Assessing farmers' vulnerability to climate change: a case study in Karnataka, India

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Abstract

In the context of observed climate change impacts and their effect on agriculture and crop production, this study intends to assess the vulnerability of rural livelihoods through a study case in Karnataka, India. The social approach of climate change vulnerability in this study case includes defining and exploring factors that determine farmers' vulnerability in four villages. Key informant interviews, farmer workshops and structured household interviews were used for data collection. To analyse the data, we adapted and applied three vulnerability indices: Livelihood Vulnerability Index (LVI), LVI-IPCC and the Livelihood Effect Index (LEI), and used descriptive statistical methods. The data was analysed at two scales: whole sample-level and household level. The results from applying the indices for the whole-sample level show that this community's vulnerability to climate change is moderate, whereas the household-level results show that most of the households' vulnerability is high-very high, while 15 key drivers of vulnerability were identified. Results and limitations of the study are discussed under the rural livelihoods framework, in which the indices are based, allowing a better understanding of the social behaviouraltrends, as well as an holistic and integrated view of the climate change, agriculture, and livelihoods processes shaping vulnerability. We conclude that these indices, although a straightforward method to assess vulnerability, have limitations that could account for inaccuracies and inability to be standardised for benchmarking, therefore we stress the need for further research.

1. Introduction

Climate change poses a great threat to the environment and to human wellbeing. The scientific community now agrees that global warming is unequivocal, affirming that it will become worse and at a human scale, will affect primarily those who are poor and more vulnerable. Vulnerability is therefore, a key issue to study in the context of climate change. The main objective of studying vulnerability at any level is to understand *who* is affected and *how* is the risk, to ultimately tackle the problem, through the implementation of policies.

This study is framed within the *Adaptation of Irrigated Agriculture to Climate Change*(AICHA) project under the supervision of researchers from the Ashoka Trust for Research in Ecology and the Environment (ATREE) in Bangalore.

This study aims to explore the process of vulnerability based on a case study in four rural villages in Karnataka, India. The objectives of this study are (1) to develop a methodology for studying vulnerability through the sustainable livelihoods approach; (1) to develop adapted vulnerability indices for the case study; and (3) to investigate and determine which are the specific socio-economic factors that determine vulnerability.

2. Conceptual framework

Climate change and variability affect all the continents and oceans, the developed and the developing countries, but not everyone is prepared in the same way to face climate change. There are abundant differences between developed and developing countries. According to the World Bank (2001)[1], over 90% of the global poor population live in developing countries, where their livelihood depends on agricultural activities. In the absence of programmess, policies, and institutions to protect those when extreme climate events strike, they are defenceless, insecure and exposed to risks, shocks and stress. Therefore we can say that in general the population of developing countries are the most vulnerable to climate change.

The Intergovernmental Panel on Climate Change ([IPCC],2007) defines vulnerability to climate change as "the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, adverse impacts of climate change", and it is a function of three factors: exposure, adaptive capacity and sensitivity.

We can use indices as tools for quantifying climate vulnerability, due to their ability to synthesize complex situations when many different factors influence the observed behaviour. In addition, indices are generally seen as the media of choice for merging academic work and political need (Hinkel, 2010). The need to understand the global problem of climate change has created a demand for vulnerability assessment at multiple levels, where indices are a straightforward method. The Livelihood Vulnerability Index (LVI), LVI-IPCC and the Livelihood Effect Index are the indices used in this study, they are all focused in climate change, and they use the same subcomponents. These indices integrate the Sustainable Livelihood Framework (SLF) and they are adapted for vulnerability assessment in the context of climate change. Therefore, in this study the term vulnerability should be understood as vulnerability associated with a livelihood. ThsSLF considers five types of household assets:natural, social, financial, physical, and human capital (Chambers and Conway, 1992). This approach is usually used to design development programmes at the community level, and is very useful for assessing the ability of households to withstand shocks such as epidemics or civil conflicts.

3.Methods

3.1. Study area

The study area is located in the Berambadi watershed, in the South of the state of Karnataka in India. The Berambadi watershed has an approximate area of 84 km^2 and is a sub-watershed of the Kabini river basin that has an area of 7,000 km^2.

Four villages were selected for this study. The main reason for selecting these villages for our study is that they were already within the AICHA project study area. We were looking for similar villages, and these four are exposed to similar climatic conditions, as they are part of the same community and have the same livelihood strategies, with similar activities.The access to all of them was easy, as they are connected to main roads by public transportation, and close to each other. Ultimately, they were chosen with the intention that the data and results would be useful for the larger-scale AICHA project. The chosen villages are Beemanabheedu, Channamallipura, Berambadi and Maddinahundi.

[1] Please find references in the detailedreport of this study.

3.2. Data collection

Data collection was divided into four main stages during our 3-months stay in India. The first stage involved gathering of bibliographical data and literature. Secondly, seven key informant interviews were held in total among the four villages in order to obtain information that would help to understand the villages' physical and social structure. Among the interviewed were the Panchayat Development Officer of three of the four villages and elders who had a life-time farming experience. Three farmer workshops were conducted with the objective of gaining a community-level perception and strategies related to the challenges and opportunities of farming and climate change. The approximate number of participants was 12 farmers, all males from different socioeconomic backgrounds. Finally, a total of 100 structured household interviews were held in the four villages (25 per village). The interviews allowed obtaining household-level information about the general social structure of the household, the five types of capital and their adaptation techniques to climate change (if any).

3.4. Data analysis

The data from the surveys were analysed at two different levels: (1) whole sample-level analysis of the data and (2) household level. This distinction was done to find if there were any meaningful differences related to the scale, in terms of what affects the vulnerability.

3.4.1. Whole sample-level analysis of the data

We applied three different composite indices for analysing vulnerability to climate change. These three indices are: LVI, LVI-IPCC, and LEI. They are all climate change-focused and they are based on the same principles. The subcomponents that make up the three indices are the same, but organised differently, depending on the conceptual framework of each, and therefore giving different final results.

The methodology used by Hahn *et al.* (2009) in their study for assessing the risks derived from climate variability and change in Mozambique, have been adapted to develop both the LVI and LVI-IPCC indices. Nevertheless, and as the authors suggest, modifications have been made to adapt it to our specific case study. We added two more major components besides the seven that contained the LVI developed by Hahn *et al.* These two components are Finances, and Knowledge and Skills. The LVI provides information of which components determine vulnerability. The LVI-IPCC indicates which of the three factors (exposure, adaptive capacity and sensitivity) influence the most when determining the vulnerability, and the LEI indicates which types of capital assets affect a household more severely.

The primary data obtained from household surveys was used to construct the indices, which are calculated based on the 100 household interviews.

Calculating the indices

All three indices have a balanced weighted average approach, which means that each subomponent contributes equally to the overall value of the index. Table 1 summarises the formulasused to calculate the indices.[2]

Table 1.*Methodology usedto calculatetheindices.*

Index	Major components	Standardize sub-components formula	Major component formula	Overall index formula	Index scale
LVI	9 livelihood components	$\text{Index Sc} = \frac{\text{Sobs} - \text{Smin}}{\text{Smax} - \text{Smin}}$	$\text{Mcom} = \frac{\sum_{i=1}^{n} \text{IndexSci}}{n}$	$\text{LVI} = \frac{\sum_{i=1}^{9} \text{WMi Mcomi}}{\sum_{i=1}^{9} \text{WMi}}$	0=least vulnerable to 1=most vulnerable
LVI-IPCC	Adaptive capacity, exposure and sensitivity	$\text{Index Sc} = \frac{\text{Sobs} - \text{Smin}}{\text{Smax} - \text{Smin}}$	$CF = \frac{\sum_{i=1}^{n} W_{Mi} M_i}{\sum_{i=1}^{n} W_{Mi}}$	$\text{LVI} - \text{IPCC} = (e - a) * s$	-1=least vulnerable to 1=most vulnerable
LEI	5 household capitals	$\text{Index Sc} = \frac{\text{Sobs} - \text{Smin}}{\text{Smax} - \text{Smin}}$	$Cv = \frac{\sum_{i=1}^{n} L_i}{n}$	$\text{LEI} = \frac{\sum_{i=1}^{5} W_i C_{Vi}}{\sum W_i}$	0=least affected to 1=most affected

3.4.2. Household-level analysis of the data

The data obtained from the household interviews was analysed by applying the LEI and using descriptive statistical methods. Because the LEI provides a household based composite index, which the LVI does not, (Khajuria and Ravindranath, 2012) it was the LEI that was applied to every household.

The vulnerability results for the households were then classified based on their frequency. For the selection of groups, intervals of 0.05 were chosen, and then households were grouped into four levelsof vulnerability: low, medium, high and very high vulnerability. After classifying the sample by type of household vulnerability, the average value for every subcomponent was calculated for each vulnerability group. Finally, a correlation analysis was developedforevery subcomponent and thelevel of vulnerability, to check which factors explain better the pattern of vulnerability.

4. Results and discussion

4.1. Global results for the index values for the whole sample

Among the one hundred respondents from the household interviews, the average age of respondents was approximately 57 years, with an experience in farming of about 33 years. Most respondents were men, and only 11% of the respondents were women. Most respondents were Hindus, with only 3% of Muslims. Respondents were selected from the size of their land, according to three categories: small farmers - less than five acres (40%), medium farmers-

[2] For further detail, please refer to the report.

between five and ten acres (40%) and big farmers - more than ten acres (20%). Unanswered or null questions were not taken into account when analysing the data.

The overall value for the LVI in the Berambadi watershed villages was found to be 0.499, indicating a moderate vulnerability to the impacts of climate change and environmental degradation. The major vulnerability components for LVI are presented in Figure1, which illustrates what features contribute more to the vulnerability of the area.

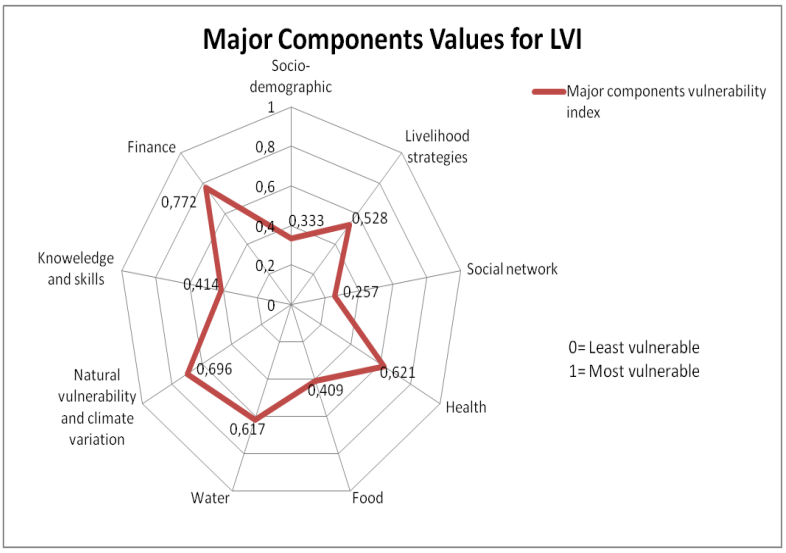

Figure 1.*Radar chart of major components of LVI*

As seen in the chart, the financial component has the largest contribution to the vulnerability of the community with a value of 0.772.Having adequate financial backups help to overcome the external risks and shocks, thus we can say that this high level in the financial sector will possibly have a negative effect on the rest of the components, because without a stable economy and economic resources, and mostly dependent on agriculture as their only source of income, makes it very difficult to cope with climate change impacts due this lack of resources, and the possibility to apply some mitigation strategies is reduced.

The second component with a large value was the natural vulnerability and the climatic variability, with a value of 0.696. This is not surprising as climate and natural resources are very important for a society that depends completely on them for their daily subsistence. Households in the area need good weather conditions to grow their crops, and this high value influences negatively to the farmers' vulnerability. The third component that affects vulnerability is health, with a value of 0.621. The reduction of the quantity of food intake during bad times, the reported missed work days due to illness, and the medium life expectancy influence increasing vulnerability as well.

The overall value for the water component is 0.617. Fifty-seven percent of farmers have access to a water source for irrigation. The lack of rain, the change in crop patterns, more access to new technologies and government helps, cause that in the last 10 years the uncontrolled drilling of new wells has increased dramatically. The rapid and uncontrolled increase of wells in recent years has caused the water level drops sharply, the farmers claim that their natural water source

is depleting year by year. Livelihood strategies have a moderate effect on vulnerability, with an overall value of 0.528. This value is clearly influenced by three main factors. The first is that at the end of the harvest, 85% of farmers do not receive the expected price for their crops but a lower price. The second factor is that 89% of the families live in semi-*pukka* or *kutcha* houses, finally is that 75% of families dependent on agriculture as their only source of income. Large dependence on agriculture greatly increases household vulnerability. Among the components that have a low weight on the vulnerability, we find knowledge and skills.Having TV at home, thus being connected to external information, is very important for example to consulting weather information, government decisions, events etc. and can be helpful to perform their functions in agriculture. Also we can observe that most farmers exchange information between them, and that for the dynamics of a society is very useful. But by contrast, 68% believe they lack enough education, which logically reduces their ability to face adverse conditions and develop the farming at the maximum performance. Food is another component that has a low weighton vulnerability, with a value of 0,409. The variable that hada larger influence on this component is that 65% of households depend only on the family farm for food: if they crops for food grains fail, they do not have the expected food for their household and need to purchase food, resulting inproblems to supply food for the family. Finally the components that have the lowest effect on vulnerability are first the socio-demographic profile with a vulnerability index of 0,333 and the social network with a value of 0,257. These villages have a good socialdistribution and they have very good social relationships.

Regarding the results for the IPCC index, we focus on the three factors contributing to vulnerability: exposure, sensitivity and adaptation. In this case, the overall result is 0.106 and therefore, like the LVI, our results suggest that the studied villages have a moderate vulnerability to climate change and climate variability. Figure 2 shows the contributing factors for vulnerability index based on the LVI-IPCC framework.

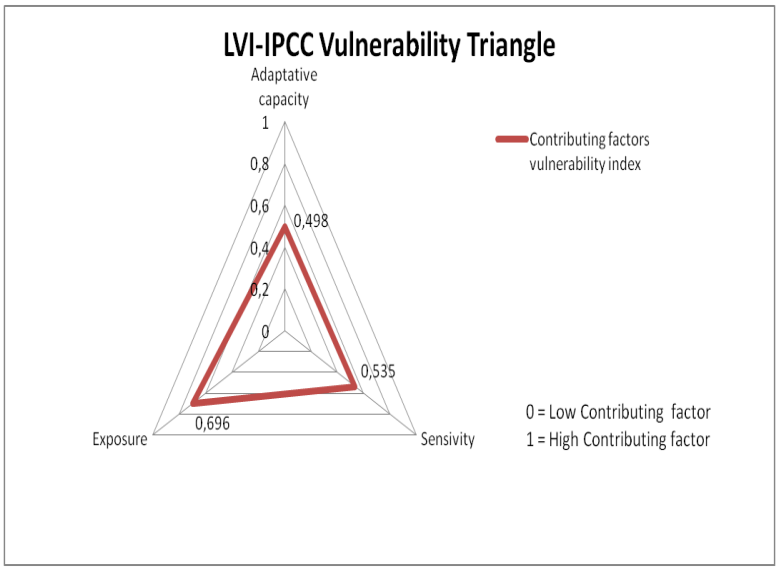

Figure 2.*Triangle chart of major components of LVI-IPCC*

The fact that the value is larger than 0 indicates that the community is more exposed to climate extremes and natural disasters than its capacity to adapt or overcome these adverse situations. As we can see, the diagram is clearly shifted to the exposure. Thus exposure, with a value 0.696, is the factor that contributes most to the level of vulnerability of the community. The adaptivecapacity has a value of 0,498. Unlike exposure and sensitivity, higher values for the

adaptive capacity indicates that the community is capable of coping with adverse situations more effectively, so acts by decreasing the vulnerability. Therefore this medium value of the adaptive capacity means that the community has a some good capacities to cope with the climate change and climate variability but not good enough to decrease the exposure and the sensitivity. Sensitivity of Berambadi watershed livelihoods toward climate change impacts is 0,535. This value indicates a moderate sensitivity to climate variations and changes, so we could argue that having a high exposure and a relatively low adaptive capacity causes the community to be so sensitive to climate changes and be negatively affected by them.

Finally, we conducted the calculation for the LEI. Results from this index suggest a moderate vulnerability to climatic change as well, with an overall value of 0.508 (Figure 3).

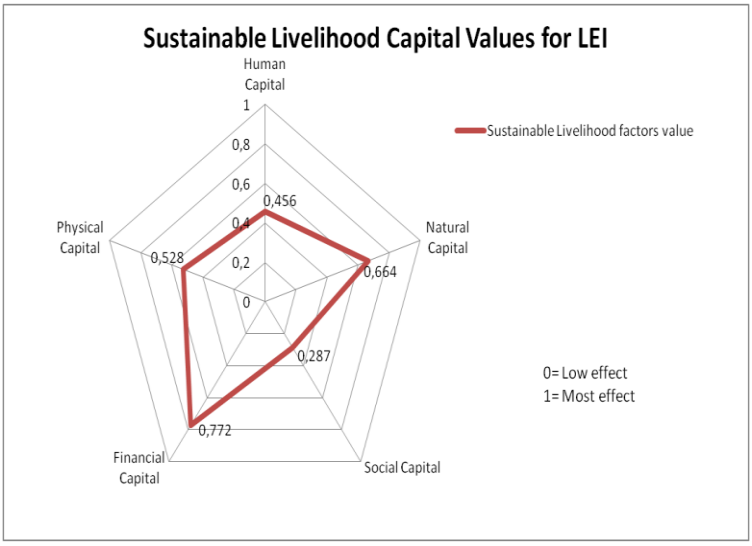

Figure 3.*Radar chart of major components of LEI*

Financial Capital, is again the most important factor increasing the vulnerability index,having the greatest effect on a household with a value of a 0,772. The household economy is very important for a good development of the family. We found some problems as crop losses, health and education costs, and the large accumulation of debts. The big dependence on farming can also create large economic instabilities.

Natural Capital is the second highest with a value of 0,664. According to the interviewed farmers, in the last 10 years there has been a decline of rainfall and its variability has grown considerably, provoking the increase of droughts. Also the temperature rise has influenced negatively the development of agricultural practices, causing up to 80% of crop losses in some cases. Another point to consider is that the vast majority of households, 92%, have problems to develop their agricultural lands. In addition, they donot have a good water supply, so the 88% confirm that their borrewells yield are depleting year after year. The Physical Capital for LEI, has the value of 0,528, having a medium effect to community households. The 89% of families live in houses of their own construction with low resistant materials and therefore very vulnerable to the extreme climate events. A 75% of households depend solely on agriculture as a source of income, which affects increasing the vulnerability. On the other hand, the agricultural diversification index, the total cultivated land and the migration have low values

contributing to decrease the Physical Capital effect on the index. The Human Capital has also a low effect with a value of 0,456. Health is the component that has a greater weight on this capital with a 0,621 due to the medium life expectancy and the bad nutrition and food reductions. Also, the missed work days due to illness affect but in lesser extent. The Knowledge and Skills, and Food contribute with similar values of 0.414 and 0.409 respectively. With a value of 0,287, the Social Capital is the least of the household vulnerability, having a low effect due to the good social networks and a good socio-demographic profile.

4.2. Houshold level results

After applying the LEI for every individual household and analysing the data, we classified the households according to their relative vulnerability. We then obtained categories of vulnerability to later work on the influence of the different drivers that determine this classification. Half of the households from the sample resulted as high vulnerability households. The second most frequent is the medium vulnerability (24%), in third place are the low vulnerability households (18%) and finally the least frequent are the very high vulnerability type of households, with only 8%.

Based on the analysis of the household interviews, it was also possible to identify which factors, out of the hypothesised factors to influence vulnerability levels, better explain behaviour of vulnerability among the four types of groups. The average values of each group for every subcomponent were calculated and then tested for correlation with the index value for that vulnerability group.

Table 2 illustrates the subcomponents that were found to correlate strongly with the LEI. Therefore, these are the 15 drivers that best explain the vulnerability pattern, and consequently have been stablished as the key factors of vulnerability in this region and for this study case.

Table 2.*Subcomponents with strong correlation (R^2> 0.90)*

R^2 value	Subcomponent	Type of capital asset
0.983	21 Perceived drought increase	Natural
0.977	48 Migration	Physical
0.976	12 Lack of information	Human
0.974	44 Household economic deficit	Financial
0.973	36 Trust	Social
0.964	23 Perceived erratic rainfall	Natural
0.963	1 Health status	Human
0.962	3 Food production	Human
0.939	15 Access to irrigation	Natural
0.937	4 Ability to provide food	Human
0.931	2 Food intake	Human
0.929	7 Time to water source	Human
0.926	42 Household cooperativeness	Social
0.925	13 Formal education level	Human
0.916	20 Perceived rain decrease	Natural

Correlations vary within and between subcomponents. The type of component with the greatest number of highly correlated subcomponents is the Human Capital, where 53.8% of the subcomponents were found to have a strong correlation ($R^2 > 0.90$) with the LEI values. The second type of capital asset with the largest number of subcomponents correlated to the LEI value is the Natural Capital with 26.6%, then the Financial Capital third (25% subcomponents correlated), physical capital (17%) and finally social capital (13%).

Remarkable differences between the four groups of household vulnerability, on perception of climate-related problems (i.e. increased drought, erratic rainfall and decreased rainfall) over the last 10 years account for the most influential factor when determining vulnerability. The financial capital, although having the highest weight at the value of the LEIforthe whole sample-level result, only showed one key subcomponent explaining the behavior of the vulnerability.

4.3. Limitations of this study

The primary limitation of the implementation of composite indices is the oversimplification of very intricate realities; which is difficult to avoid when applying any index of this sort. About the LEI specifically, the lack of literature about the feasibility of applying the LEI in different study areas and of prior studies that could allow comparisons also constitute an important limitation. Therefore we stress the needs for further research.

A separate issue of no less importance is the subjectivity ruling the selection of indicators and factors that compose the indices and their directionality. Additionally, the fact that all of the subcomponents have the same weights in the formulas is also problematic, as considering that access to irrigation sources and the house type have the same importance on vulnerability to climate change can be very misleading. Nevertheless, the allowed subjectivity for selecting components and subcomponents could be considered a strength, since this structure allows the indices to be adapted to fit the needs of a particular community or end users.

That said, it should be reminded that factors' importance in vulnerability is highly dependent on the time frame. Therefore, in the short term (months) health status and food intake might resonate the most with vulnerability. In the medium term (years), access to credit and economic autonomy; and the most important factor, whereas in the long term (decades), could be equal access to education (Brooks *et al.*, 2005). Further studies should include an expert focus group discussion to determine weights to each subcomponent and to improve the quality of the data and obtained results.

We must keep in mind that all the indices were constructed based on a review of available data for our particular study area and purpose, and may not apply to other communities or populations, as well as the survey questions. The standardised components and final results are specific to our study area, in a specific time with specific priorities, and they should not be extrapolated to larger areas. Thus this means that our resulting values for the indices are not strictly comparable with future studies unless these follow the same methods and purposes.

In terms of the methodology, in spite of carrying out careful methodological refinements, the sample is still not representative of some minorities such as female-lead households and households with migrating members, due to possible sampling bias. Although it is probably accurate that there are a lot less households lead by women, but lack of secondary data did not allow us to verify this issue. Other possible sources of bias could be unanswered questions from

the questionnaire, that despite not being considered while analysing data, account for a bigger margin of error and a smaller sample. Self-reported data is also a potential source of bias, as some of the questions about perception rely heavily on the respondents' memory for very long periods of time: up to ten years.

Due to limited data and resources, most of the analyzed data used to construct these indices was accounted in binary terms, which reduces the possibility of identifying smaller vulnerability intervals and more subtle differences and interactions. Another point is the possibility of masking extreme values by utilisation of the means to calculate the indices. It is suggested that the results are treated with caution.

5. Conclusions

The purpose of this study was to explore the process of vulnerability in the area. The specific objectives were to define household-level factors most likely to influence vulnerability within the studied community, to develop and apply different quantitative vulnerability indices, and to investigate which of the socio-economic factors proposed determined the vulnerability pattern.

Notwithstanding the described limitations in Section 4, this is a good first approach which allows a better understanding of the vulnerability status of the studied communities. Our results can be used to be compared with more extensive studies of the AICHA Project. These indices are all straightforward methods that use both empirical and theoretical insights to select and aggregate factors that affect vulnerability. The LEI, specifically, has the advantage of allowing household-level targeting, as opposed to targeting an entire community.

The main intention of applying the LVI, LVI-IPCC and LEI is to help identify vulnerable communities, to gain understanding of the factors that determine vulnerability, and to prioritise the potential areas for intervention. They should be used in the development research context, by development organisations, governments and policy-makers, in order to proceed to the application of corrective measures, and therefore aim to improve their adaptive capacity and increase their resilience to global and climate change.

According to the vast literature on the subject and numerous case studies (i.e. Ellis, 2009; Urothody and Larsen, 2010; Chambers, 2006; Eakin and Bojórques-Tapias, 2008; Liu *et al*., 2008), livelihood diversification is a very efficient way to reduce vulnerability. Diversification beyond the farm is proposed as a suitable adaptive practice. Nevertheless, we strongly believe that in order to suggest the best paths to reduce these communities' vulnerability, participative and deliberative processes should be held, where the relevant stakeholders from every village could be involved and are given a voice as to what would be the best ways to proceed.

Additional recommendations for future studies are to include governance indicators, as civil and political rights and opportunities are very relevant for livelihood strategies and assessment (Brooks *et al.* 2008). Also, including a more extensive global context could reveal important information for long term vulnerability and predictions (Downing, 1991).