., extreme weather events, using two sets of indicators, (1) livelihood assets as indicators of adaptive capacity, and (2) indicators of sensitivity and exposure. The study was carried out in two communities of Kailali district, Nepal, one susceptible to floods and the other to droughts. A vulnerability index, computed from livelihood assets indicators developed in consultation with local people, was used to categorize the surveyed households into three vulnerability groups. Indicators of adaptive capacity and indicators of sensitivity and exposure differed significantly across these groups. The rising trend of extreme rainfall events and drought conditions have increased the vulnerability of agriculture based livelihoods in the study area. Adaptation measures were adopted by households depending on their endowment with key livelihood assets. Annual income, training and land holding size were identified as major adaptive capacity indicators, while distance of households from rivers was the key sensitivity and exposure factor. The findings suggest that programs aimed at facilitating adaptation to climate change and variability have to be integrated with disaster risk management and need to incorporate strategies for improving local livelihoods.

Key words: climate change, livelihood assets, vulnerability, adaptive capacity, adaptation.

1. Introduction

Like many other parts of the world, Nepal has been experiencing climate variability in recent decades. According to Shrestha et al. (1999), annual average temperature has increased by about 0.06ºC per year during 1971-1994. A higher rate of temperature increase at higher altitudes (Baidya et al., 2008; Shrestha et al., 1999) may accelerate the retreat of Himalayan glaciers (Bajracharya et al., 2007), eventually causing an increase in floods and landslides (Uprety et al., 2017). In addition, an increase in extreme rainfall events in Nepal has caused loss of lives, agricultural land and physical infrastructure, and will further worsen peoples' living conditions (Regmi and Adhikari, 2007). The dependency of developing countries' economies and livelihoods on climate sensitive sectors such as agriculture (Agrawala et al., 2003) exacerbates their vulnerability to climate change. The agriculture sector of Nepal is especially susceptible to water scarcity and extreme rainfall events (Gawith et al., 2017; Agrawala et al., 2003). WFP (2009) reported that winter droughts in 2008 and 2009 along with flood events, caused failure of crop production and food shortages in 40 out of 75 districts in Nepal. Vulnerability of peoples' livelihood in Nepal is further compounded by susceptibility to geomorphic hazards due to extreme mountain topography (Shrestha et al., 2005) as well as by political instability and insurgency, migration and dependency on remittances, and declining agricultural production (NCVST, 2009). However, marginalized groups are more vulnerable to climate change in Nepal (Macchi et al., 2015).

The definition of vulnerability varies from author to author. Exposure to threats or stresses, and capacity to respond to those threats and stresses are, however, the most elementary components of vulnerability (Timmerman, 1981; Cutter, 1993; Watts and Bohle, 1993; Adger, 2006). Vulnerability can, therefore, on the most basic level be defined as a function of exposure, sensitivity and adaptive capacity (Smit and Pilifosova, 2003).

Exposure is the intensity and nature of the stress to which a community is exposed; sensitivity is the degree to which the community is being affected by stress (IPCC, 2001); adaptive capacity is the capability of the community to adapt and to cope with changing conditions (Adger, 2006). Adaptation, finally, refers to the actions undertaken at different spatial scales to adapt and to cope (Smit and Wandel, 2006). Vulnerability can be categorized into bio-physical vulnerability, social vulnerability and a combination of both bio-physical and social vulnerability (Dolan and Walker, 2004). Brooks (2003) links biophysical vulnerability with hazards and their outcomes, and social vulnerability with the internal state or condition of communities. Vulnerability is, however, in most cases determined by both internal and external factors (Fussel, 2007), such as when famine events result not only from bio-physical hazards but also from inadequate entitlement to resources (Sen, 1981). Vulnerability assessments are capable of providing a framework for policy measures focusing on social issues such as poverty reduction and diversification of livelihoods (O'Brien et al., 2004), which can help to reduce the vulnerability of communities. In the context of climate change, vulnerability assessments are an essential tool to understand in which ways people are vulnerable to climatic stress (Eakin and Bojorquez-Tapia, 2008), to assess their needs, and to direct limited available resources towards those who are in a particular need of them (Sullivan and Meigh, 2005). Vulnerability assessments at national (Adger and Vincent, 2005) or sub-national (Cutter et al., 2003; O'Brien et al., 2004) level can give a broad picture from the policy perspective, but mask the variability at household level (Vincent, 2007). It is, therefore, necessary to identify key factors that facilitate adaptation at the household level (Smit and Wandel, 2006).

The conceptual framework of this paper builds upon the argument of Kelly and Adger (2000) that vulnerability is due to lack of resources, existing social conditions and structures that hinder the ability of people to cope with stresses. However, Burton et al

(1993) and Adger (2006) have stressed that vulnerability of a community to natural hazard depends also on the physical characteristic of their place and on dependency on natural resources. In congruence with recent research (Hahn et al., 2009; Deressa, 2008), we have therefore, included exposure and sensitivity factors in our assessments of vulnerability to climate change. This study was conducted in two biophysically distinct areas in Kailali district of Nepal, one affected by the flood and the other by drought. Its aim was to identify and assess farmer households' vulnerability to climate induced stress, and to examine the role of livelihood assets in their adaptive capacity.

2. Study area

Kailali district in the Far Western development region of Nepal (figure 1), is situated between 28°22′ to 29°05′ north latitude and 80°30′ to 81°18′ east longitude, covering about 3235 sq.km with a population of about 616,697. The elevation ranges from 109 m to 1950 m above mean sea level. The climate of the district is tropical, with an average maximum temperature of 30.50°C and an average minimum temperature of 17.70°C. The average annual rainfall is 1840 mm. The district has witnessed floods and winter drought consecutively for three years in 2007, 2008 and 2009.

Forest covers about 65 percent of district's total area. Agriculture covers only 27.8 percent of the district's area even though nearly fourth-fifth of the district's population depends on agriculture for their livelihood (DDC, 2007). The two studied communities, Godavari and Pawera, are situated close to the Budhi Tala and Mohana rivers, respectively. Godavari is situated in the Siwalik hills that border upon the Terai plains, and which are characterized by fragile geology, coarse textured shallow soil and steep slope, susceptible to landslides and erosion. Godavari is situated at about 30 km distance from the district headquarter. The area lacks essential infrastructure like roads and irrigation canals. The households, therefore depend on rain-fed irrigation, but were insufficient in water due to recent drought events. While Godavari is also affected by floods and storms, drought is the major climatic hazard. It is therefore referred to as the drought affected area. Pawera, situated in the Terai, at the northern rim of the Indo-Gangetic, is, on the other hand, affected mainly by floods and storms, and is therefore referred to as the flood affected area. It is easily accessible by road, and the district headquarter is at about 20 km distance from Pawera.

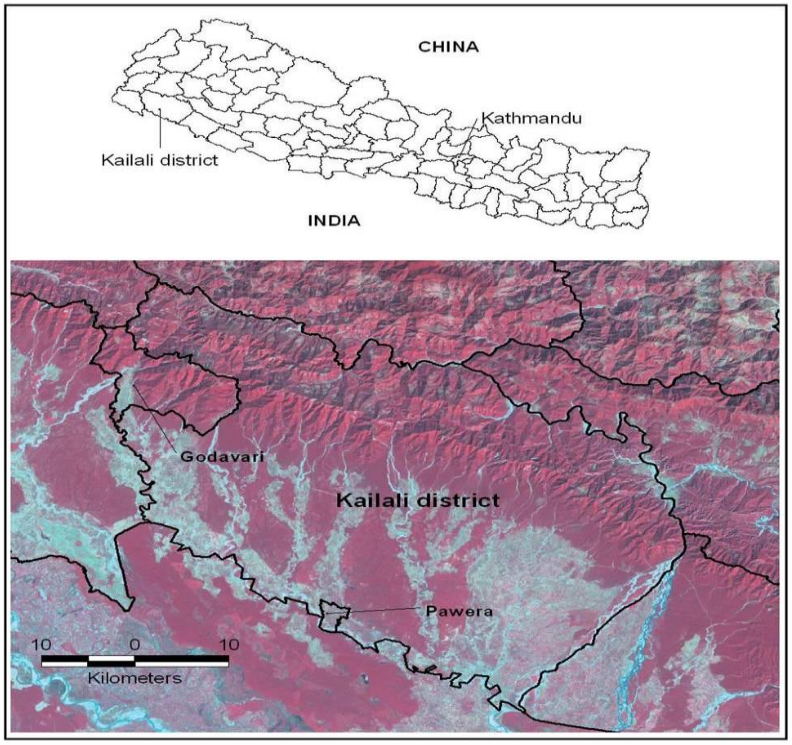

Figure 1: Location of Study Area

Agriculture is the major occupation of the households in both areas. Paddy and wheat are the major crops. In both areas, labor is the major off-farm income source, mostly in the form of seasonal unskilled labor like agricultural labor or employment as rickshaw drivers, porters, gatekeepers etc.

3. Methodology

A household questionnaire survey was conducted from October to December 2009. Simple random sampling was employed for selecting 98 households in the flood affected area and 82 households in the drought affected area. The questionnaire was designed to collect information about indicators of adaptive capacity, sensitivity and exposure, of livelihood strategies, and of adaptation measures. Key informants interviews and group discussions were conducted mainly to collect information on past natural disaster events. The data were analyzed and interpreted, using ANOVA test, along with quantitative statistical tools such as principal component analysis and linear multiple regression using Statistical Package for Social Sciences (SPSS) Version 16.

Climatic data from 1977 to 2008 of two weather stations (Dhangadi and Godavari) located in and around the study area were collected from the Department of Hydrology and Meteorology of Nepal. Indices of temperature and precipitation, as suggested by Zhang and Yang (2004), were calculated for analyzing trends of temperature and precipitation. Data homogeneity tests and student's t test for testing significance of trends were performed using RclimDex software package (available at http://cccma.seos.uvic.ca/ETCCDMI/software.shtml).

Indicators are widely used for the quantitative assessment of vulnerability (Eakin and Bojorquez-Tapia, 2008). The indicators influencing vulnerability and adaptive capacity are extensively dealt with in the literature (Yohe and Tol, 2002; Adger and Vincent, 2005; Eakin and Bojorquez-Tapia, 2008). The computation of composite scores for indicators has also been widely discussed (Vincent, 2007; Adger and Vincent, 2005: Cutter et al., 2003; Eakin and Bojorquez-Tapia, 2008). Indicators of livelihood assets as described in DFID (1999) play a vital role in determining the adaptive capacity of households (Nelson et al., 2010). Hinkel (2011) argue that uses of vulnerability indicators should be limited to identifying vulnerable regions or sectors and that the process of indicator selection is often not transparent. Moreover, the emphasis on expert judgment has led to a neglect of local peoples' judgment on the importance of vulnerability indicators (Eakin and Bojorquez-Tapia, 2008).

In recognition of these deficiencies, this study has used indicators for identifying vulnerable households, and has employed a participatory process of experts and local people selecting indicators and judging their relative importance for pairwise comparison to assign weights to the indicators. The indicators belonging to a particular livelihood asset were assigned different weights and their sum was equaled to 1 (Appendix A). The weights were derived using AHP. AHP is a multi-criteria decision analysis tool (Saaty, 1980), which derives weights solely based on pair wise comparison of the indicators. The pair wise scores were quite similar in both areas, so for convenience of calculation only single pair wise comparison scores were used. The possible reason for similarity of weights could be similar socio-cultural lifestyle based on agriculture.

All indicators were categorized into three groups, i.e. low, medium and high, with scores of 0.33, 0.67 and 1, respectively, in consultation with local people during group discussions. Group discussions were conducted in both areas. Groups comprised of 8 local people and 2 extension officers working for a non-governmental organization in the flood affected area, and of 5 local people in the drought affected area and 1 local government officer. Each participant was provided with a list of livelihood assets, prepared by the research team in consideration of local context and literature. The participants were free to add or remove any assets that they found missing or irrelevant. The participants were requested to assign weights to each livelihood asset, ranging from 1 (equal importance) to 9 (extreme importance of one asset over other assets). The criteria and rating scale for adaptive capacity and sensitivity and exposure indicators is shown in Appendix B and C.

Ranking of indicators by local people was strongly determined by their livelihood. As livelihoods depend mainly on agriculture, people considered other physical assets as relevant only, provided they have enough land for farming. They considered formal education as important for their children but as not so important for elders who, they thought, would benefit more from trainings. Farmers were also convinced that more income sources can earn higher income. They, accordingly, assigned more weight to income sources than to other indicators of financial assets. They also assigned more weight to water availability as they believed crop diversity can be increased only if they have enough water.

Adaptive capacity index was calculated as expressed in equation 1

Adaptive capacity index = $\sum H_{ij} + \sum P_{ij} + \sum F_{ij} + \sum S_{ij} + \sum N_{ij}$--------------------------Equation (1)

Where, H_{ij}= i^{th} human capital indicator for j^{th} household

P_{ij}= i^{th} physical capital indicator for j^{th} household

F_{ij}= i^{th} financial capital indicator for j^{th} household

S_{ij}= i^{th} social capital indicator for j^{th} household

N_{ij}= i^{th} natural capital indicator for j^{th} household

The exposure and sensitivity are considered as inseparable elements of vulnerability at the household level (Smit and Wandel, 2006). To overcome inconsistencies, equal weights were assigned to each indicator. Exposure and sensitivity index was calculated as follows:

Exposure and Sensitivity index = PF+PE+RD+FI+DR----------------------------Equation (2)

Where, PF= Proportion of agricultural based income to total income

PE= Prior exposure to disasters (flood or drought)

RD= Time taken for recovery from disasters

FI= Months without sufficient food

DR= Distance from river

Agriculture, being climate sensitive sector, the households which derive majority of their income from agriculture was considered as sensitive to climate variability. According to local experts, repeated exposure of households to disaster diminishes households' resources and increases their vulnerability. Since loss of agricultural land and crops causes' limited food supply, the number of months without sufficient food was chosen as a proxy of sensitivity of households to climate variability. In both areas, households closer to a river were reported to sustain more damage from floods than households farther from the river. Distance from rivers was, therefore, selected as an indicator of exposure.

The total score of both indices i.e. adaptive capacity index and exposure and sensitivity index was converted into a scale of 0 to 1 for computing vulnerability index. Deressa et al. (2008) calculated the vulnerability index as shown in equation 3.

Vulnerability index (VI) = (Adaptive capacity index) - (Exposure and sensitivity index) ---- Equation 3

According to equation 3, higher net values of the index mean lesser degree of vulnerability. However, since the term "vulnerability" has a negative connotation (Adger, 2006), as the degree of vulnerability increases with the degree of exposure and sensitivity and presence of adaptive capacity lessens the degree vulnerability. We express vulnerability as residual after deducting adaptive capacity from exposure and sensitivity, as given in Equation 4.

Vulnerability index (VI) = (Exposure and sensitivity index) - (Adaptive capacity index) ----Equation 4

The vulnerability index, which theoretically ranges from -0.67 to 0.67, was divided into three equal intervals: less vulnerable (-0.67 to -0.22), moderately vulnerable (-0.22 to 0.23), and highly vulnerable (0.23 to 0.67). One-way ANOVA test was use to test the significance of indicators among the three categories. PCA with Varimax rotation was performed separately (for the drought and the flood affected area) for the selection of variables. To identify the key factors influencing vulnerability of households to climate variability, variables were input in a stepwise regression. The vulnerability index was used as dependent variable; only selected independent variables, those having higher factor loadings, were input in regression analysis. The multiple regression models can be expressed as:

$$Y= a+C_1X_1+C_2X_2+C_3X_3+\ldots\ldots\ldots\ldots C_nX_n,$$

Where Y= dependent variable (vulnerability index), X= independent variables (indicators of adaptive capacity, exposure and sensitivity), a= intercept (constant), and C_1, C_2, C_3…...C_n= coefficient of independent variables X_1, X_2, X_3……..X_n. The probability of an independent variable to enter the model was F<= 0.05 and probability to remove at F>= 0.10.

4. Results and discussion

4.1 Trends of temperature and rainfall

The study area has been experiencing trends of rising temperatures and declining precipitation over the past three decades. The increasing trend of temperature indices such as monthly minimum value and monthly maximum value of daily minimum temperature, warm nights etc. matches with trends of other stations in lowland Nepal as reported by Baidya et al. (2008). The trend of temperature indices was, however, found to be statistically insignificant, except for the trend of cool nights, which are increasing in number at a rate of 3 days per decade (P value <0.05). Trend analysis showed that annual average maximum temperature has been increasing at the rate of 0.19°C per decade (Figure-2a) and that annual average minimum temperature has increased at the rate of 0.01°C per decade (Figure 2b). Annual average maximum temperature has remained above 30°C since the year 2000. The local people also perceived the number of hot days has increased and that, correspondingly, the number of cold days has decreased. They felt that the occurrence of mosquitoes even in the months of November and December was a clear indication of a rise in temperature.

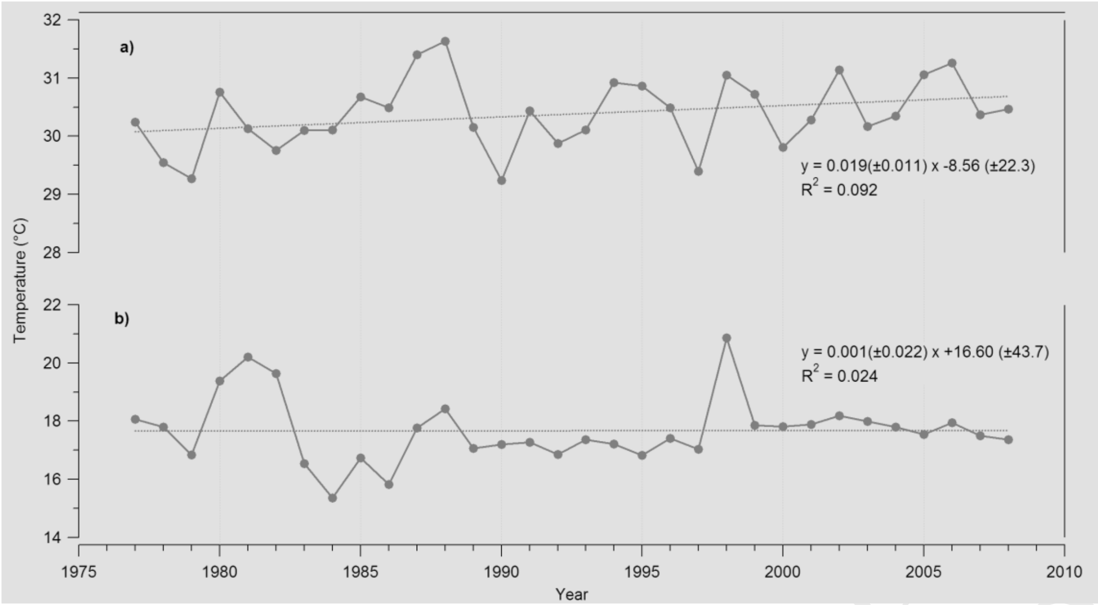

Figure 2: Trend of temperature (a) Annual average maximum temperature (b) Annual average minimum temperature.

Three indicators of the Expert Team on Climate Change and Detection and Indices (ETCCDMI) for precipitation were analyzed. Moderately rainy days, very wet days and extremely wet days were calculated following the methodology of Goswami et al. (2006). The rainfall data suggest that during 1977-2008, the total rainfall has declined in the flood affected area and in the drought affected area at a rate of 55 mm and 43 mm per decade, respectively (Table 1). In the drought affected area, the number of consecutive dry days has increased and the number of consecutive wet days has decreased significantly. A similar trend was observed in the flood affected area. Key informants opined that deforestation and increased heavy precipitation events in elevated areas have triggered floods in the low lying areas of Kailali district.

Table 1: Trend of precipitation during 1977-2008

Indicators (Units)	**Definition**	**Dhangadi (Flood affected area)**	**Godavari (Drought affected area)**
Consecutive dry days (CDD)	Maximum number of consecutive days with rainfall<1mm	0.955	1.989*
Consecutive wet days (CWD)	Maximum number of consecutive days with rainfall>=1mm	-0.015	-0.188*
Annual total wet-day precipitation	Annual total precipitation in wet days (rainfall>=1mm)	-0.556	-0.430
Moderate rainy days	>5mm and <100 mm of rainfall in a day	8.364	-7.774
Very wet days	>100 mm and <150 mm of rainfall in a day	0.04	0.032
Extremely wet days	>150 mm of rainfall in a day	-0.007	0.01

* Significant at 0.05 significant levels

There was a high inter-decadal variation for monsoonal rainfall pattern during June to August with relatively shorter monsoon duration in the recent years compared to the past. During 1999-2008, monsoon started on average in the third week of May while in earlier decades (1979-1988 or 1989-1998) it had started in the second week of June. Similarly, the monsoon has ended on average in the last week of August in the years after 2003, while before 2003 it had lasted until the end of September. In comparison to other decades, the period 1999-2008, saw a decline in the amount of rainfall for all summer monsoon months. In both areas, there is a declining trend of winter rainfall (December to February) with almost zero precipitation in November and December. Climatic data analysis revealed that drought conditions prevailed in both areas. However, households in the flood affected area were not as badly affected by the decline in winter rainfall as households in the drought affected mainly on account of their having access to irrigation facilities. The observed climatic variables suggest that the area has experienced some climatic variability. The drought conditions prevailed in the areas, as revealed by climatic data analysis, the households in the flood affected area were not as badly affected by the decline in winter rainfall as households in the drought affected mainly on account on their having access to irrigation facilities.

4.2 Vulnerability assessment of households

Based on the computed vulnerability index, 70 percent of households in the flood affected area were rated as moderately vulnerable, 24 percent as highly vulnerable, and 6 percent with low vulnerability. In the drought affected area, 45, 53 and 2 percent of households were categorized to the high, moderate and low vulnerability groups, respectively. Despite having relatively higher adaptive capacity (an index value ranging from 0.65 to 0.74), 10 percent of households in the flood affected area were ranked as highly vulnerable because their sensitivity and exposure index values were also high (index value above 0.85). One-way ANOVA test of livelihood assets showed that physical, financial and human assets were significantly different among vulnerable groups in the flood affected area, while only financial and human assets were significantly different in the drought affected area (Table 2). It was found that while the group with low vulnerability does not rank first with respect to all livelihood assets, the high vulnerability group always ranks last.

Table 2: Mean scores of adaptive capacity index for different vulnerability groups

Indicators	Flood affected area Vulnerability group				Drought affected area Vulnerability group			
	Low	Moderate	High	F value	Low	Moderate	High	F value
Physical	0.77	0.70	0.62	3.55**	0.65	0.50	0.44	2.98
Financial	0.78	0.64	0.52	7.63	0.72	0.45	0.41	17.68*
Human	0.54	0.62	0.49	3.12**	0.43	0.30	0.25	4.73*
Social	0.73	0.63	0.66	2.11*	0.64	0.71	0.67	0.44
Natural	0.64	0.63	0.63	0.42	0.82	0.75	0.70	1.19

Note: *, **Significant at 0.05 and 0.01, respectively

The role of livelihood assets in improving the adaptive capacity of households is explained below:

a. Physical assets: Households buy livestock such as goats from the income generated from non-farm sources to be sold again in times of emergency. Owning a radio and a telephone are vital sources of information on local climate. People reported that forecasts of heavy rainfall and floods by the local radio stations help them take up early preparedness measures, like shifting property to the upper storey of their house.

b. Financial assets: In both areas, female co-operative groups provide households with loans without any collateral at a low interest rate of 20 percent per year, while local money lenders charge about 48-60 percent per year. Emergency funds are available for repairing houses damaged by floods and storms.

c. Human assets: In both areas, household members with more than 11 years of education are engaged in high income generating activities either as staff at government offices or as schoolteachers.

d. Social assets: Self-help groups such as farmer's groups and female co-operatives are supported by non-governmental agencies in the flood affected area only. Benefits include trainings and loan at low interest. Community practices such as helping flood victims, donating goods and labor, and sometimes lending money without interest rate were reported in both areas.

e. Natural assets: In the flood affected area, water for cropping is available round the year and households are thus unaffected by winter drought; households in the drought affected area, on the other hand, are affected because they depend on rainwater for cropping. Households in the flood affected area cultivate a diversity of crops to mitigate crop failures and to decrease their exposure to price fluctuations.

Indicators of sensitivity and exposure were found to differ significantly between vulnerability groups in both areas (Table 3). Households in both areas, which had expanded agricultural land and housing area onto the river banks, reported more flood damage than others. Losses of crops and agricultural land for three years in a row had deprived households of resources, while buying food, repairing houses etc., had increased their expenditure. To fulfill their needs, highly vulnerable groups depend strongly on low-paid off-farm income.

Table 3: Mean scores of sensitivity and exposure index for different vulnerability groups

Indicators	Flood affected area Vulnerability group				Drought affected area Vulnerability group			
	Low	Moderate	High	F value	Low	Moderate	High	F value
DR	0.45	0.76	0.97	17.39*	0.35	0.70	0.85	7.34*
PF	0.35	0.44	0.57	8.64*	0.35	0.62	0.73	12.54*
RD	0.55	0.67	0.82	10.14*	0.35	0.52	0.58	4.00**
FI	0.51	0.83	0.98	10.67*	0.35	0.80	0.96	14.15*
PE	0.46	0.64	0.97	13.55*	0.35	0.41	0.77	10.40*

Note: *, **Significant at 0.05 and 0.01, respectively

The average adaptive capacity of households was comparatively higher (an index of 0.68) in the flood affected area than (0.51) in the drought affected area (0.51). Basic facilities like roads, higher education and markets were more easily accessible in the flood affected area than in the drought affected area. The average sensitivity and exposure index of households were 0.69 and 0.70 in the flood and in the drought affected area, respectively. Households in the drought affected area sustained less damage due to floods than households in the flood affected area but were exposed to drought as well. Government and non-government organizations have carried out more efforts in the flood affected area than in the drought affected area, possibly because of the greater geographical remoteness of the drought affected area. Therefore, vulnerability of households in the drought affected area to climatic variability is exacerbated by exposure to natural disasters as well as by geographical remoteness and lack of access to basic infrastructures and facilities.

4.3 Factors affecting the vulnerability of households

To identify factors affecting vulnerability, 21 variables were used initially to identify the significant variables with higher factor loadings employing Principal Component Analysis technique and then those variables were used in a stepwise regression analysis to identify the significant factors of vulnerability. Bartlett test of sphericity was at $p<0.01$ significant level. The threshold value for the overall measure of sampling adequacy was 0.50 and was examined for each variable before proceeding for PCA (Hair et al., 2009). Indicators which did not meet the above mentioned criteria were dropped from the analysis. The factor loadings above 0.50 and Eigen values greater than 1 were considered as significant variables for extraction of factors.

4.3.1 Flood affected area

For the flood affected area, the principal component analysis extracted 17 variables out of 21 into 6 components with cumulative variance of 68.22% (Table 4). Component 1 is related to 'agricultural production'. Households with less land holding area had a higher number of months without sufficient food. Component 2 is about 'household economy'. This shows that households with literate members earn more income than those with illiterate members. Component 3 is characterized by age-income diversity. This means that household members who have reached labor age are involved in different income generation activities. Non-governmental organizations have provided skill development training, including disaster risk management training to the members of the self-help groups. Training, participation and affiliation to social groups were inversely associated with time taken to recover from disaster in Component 4, which can be labeled as 'benefits of group affiliation'. The households closer to rivers were affected by the floods repeatedly. Thus, the inverse association between distance from river and prior exposure to disasters in Component 5 is labeled as 'topographical exposure'. Crop diversity and availability of water were found to be positively associated. Component 6 is characterized by only 'natural capital'.

Table 4: Results of principal component analysis with Varimax rotation for the flood affected area

Variables	**Rotated Factor Loadings**					
	1	**2**	**3**	**4**	**5**	**6**
Land area	.713					
Months without sufficient food	-.632					
Access to modern farming tools	.617					
Livestock unit	.607					
Annual Income		.773				
Percent of literate members		.733				
Possession of Savings		.720				
Labor aged members			.780			
Income diversity			.754			
Training				.784		
Participation				.732		
Time taken to recover from disasters				-.558		
Affiliation to social groups				.545		
Distance from river					.745	
Prior exposure to disasters					-.566	
Crop diversity						.763
Water availability for cropping						.743
Eigen values	3.70	2.21	1.64	1.45	1.21	1.05
Percent of variance	23.77	12.99	9.6	8.51	7.12	6.23

The model of stepwise regression was free from collinearity influence as tolerance values of variables were above 0.90 and variance inflation factors (VIF) ranged from 1 to 1.05. Of 6 variables with the highest loading, only three variables showed a significant relation with the vulnerability index. Table 5 shows that annual income of households was the major factor influencing vulnerability of households as this was the first variable included in the model during stepwise regression. The other major factors that influence vulnerability include distance from river and training received by households. Model 1 was moderate (R^2=.408, P<0.01) in predicting vulnerability of households, while model 2 and 3 (R^2=0.686 and .692 respectively, P<0.001) were good for prediction of household vulnerability.

Table 5: Factors of vulnerability in flood affected area

Models	Constant	Independent Variables			F value	R^2
		Annual income	Distance from river	Training		
Model 1	1.883	-.385[a]			52.466**	.408
Model 2	2.075	-.342[a]	-.186[a]		81.832**	.686
Model 3	2.074	-.339[a]	-.184[a]	-.137[a]	58.763**	.692

Note: [a] Unstandardized coefficients, **Significantly different at 0.01 level

The vulnerability of households decreases with increasing income level, distance from river and participation in training. Households with low income were unable to fully repair their houses. The high vulnerability households could not even afford to pay the interest rates of loans offered through emergency funds. Households with high annual income, on the other hand, have access to savings or to the emergency fund for a complete repair of their houses. Hence, households with low annual income required a longer time for recovery after flood damage than households with high income. Frequency and intensity of damage to households were higher close to the river than further away from the river. Training in skill development and disaster risk management improved their livelihood and coping capacity and helped to reduce their vulnerability.

4.3.2 **Drought affected area**

For the drought affected area, the principal component analysis extracted 16 variables that explained cumulative variance of 72.26 % (Table 6). The variables of Component 1 are associated with financial, human and physical capital, and labeled as 'affordability'. High annual income enables households to invest in education of family members and electronic devices like radio. Educated members are also qualified for high paying jobs. Component 2 consisting of social and financial capital was labeled as 'benefits of social affiliation'. Component 3 was labeled as 'age-income diversity'. Similar to the flood affected area, households with a higher number of labor aged members were involved in more income generating activities. The variables in Component 4 are related to 'physical asset' only. Component 5 is labeled as 'agricultural production'. Availability of water increased crop diversity, which in turn provided alternative food options. The variables of component 6 are labeled as 'sensitivity and exposure' of households.

The tolerance values of each variable in the models were above 0.85 and variance inflation factors (VIF) was more than 1 and less than 1.25. The multiple regression analysis (Table 7) showed that annual income was the major factor influencing vulnerability, followed by distance of households from river and by land holding size. Models 1 and 2 were moderate (R^2=.405 and .527 respectively, $P<0.01$) in predicting vulnerability of households, while model 3 (R^2=0.602, $P<0.001$) was good for prediction of household vulnerability.

Table 6: Results of principal component analysis with Varimax rotation for the drought affected area

Variables	Rotated factor loadings					
	1	2	3	4	5	6
Annual Income	.843					
Percent of literate members	.790					
Possession of Savings	.734					
Access to information sources	.739					
Affiliation to social groups		.912				
Participation		.869				
Access to credit		.739				
Labor aged members			.849			
Income diversity			.791			
Land area holding				.674		
Livestock unit				.595		
Crop diversity					.588	
Months without sufficient food					-.488	
Availability of water for cropping					.469	
Distance from river						-.621
Time taken to recover from disasters						.546
Eigen Value	3.56	2.13	1.71	1.66	1.23	1.09.
Percent of Variance	22.29	14.50	10.70	10.41	7.71	6.65

Table 7: Factors of vulnerability in drought affected area

Models	Constant	Independent Variables			F value	R^2
		Annual income (X_1)	Distance from river (X_2)	Landholding size (X_3)		
Model 1	1.166	-.227 [a]			15.721	.405
Model 2	1.484	-.221 [a]	-.152 [a]		15.198	.527
Model 3	1.209	-.156 [a]	-.189 [a]	-.147 [a]	13.329	.602

Note: [a] Unstandardized coefficients, **Significantly different at 0.01 level

The income level of households improved their access to resources such as information sources, education and savings, which are vital in reducing their vulnerability. Members of the highly vulnerable groups complained about not being able to afford agricultural inputs, improved crop varieties and repair damage due to floods and storms. Vulnerability of households is exacerbated by location closer to the river. Land is the major means of production and larger size of land holdings can influence households to invest in irrigation, fertilizer or drought hardy crop varieties to minimize their vulnerability.

4.4 Local adaptation measures

Communities rely on locally available resources and on traditional knowledge to adapt to climate change. Households with limited access to resources are in a state of 'adaptation deficit', i.e. unable or able to only a limited extent to adapt to threats posed by climate variability. Adaptation measures are divided into planned and autonomous adaptation measures. In this section, we examined types of adaptation measures adopted by the households belonging to different vulnerability groups.

4.4.1 Planned adaptation measures

The following were the adaptation measures adopted by communities with the help of external agencies and only limited to flood affected area.

(i) Physical measures: A gauging post has been set up on the bank of the river Mohana and an alarm is sounded using a manually operated siren, whenever the river rises above a defined risk level. Posts readings are transmitted to the district headquarter offices via telephone, and disseminated through the district by local radio stations. Non-governmental organizations provide communities with training and funds for setting up physical structures like check-dams and spurs, and for constructing temporary embankments by piling up sand bags, along with bamboos, and also by planting bamboo along the river bank. The households across different vulnerability groups benefitted with this measure.

(ii) Livelihood development measures: Households cultivate crops like water melon, peanuts, bitter gourd etc. on river beds during the dry season (November to May) when river beds are exposed due to low water level. River bed cultivation is carried out by farmers groups on both public and private land. Groups using public land have to pay a levy to the District Development Committee, which is then obliged to use the collected amount for fortifying river banks against floods. This measure was found to be widely adopted by households belonging to moderate and high vulnerability groups.

In the flood affected area, emergency funds were established with contributions from both local people and external agencies. Households raise their contributions by selling grains. Money from the emergency fund is used for conducting training programs and delivering loans for repairing houses damaged by storms. About 10 and 68 percent of households belonging to low and moderate group respectively, reported that they sought for loans from emergency fund for repairing houses

4.4.2 Autonomous adaptation measures

These measures were innovations by the communities themselves in response to unfavorable climatic conditions.

(i) Physical measures: In the flood affected area, households construct *machans, i.e. sheds* raised above ground by wooden pillars for storing domestic property, grain etc close to their houses. They also raise the plinth of their houses to prevent floods from entering. These measures require few resources and are therefore widely adopted by the highly vulnerable group. Medium and low vulnerability households add a storey to their houses to provide space for storing property during floods. In response to grain damage by floods in prior years, they either raise mud silos above ground or buy steel silos. Only few less vulnerable households can afford steel silos. In both areas, households belonging to moderate and highly vulnerable groups encroach upon forest and river buffer zones, following damage caused by climatic hazards or in an attempt to expand their agricultural land, increasing their vulnerability to flood and landslide damage.

(ii) Agricultural measures: The cultivation period of certain crops was reported to be earlier now than 10 years ago, mainly on account of the adoption of improved varieties of rice and wheat. Even though these varieties are drought resistant, they were adopted primarily to increase agricultural production and not in response to climatic variability. This confirms the findings of other studies that communities adopt measures in response to many factors and not only in response to climatic conditions (Stringer et al., 2009, Manandhar et al., 2011). In drought affected area, only 28 and 16 percent of households belonging to highly and moderate vulnerable groups respectively, could afford for improved crop varieties. Boring ground water, pumping river water and conserving natural springs are among the measures adopted for coping with drought conditions. In the drought affected area, the less vulnerable households have set up electrical water pumps for pumping river water for irrigation, which enabled them to harvest winter crops in 2008. Other households in the drought affected area diverted the excess flow of springs after heavy rainfall in 2008 to a pond and from there to their agricultural land for irrigation.

(iii) Seasonal migration and out-migration: About 32 and 72 percent of households' members belonging to highly vulnerable group in flood affected area and drought affected areas respectively, migrated to India for unskilled labor work. After crop failures in recent years, migration has increased dramatically in the drought affected area. A number of households belonging to medium vulnerable group have migrated out of both areas to locations close to their relatives, reporting floods and droughts as the sole reason for their migration.

5. Conclusion

The trend of gradually rising temperatures and extreme precipitation events, which has made people in Nepal vulnerable to climate induced stress, is also discernible in the study area, though statistically insignificant. From among the groups vulnerable to climatic stress to varying degrees, households in the high vulnerability group possess less livelihood assets than other vulnerability groups. Possession of a range of different livelihood assets enables households to cope with climatic hazards.

Comparing the two study sites it was found that a higher proportion of households were highly vulnerable in the drought affected area. The households in the drought affected area were exposed to more stresses (i.e. climatic hazards, geographic remoteness and inaccessibility of facilities) than households in the flood affected area. This suggests that even on district level, some communities are exposed to multiple stressors. Since people adopt adaptation measures in response not only to climate variability, the current focus on climate change should not detract from other stressors and priorities of communities. This means also that policy guidance and adaptation strategies formulated at district level will not adequately address the issue of vulnerability, as some communities require more context- and location-specific approaches. The study shows that sufficient annual income, training and land holding size can help to reduce the vulnerability of households. In addition, households who are situated further away from rivers were found to be less affected by flood impacts. The linking of livelihood- and exposure-related factors to hazards-related factors suggests that livelihood improvement programs (such as income generation, access to credits and training) should be integrated with disaster risk management programs (such as flood control measures). Such an integrated approach provides, moreover, an opportunity for mainstreaming climate change adaptation into development activities (Pouliotte et al., 2009).

The households belonging to low vulnerable groups could afford for more effective adaptation measures than moderate or low vulnerable groups. The degree of adoption of adaptation measures is consistent with vulnerability grouping. The resources used by households for coping with climatic hazards were not always sufficient and support of external agencies was thus crucial. The interventions of external agencies were focused on and limited to the flood affected area, as the havoc created by floods was more noticeable than the impact of droughts. Climatic hazards like drought, which recur on a moderate level, can, however, in the long run cause a greater cumulative loss than single big disasters (Hossen et al., 2009). Adequately responding to such hazards calls for a shift from disaster response to a precautionary approach. The list of indicators enlisted in this study is not exhaustive and varies depending on local context. Though employing a participatory approach is time consuming and though it may be difficult for making local people to understand the weighting system, involving local people can provide a more informed basis for designing location- and context-specific adaptation measures. Participatory approach helps understanding people's perception about importance of livelihood assets to reduce vulnerability and adopt adaptation measures. This helps to design more effective interventions by building upon current resources and strategies of local people to reduce their vulnerability.

References

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

Adger, W.N., Brooks, N., Bentham, G., Agnew, M. and Eriksen, S. (2004) New indicators of vulnerability and adaptive capacity. Tyndall Centre for Climate Change Research. Technical report 7.

Adger, W.N. and Vincent, K. (2005) Uncertainty in adaptive capacity. *Comptes Rendus Geosciences*, 337(4), 399-410.

Agrawala, S., Raksakulthai, V., van Alast, M., Larsen, P., Smith, J. and Reynolds, J. (2003) Development and climate change in Nepal: Focus on water resources and hydropower. Organization for Economic Co-operation and Development, COM/ENV/EPOC/DCD/DAC (2003)1/FINAL http://www.oecd.org/dataoecd/6/51/19742202.pdf (Accessed March 2009).

Bajracharya, S.R., Mool, P.K., and Shrestha, B.R. (2007) Impact of climate change on Himalayan glaciers and glacial lakes: Case studies on GLOF and associated hazards in Nepal and Bhutan. International Center for Integrated Mountain Development (ICIMOD), Nepal.

Baidya, S.K ., Shrestha, M. L. and Sheikh, M. M. (2008) Trends in daily climatic extremes of temperature and precipitation in Nepal. *Journal of Hydrology and Meteorology*, 5 (1), 38-51.

Brooks, N. (2003) Vulnerability, risk and adaptation: A conceptual framework. Tyndall Centre for Climate Change Research and Centre for Social and Economic Research on the Global Environment (CSERGE), School of Environmental Sciences University of East Anglia. Tyndall Center Working paper 38.

Cutter, S.L., Boruff, B.J. and Shirley, W.L. (2003) Social vulnerability to environmental hazards. *Social Science Quarterly*, 84 (2), 242-261.

DDC (2007) Kailali District Profile, 2007. District Development Committee, Kailali, Nepal.

Deressa, T.T., Hassan, R.M. and Ringler, C. (2008) Measuring Ethiopian farmers' vulnerability to climate change across regional states. IFPRI Discussion Paper 00806. International Food Policy Research Institute.

Deressa, T.T., Hassan, R.M., Ringler, C., Alemu, T. and Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Niles Basin of Ethiopia. *Global Environmental Change*, 19 (2), 248-255.

DFID, 1999. Sustainable Livelihood Guidance Sheets.
http://www.eldis.org/go/livelihoods/ (Accessed June, 2009).

Dolan, A.H. and Walker, I.J. (2004) Understanding vulnerability of coastal communities to climate change related risks. *Journal of Coastal research*, SI 39 (Proceedings of the 8th International Coastal Symposium), Itajaí, SC – Brazil, ISSN 0749-0208.
http://www.coastalcommunities.ns.ca/documents/dolan.pdf (Accessed March, 2009).

Eakin, H. and Bojorquez-Tapia, L.A. (2008) Insights into the composition of household vulnerability from multi-criteria decision analysis. *Global Environmental Change* 18(1) 112-127.

Fussel, H-M. (2007) Vulnerability: A generally applicable conceptual framework for climate change research. *Global Environmental Change*, 17 (2), 155-167.

Gawith, D., Hill, G. and Kingston., D. (2017). Determinants of Vulnerability to the hydrological effects of climate change in rural communities: evidence from Nepal. *Climate and Development*, 9 (1), 50-65.

Goswami, B.N., Venugopal, V., Sengupta, D., Madhusoodanan, M.S. and Xavier, P.K. (2006) Increasing trend of extreme rain events over India in a warming environment. *Science*, 314 (5804), 1442-1445.

Hahn, M.B., Riederer, A.M. and Foster, S.O. (2009) The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change—A case study in Mozambique. *Global Environmental Change*, 19 (1), 74-88.

Hair, J.F., Black, W.L., Babin, B.J., Anderson, R.E. and Tatham, R.L. (2007) Multivariate Data Analysis. Macmillan Publishing Company, New York, USA.

Heltberg, R., Bennett, P.S., Jorgensen, S.L. (2009) Addressing human vulnerability to climate change: Toward a 'no-regrets' approach. *Global Environmental Change*, 19 (1), 89-99.

Hinkel, J (2011) Indicators of vulnerability and adaptive capacity: towards a clarification of the science policy interface. *Global Environmental Change*, 21 (1), 198–208.

Hossen, M.A., Ahmed, S.U., Abedien, M.Z. (2009). Mainstreaming livelihood-centered approaches to disaster management project. Practical Action-Bangladesh, Dhaka, Bangladesh.

Intergovernmental Panel on Climate Change (IPCC, 2001) In: McCarthy, J., Canziani, O., Leary, N., Dokken, D. and White, K. (Eds.), Climate change 2001: Impacts, Adaptation, and Vulnerability. Cambridge: Cambridge University Press.

Kelly, P.M. and Adger, W.N. (2000) Theory and practice in assessing vulnerability to climate change and facilitating adaptation. *Climatic Change*, 47 (4), 325–352.

Macchi, M., Gurang, A.M., and Hoermann, B. (2015). Community perceptions and responses to climate variability and change in the Himalayas, *Climate and Development*, 7 (5), 414-425.

Manandhar, S., Schmidt-Vogt, D., Perret, S. and Kazama, F. (2011) Adapting cropping systems to climate change in Nepal: a cross-regional study of perceptions and practices. *Regional Environmental Change* 11 (2), 335-348.

Mirza, M. M. Q. (2003) Climate change and extreme weather events: can developing countries adapt? *Climate Policy* 3 (3), 233–248.

Mertz O., Halsnæs, Kirsten, Olesen, J.E. and Rasmussen, K. (2009) Adaptation to climate change in developing countries. *Environmental Management*, 43 (5), 743-752.

Moench, M. (2009) Responding to climate and other change processes in complex contexts: Challenges facing development of adaptive policy frameworks in the Ganga Basin. *Technological Forecasting and Social Change*, 77 (6), 975-986.

Nelson, R., Kokic, P., Crimp, S., Martin, P., Meinke, H., Howden, S.M., de Voil, P. and Nidumolu, U. (2010) The vulnerability of Australian rural communities to climate variability and change: Part II- Integrating impacts with adaptive capacity. *Environmental Science and Policy* 13 (1), 18-27.

NCVST (Nepal Climate Vulnerability Study Team, 2009) Vulnerability through the eyes of vulnerable: Climate change induced uncertainties and Nepal's development predicaments. Institute for Social and Environmental Transition-Nepal (ISET-N, Kathmandu) and Institute for Social and Environmental Transition (ISET, Boulder, Colorado) for Nepal Climate Vulnerability Study Team (NCVST) Kathmandu.

O'Brien, K., Leichenko, R., Kelkar, U., Venema, H., Aandahl, G., Tompkins, H., Javed, A., Bhadwal, S., Barg, S., Nygaard, L., and West, J. (2004) Mapping vulnerability to multiple stressors: climate change and globalization in India. *Global Environmental Change*, 14 (4), 303-313.

Pouliotte, J., Smit, B. and Westerhoff, L. (2009) Adaptation and development: Livelihoods and climate change in Subarnabad, Bangladesh. *Climate and Development*, 1 (1), 31-46.

Prowse, M. and Scott, L. (2008) Assets and Adaptation: an emerging debate. *IDS Bulletin*, 39 (4), 42-52.

Regmi, B.R. and Adhikari, A. (2007) Human Development Report 2007. Climate change and human development – risk and vulnerability in a warming world Country Case Study-Nepal. Local Initiatives for Biodiversity, Research and Development (LI-BIRD), Pokhara, Nepal.

Saaty, T.L. (1980) The Analytic Hierarchy Process, Planning, Priority Setting, Resource Allocation. McGraw-Hill, New York.

Shrestha, A.B., Wake, C.P., Mayewski, P.A., and Dibb, J.E. (1999) Maximum temperature trends in the Himalaya and its vicinity. An analysis based on temperature records from Nepal for the period 1971-94. *Journal of Climate,* 12 (9), 2775-2787.

Shrestha, K.L., Sherchand, K., Sapkota, B.K. and Ghimire, M. (2005) Socioeconomic and physical perspectives of water related vulnerability to climate change in the Bagmati river basin in Nepal. *Science and Culture*, 21 (7-8), 260-272.

Smit, B., Pilifosova, O. (2003) From adaptation to adaptive capacity and vulnerability reduction. In: Smith, J.B., Klein, R.J.T., Huq, S. (Eds.), Climate Change, Adaptive Capacity and Development. Imperial College Press, London.

Smit, B. and Wandel J. (2006) Adaptation, adaptive capacity and vulnerability. *Global Environmental Change,* 16 (3), 282-292.

Stringer, L.C., Dyer, J.C., Reed, M.S., Dougill, A.J., Twyman, C. and Mkwambisi, D. (2009) Adaptations to climate change, drought and desertification: local insights to enhance policy in southern Africa. *Environmental Science and Policy*, 12 (7), 785-765.

Sullivan, C. and Meigh, J. (2005) Targeting attention on local vulnerabilities using an integrated index approach: the example of the climate vulnerability index. *Water Science and Technology*, 51 (5), 69–78.

UNFCC (United Nations Framework on Climate Change, 2007) Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries. United Nations Framework Convention on Climate Change, Bonn Germany
http://unfccc.int/resource/docs/publications/impacts.pdf (Accessed January 2009).

Uprety, Y. Shrestha, U.B., Rokaya, M.B.,Shrestha, S., Chaudhary, R.P.,Thakali, A., Cockfield, G. and Hugo, A. (2017). Perceptions of climate change by highland communities in the Nepal Himalaya. *Climate and Development*, http://dx.doi.org/10.1080/17565529.2017.1304886 (Accessed May 2009).

Vincent, K. (2007) Uncertainty in adaptive capacity and the importance of scale. *Global Environmental Change*, 17 (1), 12-24.

Watts, M.J. and Bohle, H.G., 1993: The space of vulnerability: the causal structure of hunger and famine, *Progress in Human Geography*, 17, 1, 43-67.

WFP (World Food Program, 2009) Crop and food security assessment May 2009. World Food Program, Kathmandu Nepal http://home.wfp.org/stellent/groups/public/documents/ena/wfp202832.pdf (Accessed January 2009).

Yohe, G. and Tol, R. (2002) Indicators for social and economic coping capacity moving toward a working definition of adaptive capacity. *Global Environmental Change*, 12 (1), 25-40.

Zhang, X. and Yang, F. (2004) RClimDex (1.0) User Manual. Climate Research Branch Environment Canada, Ontario, Canada. http://cccma.seos.uvic.ca/ETCCDMI/RClimDex/RClimDexUserManual.doc (Accessed December 2009).