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

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List of abbreviations

AICHA - Adaptation of Irrigated Agriculture to Climate Change

AMBHAS - Assimilation of Multi-satellite Data at Berambadi Watershed for Hydrology and Land Surface Experiment

ATREE - Ashoka Trust for Research in Ecology and the Environment

BCCI - Bangalore Climate Change Initiative

DFID - Department for International Development

GHG - Greenhouse Gases

HadCM3 - Hadley Centre Coupled Model

IISc - Indian Institute of Science

IPCC - Intergovernmental Panel on Climate Change

KCCAP - Karnataka Climate Change Action Plan

LEI - Livelihood Effect Index

LVI - Livelihood Vulnerability Index

LVI-IPCC - Livelihood Vulnerability Index based on Intergovernmental Panel on Climate Change

PRECIS - Providing Regional Climates for Impact Studies

SLF - Sustainable Livelihood Framework

SRES A1B - Special Report on Emission Scenario

WP - Work Package

WWF - World Wide Fund

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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 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. Results and limitations of the study are discussed under the rural livelihoods framework, in which the indices are based, allowing a better understanding of social behaviour and trends, as well as a holistic and integrated view of climate change, agriculture, livelihoods and 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, therefore we stress the need for further research.

1. INTRODUCTION

1. INTRODUCTION

Climate change poses a great threat to the environment and to human wellbeing. The scientific community now agrees that warming of the climate system is unequivocal, affirming that it will become worse, and at a human scale will affect primarily those who are more poor and vulnerable. Vulnerability is therefore, a key issue to study in the context of climate change. Novel methods and tools for vulnerability assessment have been developed and widely discussed, which have contributed to the use of vulnerability in the analysis of sustainable livelihoods research. The main objective of studying vulnerability at any level is to understand the processes behind it and to ultimately tackle the problem, that at an administrative level is achieved through the implementation of policies.

It has been found that both in developed countries and in the developing world, groups that are marginalised (i.e. rural communities and the poorest part of the population), will suffer an unequal burden of climate impacts (Adger, 2006), thus the importance of assessing their vulnerability to climate change.

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. The AICHA project is a three-year project, conducted primarily by the Indian Institute of Science (IISc) and the Institut National de la Recherche Agronomique (France), in collaboration with other research partners from India and France. The project proposes a multidisciplinary approach, combining hydrology, agronomy and socio-economics for studying the impact of climate change on groundwater-irrigated agriculture, focusing on the effects on cropping systems and water resources.

This study aims to explore the process of vulnerability based on a case study in four rural villages in India. The objectives of this study are (1) to define household-level socio-economic factors that influence vulnerability; (2) to develop a methodology for studying vulnerability through the sustainable livelihoods approach; (3) to develop adapted vulnerability indices for the case study; and (4) to investigate and determine which are the specific socio-economic factors that determine vulnerability.

To answer the research questions described above, we introduce the conceptual framework of this study in Section 2 and describe the AICHA project, the study area and the methods for data collection and analysis in Section 3. The results and discussion, as well as the limitations of the study are presented in Section 4 and in Section 5 we describe the overall conclusions.

1. 1. General trends in agriculture, population and natural resources

Population growth is undeniably linked to an increased food demand, that consequently is associated with an increasing pressure on natural resources and agricultural output. This situation will considerably increase water consumption and competition for resources. This, combined with observed impacts of climate change, leads to an expected decrease in water availability in many regions. On the Fourth World Water Development Report, the United Nations (2012) predict a 19% increase in water consumption for agriculture by 2050, and could be greater if no policy intervention or technological improvement are implemented, considering that 70% (and in some cases up to 90%) of freshwater extraction is used for agriculture.

Asia is the most populated continent and the population growth projection estimates that it will add 3.04 billion people in a 50-year period: between 2050 and 2100. The greatest population growth is expected to come from South Asia, where most of the world's poor live, primarily in rural areas. The situation in India is not different. It is the second largest populated country in the world after China with around 1250 million people, and the country's population is expected to increase more than 500 million people in the next 50 years, according to the United Nations Department of Economic and Social Affairs (2002, [as cited by IPCC, 2007]).

Bearing this in mind, population growth will decrease the amount of land per capita for agricultural use at the same time as more food is needed. Food demand could be met by more intensification of agricultural practices, but this faces other challenges, as agriculture returns per hectare have limits and they are globally declining during the last decades. Intensification means more environmental impacts and more requirement of resources, in a global context of post-peak production of non-renewable natural resources (oil, phosphorus, metals, etc.), and finally, agricultural intensification will also be inextricably affected by climate change. Sixty percent of India's irrigated land is from groundwater, which represents a significant amount of water withdrawal, considering that India holds one third of the world's total irrigated area (Assimilation of Multi-satellite Data at Berambadi Watershed for Hydrology and Land Surface Experiment [AMBHAS], 2010), where the depletion of water tables due to over-extraction of groundwater is already a unsolved issue in some regions of the country.

1.2. Climate change trends in India and effects on water and agriculture

Some studies show that climate change effects have already been observed in India, with evidence showing an increase of 0.4-0.6°C in the past 100 years (Bhattacharya, 2007). Increasing trends in annual mean temperature and a more marked warming during post monsoon and winter have also been observed (Cruz *et al.*, 2007). Extreme climatic episodes like intense rains and consequent floods give evidence for climate change. The 2005 flood in Mumbai led to the death of over 1,000 people and damages of more than US$250 million (India Meteorological Department, 2002, 2006; Dartmouth Flood Observatory, 2003). Droughts in 1999 and 2000 led to a decline in water tables in North West India. The following droughts between 2000 and 2002 had an even more devastating impact, resulting in poor crop yield and episodes of mass starvation that affected about 11 million people in Eastern India (India Meteorological Department, 2006). Furthermore, according to the Intergovernmental Panel on Climate Change (IPCC)'s Fourth Assessment Report for Climate Change (2007), the frequency of hot days and heat waves in India has increased over the past century. For what is expected, the report predicts a 0.68°C temperature increase per century, as well as an increase in extreme rains and floods.

Although there is not enough literature about the impact of climate change on groundwater, it is estimated that it will affect the recharge rates (IPCC, 2007), which will only aggravate the human pressure on water and food security. Climate change will, however, increase water salinity as a result from global warming, and India is especially prone to it. Over-exploitation of groundwater results in water tables depletion and decreasing groundwater levels, leading to sea water intrusion to aquifers in coastal areas (IPCC, 2007).

On water availability in India, Gupta and Deshpande (2004, [as cited by IPCC, 2007]) affirm that by 2050 there will be a decrease of 680 m^3/year per person, compared to that in 2001. Moreover, the Central Water Commission, (2001, [as cited by IPCC, 2007]) predicts that before 2025 water availability per capita in India will fall below 1,000 m^3/year, reaching a state of water stress for the population.

The most vulnerable to climate change are the poor sectors of the population, that out of economic pressure are usually driven to pursue short-term subsistence goals, that usually trigger ecosystem and environment abuse. Hence the effects of climate change on agriculture and water resources are without a doubt relevant in poor rural communities.

1.3. Climate change: projections and impacts in Karnataka

Climate change is having and will have during the following decades a deep impact on human and ecosystems through variations in global average temperature and rainfall or the increase of greenhouse gases (GHG). In a developing country like India, climate change is one of the biggest environmental threats, having impacts on food production, water availability, forest biodiversity, livelihoods and of course in its economy, especially on the poorest. These consequences are the resulting effect of the interactions between climate and humans and their impact on natural and managed environments.

Karnataka is the eighth major State in India and the second most vulnerable State to be impacted by climate change, as North Karnataka regions have the most arid and driest regions (Bangalore Climate Change initiative, BCCI, 2011). Agriculture is a crucial sector for Karnataka, where over 50% of the population income comes from agriculture and more than 80% of the farms are rainfed. The variation of climate might be an important role to farmers' livelihood security and to maintain the farmers' productivity, hence the importance to understand the current climate variability. The annual rainfall in the State varies roughly from 50 to 350 cm. The South-West monsoon (June to September) is the major rainy season during which the State receives 80% of its rainfall, in the winter season (January to February) is less than 1% of the annual total, and in the hot pre-monsoon season (March to May) about 7%, finally in the post-monsoon season (October to March) about 12%. The hot and dry weather occurs in April to May. In May, mean maximum temperature can go up to 40 degrees. In winter the temperature during this season ranges from 32°C and reduces to 20°C, for the pre-monsoon season the temperatures ranges from 34° C to 22°C approximately (BCCI, 2011).

Information on the spatial and temporal variability of rainfall is important in understanding the hydrological balance on a global/regional scale. The distribution of precipitation is also important for water management in agriculture, power generation and drought-monitoring. In India, rainfall received during the southwest monsoon season (June–September) is crucial for its economy (BCCI, 2011), as the variability in this rainfall season combined with increasing temperatures and high variability, could cause extreme events like droughts or floods resulting in reduction in agricultural output affecting the economy and the population.

In the last fifty years, climate variability has had a tendency to increase, whereas rainfall has fallen into a trend of -1 mm/day/100years, (about 6% decline in 50 years). On the other hand, the temperatures have also experienced increment in the variance of 14.5% in some areas and increase of more than 0.6 °C both in the high and in the minimum temperatures (BCCI, 2011).

1.3.1.Climate change projections for Karnataka

In the Karnataka Climate Change Action Plan (KCCAP) (BCCI, 2011), data from the Hadley Centre Coupled Model (HadCM3) was used. The HadCM3 is a global climate model downscaled by Providing Regional Climates for Impact Studies (PRECIS) model, a regional climate model for downscaling climate projections. The combination of HadCM3 and PRECIS models is known as the HadRM3 model. The pathways for atmospheric greenhouse gases (i.e. CO_2, CH_4, N_2O, CFCs) are prescribed from the Special report on emission scenarios (SRES A1B) mid-term (2021-2050) projections. Climate change projections were made:

- For daily values of temperature (average, maximum, minimum)
- For daily values of precipitation
- At grid-spacing of 0.44250 latitude by 0.44250 longitude
- For periods of 2021-2050 relative to the baseline period 1961-1990 (also referred to as either 1975 or 1970s)

The results of this study are as follows:

Karnataka is projected to experience a warming of 1.8 to 2.2°C by 2030, minimum and maximum temperatures, respectively; however, the increase in the minimum temperature projected is slightly more than that of the average and the maximum temperatures. In addition the minimum temperature will go up as much as 2.4 to 3.3 °C in the winter months (November to February) and the maximum temperature will go up by as much as 2.7 °C in June and November. Finally in May the maximum temperature projected goes up to 41.3°C.

Concerning rainfall, the North-Eastern and South-Western regions of the State are projected to decrease in the amount of rainfall annually, especially in the summer monsoon (June to September), for this reason, most Northern districts are projected to have an increase in drought incidences by 10-80% in Kharif season (monsoon season) and most of the Eastern districts will increase the frequency in droughts in double in Rabi season (post-monsoon season). However the Western region of the State is projected to have more rainfall and hence less number of droughts during the Rabi season.

If these predictions are real, these results would be actually harmful to the different cropping systems and natural ecosystems.

1.3.2. Climate change impacts in Karnataka

For a country that largely depends on monsoon patterns and winter months to maintain its agricultural production, any shift in climatic conditions will have an impact in the natural resources and in consequence, on the economy. An accelerated warming in the recent decade has added to a perceptible alteration in the livelihoods and growth patterns of crops (World Wide Fund [WWF] India Report, 2011). The rapid development and the urbanization have already posed major threats to the natural resources and the ecosystem in many parts of the country. These impacts will in the future add more stress on the resilience of ecosystems.

Forests are crucial in the context of climate change, since deforestation and land degradation contribute to global CO_2 emissions in about 20% (BCCI, 2011). Forests are a habitat for a vast amount of species and different ecosystems. Climate change can affect negatively, affecting biodiversity, forest regeneration and the biomass production with an immense impact. In Karnataka the forests occupy 19% of the geographic area, with a biodiversity hotspot in the Western Ghats. By 2030 the 38% of forests in Karnataka will be affected by climate change and a 45% of the area will shift in forest types. In addition, fragmented forests in the North of the State are especially vulnerable to climate change, increasing risks of fire and pests (BBCI,2011).

The agricultural sector is also heavily affected by climate change because it depends on several factors such as increasing temperature, variability of precipitations and GHG emissions. This can affect food security, crop patterns, crop yield, among others. Sixty-six percent of the population lives in rural areas in Karnataka where their main income source is farming. Additionally, Karnataka is one of the few States with lowest proportion of area under irrigation (70% rainfed farming) and second State of drought-prone areas. Difficult access to water, rainfall variability, different agricultural practices, and difficult access to new technologies, increase the chance of crop failure and decrease in production. According to the KCCAP (2011) there is a direct influence of food security production on the seasonality and the distribution of rainfalls annually. Hence under the influence of climate change, these effects can be more severe in the next years, affecting agriculture with shifts in the sowing time and length of growing seasons geographically, which would alter planting and harvesting times of crops and varieties currently used in a particular area.

If we consider the temperature increases, also the evapotranspiration rates would raise, affecting the efficiency of water use. Furthermore, warmer temperatures could shift the insect and pest ranges and change the weather variability, increasing extreme events like droughts and floods. For the 2035s scenario built by the BCCI, the productivity of Kharif (monsoon season) crops such as irrigated rice plantation in the State is likely to change by a range of -14.4% to 9.5% from its base yield, and is projected to decrease the yields up to about 8.2%. On the other hand, the rainfed rice plantations' yield variability projected is in the range of -13.8% to 7.2% with large portion of the region likely to lose the rice yields up to 9.6%. Climate change is also likely to change yields of maize from in a range of 27.6 % to -19.3 % and sorghum by 17.2 % to -18.4% in different districts with respect to baseline yield. Furthermore the total productivity is likely to decrease by about 1.2% in the State, due to the benefit of the raise in temperature and CO_2 level.

Water availability, crucial for the sustainability of ecosystems and the economy of India is vastly affected by climate change as well. The IPCC (2007) predicts an intensification of the global hydrological cycle, affecting both the ground and surface water supply, with runoff declining in most streams and rivers. In addition, different catchments are likely to respond differently to the same change in climate drivers, depending largely on the catchments' physiogeographical and hydrogeological characteristics and the amount of lake or groundwater storage in the catchment. The IPCC has predicted with high confidence that the drought-affected areas will increase in frequency as well as the severity of drought, which includes India.

Karnataka has seven river systems, where the Krishna and Cauvery are the two most important occupying almost 78% of the total basin area of Karnataka. The future decrease in the precipitations will cause a slight increase in runoff. Otherwise the evapotranspiration will decrease, considering that the major source of water for irrigation is groundwater. This could have severe impacts on crops, specially intensive-water crops such as rice, sugarcane or banana, that would likely be under water stress, causing possible changes in crop patterns and changes in cultivated species.

The cumulative effect of the above mentioned projected impacts could have repercussions on the population’s economy, since the large number of poor and marginalised population aggravates the situation. The primary sector of the economy (i.e. agriculture, fishing activities, livestock rearing) are directly influenced by climate change, thus affecting the population that depends on it. In Karnataka this sector will be the most affected (BCCI, 2011).

2. CONCEPTUAL FRAMEWORK

2. CONCEPTUAL FRAMEWORK

Climate change is a reality. The increase in global average in air and ocean temperature, widespread melting of snow and ice and rising sea level, are some of the effects that are observed since the last years and tend to increase. The anthropogenic activities over the last three decades have had an important influence on these changes on numerous physical and biological systems, due to the increase in GHG concentration, the increase in urbanisation and pollution, constant land changes and degradation (IPCC, 2007).

Climate change and variability affect all the continents and oceans, the developed and the developing countries, but not everyone is exposed in the same way to climate change. There are abundant differences between developed and developing countries. According to the World Bank (2001), over 90% of the global poor population live in developing countries, where their livelihood depends on agricultural activities. In the absence of regulations, policies, and institutions to protect those when extreme climate events strike, they are defenceless, insecure and exposed to risks, shocks and stress. Very often the poor in developing countries are deprived of their entitlements and vital necessities, because they are heavily dependent on their natural environment for their own support (IPCC, 2001). Moreover, developed countries can implement regulations and policies that offer early warning signals and back-up plans and enhance their ability to recover from the impact of climatic events. Therefore we can say that in general the population of developing countries are the most vulnerable to climate change.

In recent times, vulnerability has become a major issue to consider for research on the human dimensions of global environmental change (Obrien *et al.,* 2004), and over time, the concept of vulnerability has been defined in many different ways and several conceptual frameworks have been developed to categorise vulnerability factors and describe the different vulnerability concepts (Füssel, 2007).

A simple definition of vulnerability in terms of climate change is the capacity or incapacity of being negatively affected by climate variability and extreme climate events and support them. Due to the intricate interactions between diverse components of the natural systems along with the human interventions, assessing vulnerability becomes a complicated piece of work. Nevertheless, vulnerability assessments are considered important tools required for cases, adaptation of social and ecological systems.

The 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 is a function of three factors:

I. The types and magnitude of exposure to climate change impacts
II. The sensitivity of the target system to a given amount of exposure
III. The adaptive capacity of the target system

Where exposure is the degree of climate stress upon a particular unit of analysis; it may be represented as either long-term change in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events. Sensitivity refers to the degree to which a system will respond to a change in climate, either positively or negatively. And adaptive capacity describes the ability of a system to adjust to actual or expected climate stresses, or to cope with the consequences. These three factors are dynamic and variable and will be different depending on the reference system that we consider to study their vulnerability. Fig. 1 shows the integrated context of vulnerability and climate change.

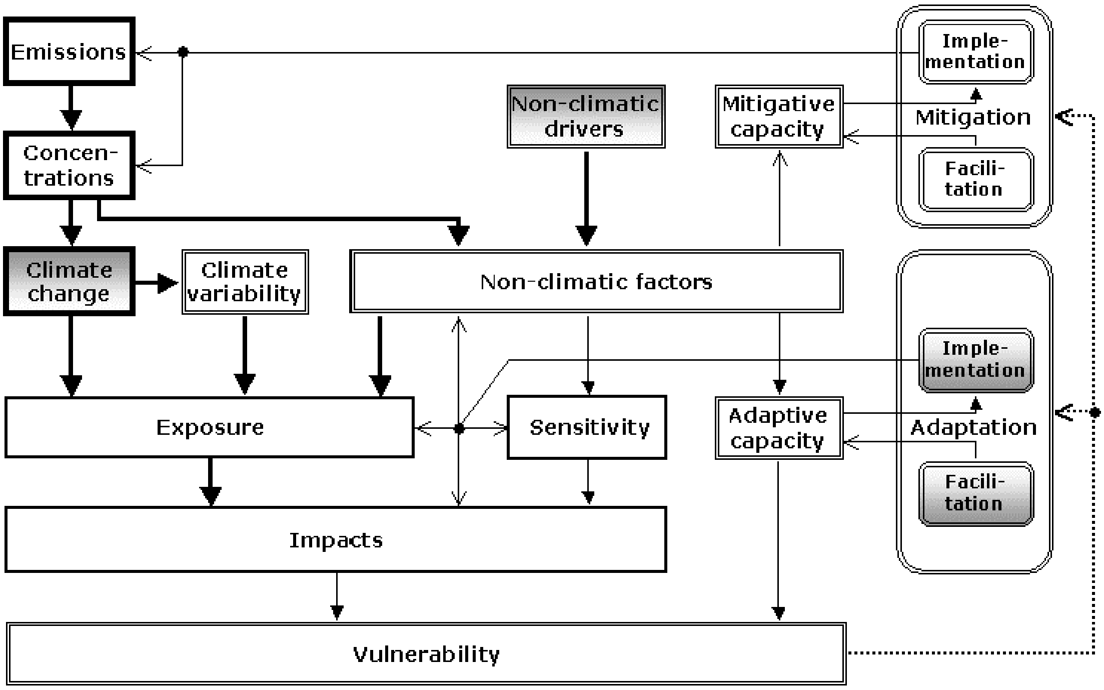

Figure 1. *Integrated vulnerability context and climate change*. (Source: Füssel, 2010)

Vulnerability assessment is a practical tool to identify the systems that are susceptible to be harmed, which are water, food security, human welfare, natural resources, among others. Knowing the systems' level of vulnerability is helpful to identify and develop reduction actions like increasing the adaptive capacity and decreasing the sensitivity and understand the dynamics between the different sectors and dimensions.

We can use indices as tools for quantifying climate vulnerability, due to their ability to synthesize complex situations with many factors, such as the vulnerability of regions, households or countries in one value that can be easily interpreted and used. 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.

In our study, one of the applied indices is the Livelihood Effect Index (LEI), which is based on the Sustainable Livelihood Framework (SLF). Therefore, in this study the term vulnerability should be understood as vulnerability associated with a livelihood. These two terms -vulnerability and sustainable livelihoods-, were integrated by the Department for International Development (DFID) in 1999. The DFID defines livelihoods as the capabilities, assets (including both material and social resources) and activities required for a means of living. Thus the sustainable livelihoods are those who can cope with and recover from stresses and shocks and maintain or enhance their capabilities and assets both now and in the future, while not undermining the natural resource base. The DFID identified and integrated the vulnerability context to the key aspects of livelihood to make it sustainable.

The sustainable livelihood approach 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. Therefore the climate change adds complexity to household livelihood security, and the sustainable livelihood approach is limited to the issues of adaptive capacity and sensitivity to climate change (Hahn *et al.*, 2009). For this reason a new approach for evaluating livelihood risks resulting from climate change integrating the climate exposures and household adaptation practices are needed.

Figure 2 represents the complete Sustainable Livelihood Framework where the vulnerability context influences directly the livelihood strategies, livelihood outcomes, structures and processes of the community, and is a determinant of livelihood sustainability.

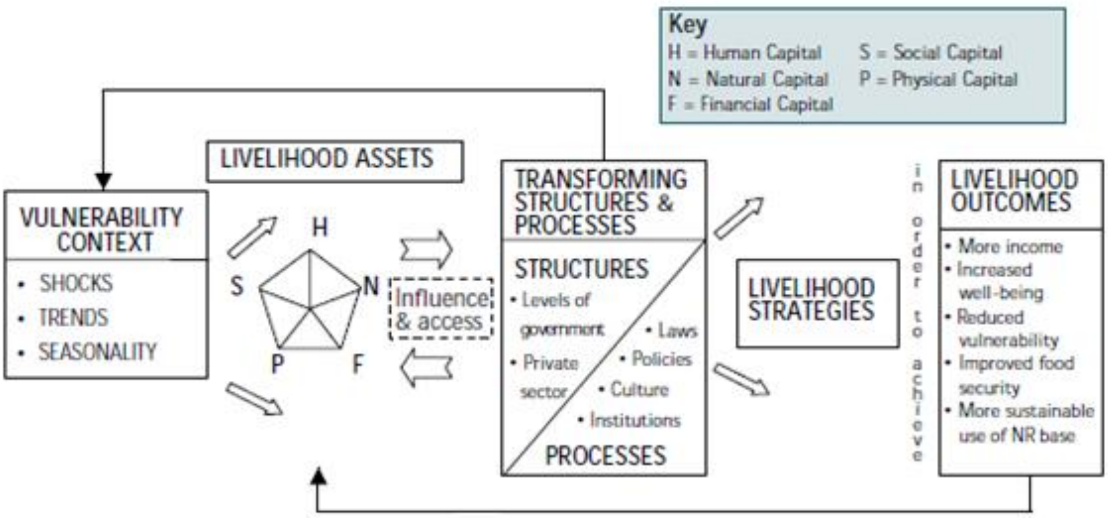

Figure 2. *Sustainable Livelihood Framework* (Source: DFID, 1999)

The indices used in this study integrate the sustainable livelihood framework and are adapted for a climate change vulnerability assessment. These indices are the Livelihood Vulnerability Index (LVI), the LVI-IPCC, and the Livelihood Effect Index (LEI). The first two were created by Hahn *et al.* (2009) to estimate the differential impacts of climate change on communities in two districts of Mozambique, and the latter was used by Urothody and Larsen (2010). The details of these indices are explained in the following section.

3. METHODS

3. METHODS

3.1 The hosting AICHA project

The main objectives of this framework project, as stated in the project proposal, are:

- To develop an integrated model of agronomy, hydrogeology and economics for assessing the sustainability of agricultural systems in the context of climatic change.
- To design a methodology for gathering relevant data sets to simulate the integrated model in a spatially distributed approach at the watershed scale.
- To develop a farmer decision model for assessing adaptability of farming systems to changing environment (climate, economics).
- To simulate the sustainability and adaptability of farming systems in the case of a small (84 km²) watershed in Peninsular India.

As one of the first projects to combine both economic impacts on crop production and hydrogeological and hydro-economic feedbacks on the future land use productivity, researchers from this project expect to provide a combined model that could be applied to basin/sub-basin scales dominated by groundwater irrigation.

The AICHA project works with three main hypotheses, namely:

- The assessment of the sustainability of irrigated agriculture must take into account the interaction and feedbacks between crop growth, water resource availability and economic drivers at the farm scale.
- Spatial interactions on the watershed scale play a dominant role in the sustainability of farming systems.
- Models must include simulation of farmer decision rules to be able to explore the possible adaptation of farming system to environmental changes.

One of the AICHA project's joint collaborators in India is ATREE, where we conducted a three-month stay for this research's fieldwork. Whilst working in India, our research was supervised by Dr. Shrinivas Badiger, research fellow and leader of the Land, Water and Livelihoods programme at ATREE. Given that the AICHA's study area is located in India, almost all of the field experiments and surveys are coordinated and held by the Indian collaborators which are IISc and ATREE.

Among the five work packages (WP) that integrate the project, our research was included in WP1 which consists of data collection on agricultural data on current practices. The task especially related to our research's objectives was task 1.2, that states: "Identification of current agricultural practices including cropping systems, irrigation, fertilisation and economics. The identification of cropping patterns, irrigation strategies and socio economical aspects involves field surveys to complement available statistical data and individual or village-level data [...] The field surveys will collect agricultural data on current practices and economic conditions of production. Important variables of interest will include the description of the cropping systems and rotations, farm gate output prices and possible contractual arrangements, input use in quantity and value (permanent and hired labour, fertilizer, pesticide, seeds). Concerning water use, irrigation practices, energy consumption by wells will also be collected."

This task was expected to be fulfilled in a 15-month period starting in February 2013. The fact that our study began before the AICHA project posed some limitations concerning access to secondary data and context information, but at the same time allowed us total freedom in matters of choosing and designing our research questions and methodology.

In addition to agronomic and socio-economic determinants of farmers' strategies, farmer's decision rules and patterns are important for the model as they will allow the assessment of sustainability, as well as the adaptability of the current farming systems, as stated in the third hypothesis. Models need to identify and characterise agricultural practices that impact water withdrawals, to gain a better understanding of the dynamics ruling the three components that are subject to the project: hydrology, agronomy and socio-economics. This is one if the main reasons that justify our study to be part of the project. Since the ATREE team has experience in implementing and analysing agronomic and socio-economic surveys in India and have knowledge of local institutions, task 1.2 is dominantly coordinated by them.

Henceforth, the document exclusively refers to our own study, unless otherwise stated.

3.2. Study area

The study area is located in the Berambadi watershed, in the South of the state of Karnataka in India (fig. 3). 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. The Berambadi watershed has a highly contrasted land use, where the major soil types are clay, clay loam and sandy clay loam (AMBHAS, 2010). There are two cropping seasons per year, which are Kharif (summer: from mid May to mid September) and Rabi (winter: from mid October to mid January).

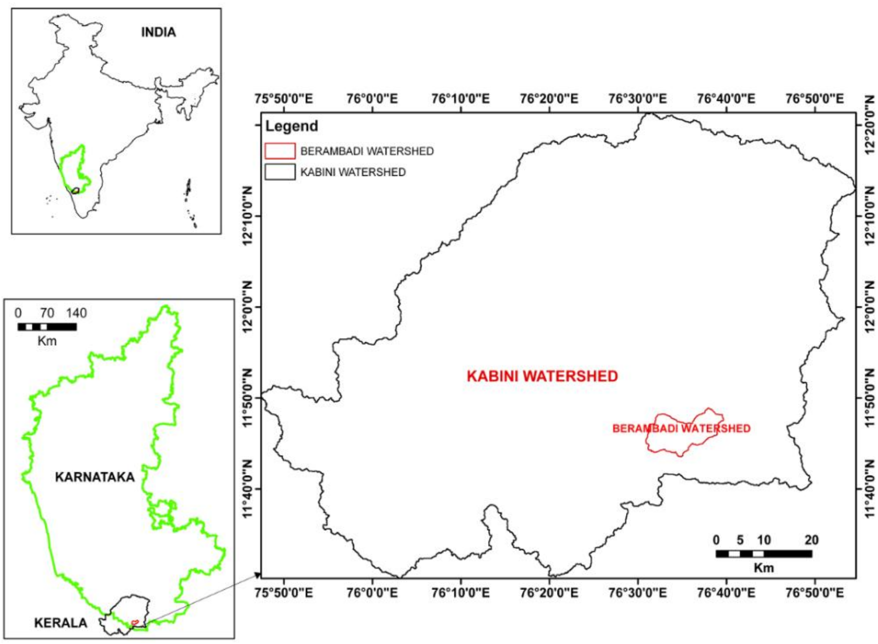

Figure 3. *Kabini and Berambadi watershed location in Karnataka State.* (Source: Assimilation of Multi-satellite Data at Berambadi Watershed for Hydrology and Land Surface Experiment [AMBHAS], 2010)

Four villages were selected for this study. The main reason for selecting these villages for our study is that they are within the AICHA project study area. We were looking for similar villages, and these four are exposed to similar climatic conditions, are part of the same community and have the same livelihood strategies, with similar activities. Access to all of them is 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 villages are Beemanabheedu, Channamallipura, Berambadi and Maddinahundi. Their location in the watershed is shown in Fig. 4 and Table 1 illustrates the most recently published population data.

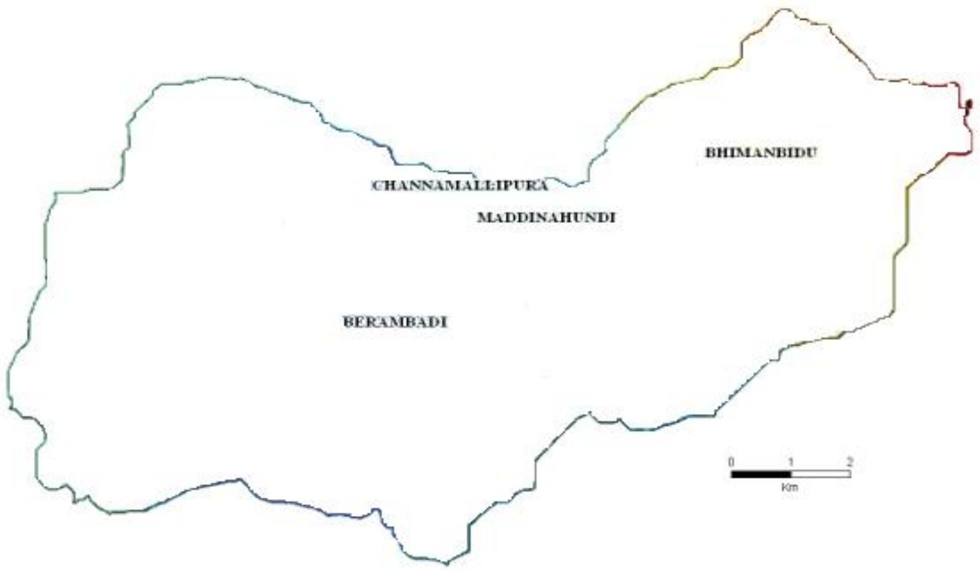

Figure 4. *Location of study area -Berambadi watershed.* (Source: adapted from AMBHAS, 2012)

Table 1. *Demographic characteristics of the study area.* (Source: 2001 census)

Village	Area (ha)	Total households	Total population
Beemanabheedu	1197	855	4069
Channamallipura	604	241	1047
Berambadi	1435	565	2887
Maddinahundi	No data	No data	No data

It was not possible to collect complementary data on its characteristics for Maddinahundi, given that it is a much smaller village and information is not available. Another disadvantage is that the most recent data is from the 2001 population census. Data from the 2011 population census is expected to be published in August, 2013.

Figures 5 and 6 show the average temperature and rainfall for Gundlupet, respectively. Gundlupet is the capital of the sub-district, and the closest *taluk* (town that serves as headquarters for additional towns and a number of villages) to the villages we study. Gundlupet is used as a reference, because the own villages' temperature and rainfall have not been studied.

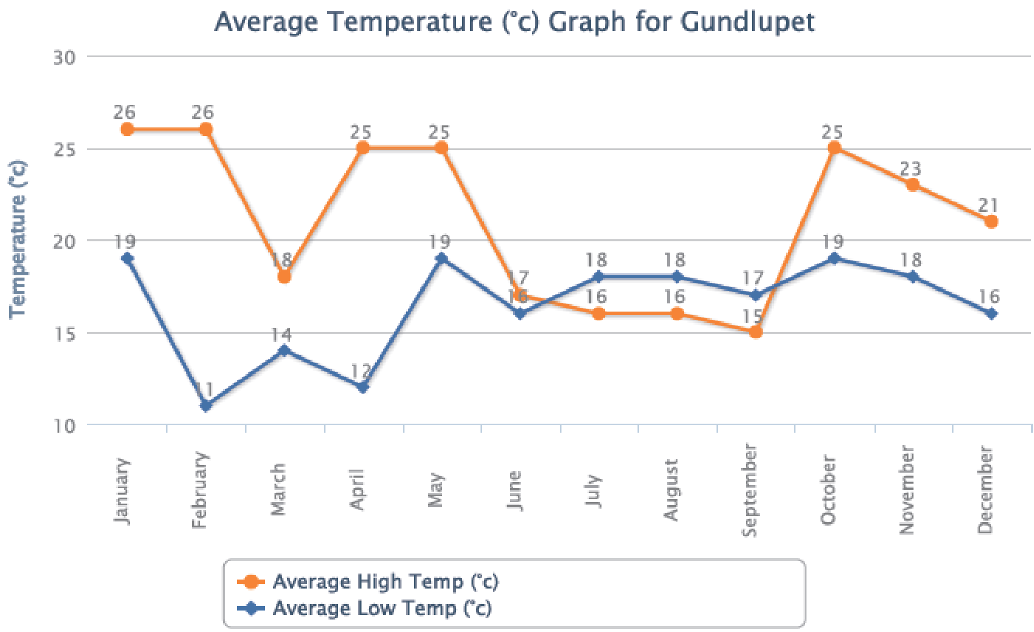

Figure 5. *Average temperature for Gundlupet.* (Source: unknown, provided by ATREE)

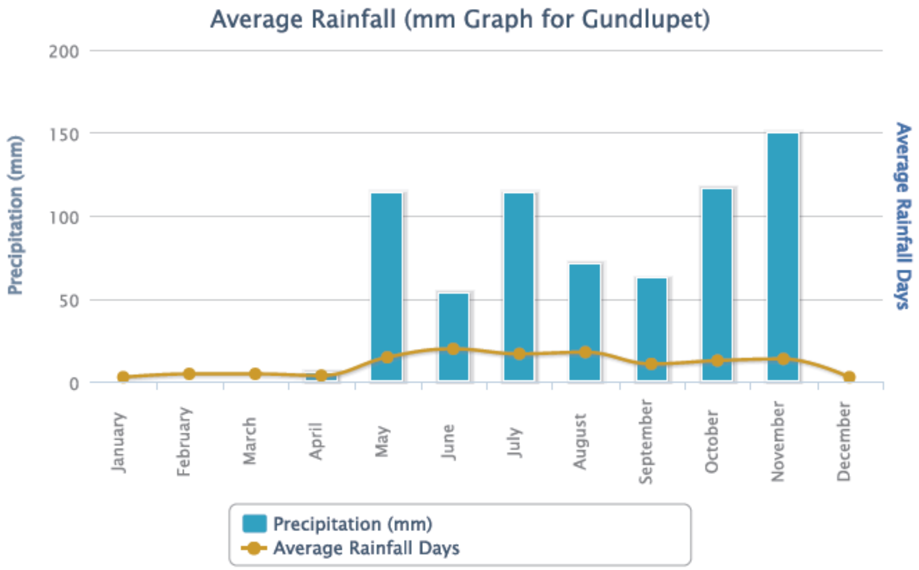

Figure 6. *Average rainfall for Gundlupet.* (Source: unknown, provided by ATREE)

3.3. Data collection

Data collection was divided into four main stages. Figure 7 shows the research methods used and the overall type of data expected to be obtained. The first stage involved gathering of bibliographical data and non-exhaustive review of academic literature about climate change in India and the state of Karnataka, effects of climate and global change in agriculture and water demands, similar previous case studies, and social research methods. Concerning research methods, it was established that for better data quality, this study had to include different sources of data, namely key informant interviews, farmer workshops and household interviews. After going through Mayoux's (2006) 'Qualitative, Quantitative or Participatory? Which Method for What and When?' it was decided that since the resources (i.e. time and budget available for the research were very limited, that the objectives are related to social impacts and the subject had to do with social perception, methodologies for data collection are mainly qualitative. Limitations of time, budget and important complementary data did not allow a design based on statistical representativity of the sample. Although the quantitative results obtained should be used with caution, they are nonetheless of special interest to the AICHA project, given that these will be the first results obtained, and will serve as a benchmark study for future results and assessments.

A better understanding of the complexity of Indian societies and especially of rural communities was only reached once in the field. Before that, there was an unconsolidated notion of how poverty punishes Indian farmers, who at the same time are enormously dependent on unpredictable rainfall.

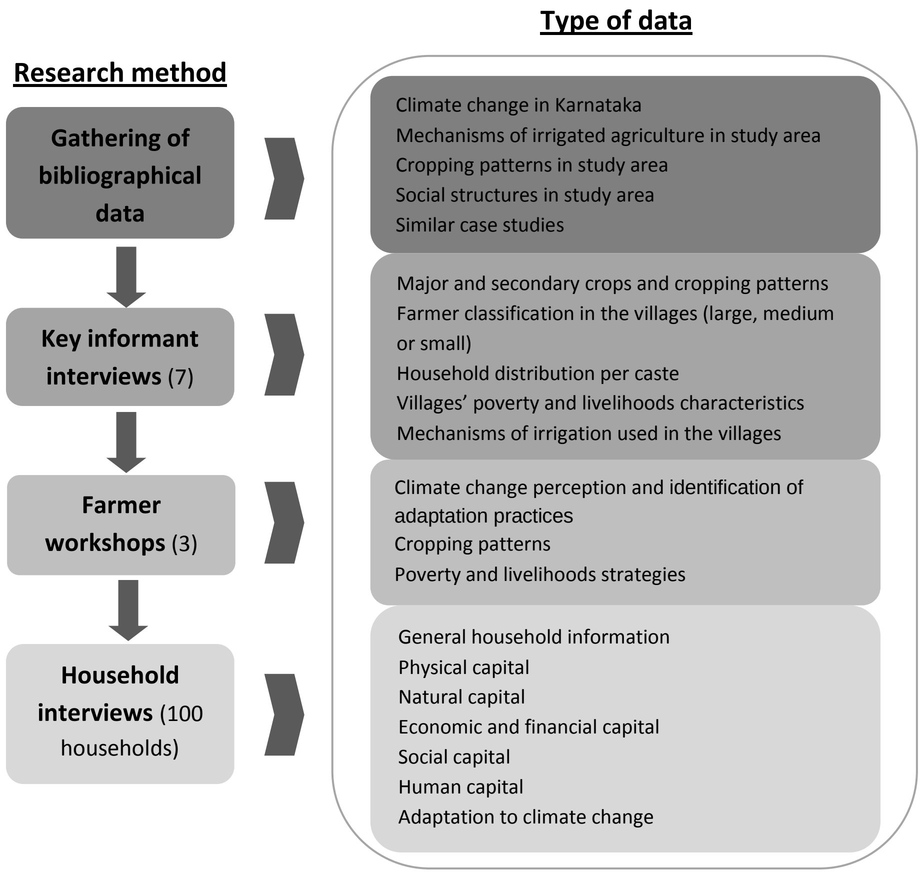

Figure 7. *Chronology of data collection* (Source: adapted from Below *et al.,* 2012).

The second stage was interviewing key informants. The interviews were held during the first trip to the field (Fig. 8). A total of seven people in the four chosen villages were interviewed. The interviewees were the Panchayat Development Officers (local self-governments at the village level) of three of the four villages and four elders who had a lifetime farming experience. In this stage the interviewees were selected by the ATREE researcher who also came to the field, given that he had experience in the geographical area and the subject. The Panchayat Development Officers helped us gain access to official information on the diversity and performance of agriculture in their villages, and the elders provided a wider vision of the village in terms of traditional social structure and livelihood strategies. The type of information collected allowed first insights into understanding the main characteristics of the communities regarding livelihood strategies, social and agronomic structures and processes shaping their vulnerability to climate change.

Figure 8. *Key informant interviews*

On the third stage of data collection, we conducted three farmer workshops (Fig. 9) with the objective of gaining a community-level perception and strategies related to the challenges and opportunities of farming and climate change. The average number of participants was 12 farmers, all males[1], from different caste, political, religious and economic (class and landholding) groups. Due to an episode of illness, neither of us could go to the field to organise a workshop with the farmers in the fourth village: Channamallipura.

For the workshop, the following questions and topics were considered:

1. Characteristics of the community: population, household distribution, caste system, education, labour force, migration and skills.
2. Perceived livelihood problems: what are the biggest livelihood problems faced by the community?
3. Community characterisation: marginal, small, medium and big farmers
4. Land ownership spread across communities
5. Present cropping system
6. History of present cropping pattern: how old is the present cropping system?

[1] It was not possible to include the voice of women in this part of the research. Farmer households in this area are predominantly lead by men, therefore the preponderance of men in the workshops. We acknowledge the bias of our results towards the perception of men.

7. What are the criteria for selecting harvested crops?
8. Who are more vulnerable to food security?
9. Had this village ever faced food insecurity problems? Why and how did they overcome the problem?
10. How would you compare your food security situation now as in previous years? Are you better, worse or the same? Why do you say so?
11. Has there been any major food crop production drop due to climate change?
12. What do you understand by climate change?
13. Have you been affected by climate change? If so, how?
14. Where did you get information on climate change?
15. How we can minimize the effect of climate change in your livelihood?

This stage of the data collection provided information that helped consolidate the household questionnaire, used on the next stage of household interviews. Plus, the information collected was useful to discuss the results obtained from the indices and general observed trends.

Figure 9. *Farmer workshops*

Finally, we approached the fourth and main stage of the study, where most of the conclusions come from. A total of 100 structured household interviews were held in the four villages between November and December 2012 (Fig. 10). The criteria for selecting the interviewed household followed a snowball sampling method, seeking to have heterogeneous cases, where five of the people interviewed were big farmers (cultivated land > 10 acres), 10 medium farmers (between 5 and 10 acres) and 10 small farmers (<5 acres of cultivated land), adding up to 25 interviewees per village.

Figure 10. *Household surveys*

The questionnaire implemented (see Annex A) was inspired by a previous study by ATREE. The questionnaire was divided into seven different sections. The first included general aspects and information about the household. In this part, livelihood strategies such as migration, migration periods and income linked to it were identified. The following five sections were each about a type of capital asset, following the sustainable livelihood framework (DFID, 1999): physical, natural, economic and financial, social, and human capital. The last section was about adaptation. In this section the interviewee had to identify both agricultural and climate-related problems they had in their farms and associated adaptation measures to cope with them. Sections 2 through 7 include both quantitative and qualitative data, as well as questions about perception of different topics, such as vulnerability and risk and climate variability. For the development of the questionnaire, we followed an iterative process, where pilot interviews were conducted first in order to test the questionnaire.

Given communication limitations due to language, three field assistants conducted the interviews in Kannada, the local language, and answers were written down in English for analysis. After doing the needed modifications to the questionnaire, the field assistants were thoroughly trained in order to gain a greater uniformity in data collection, and then sent to the field. During the whole course of the interviews, we were with the field assistants ensuring the quality of the process. With the help of the ATREE researcher that collaborated with us, we made sure that they translated the questionnaires and asked the questions in the same way to every interviewee. Also, is was reinforced that common doubts were solved in the same way by them (i.e. translation of words with several meanings was always made uniformly, standardising translations). Reviews of the answered questionnaires and answering of questions and doubts were addressed at the end of every session (twice a day).

The interviews allowed to obtain household-level information about the general social structure of the household, the five types of capital mentioned before, and their adaptation techniques to climate change, if any. This information complemented well with the data collected from the key informant interviews and the farmer workshops, since they helped gain a global vision of the villages.

3.4. Data analysis

The data from the surveys was 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 value 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.

In India many farmers have serious subsistence problems due to lack of income and loss of money for diverse reasons, such as crop loss due to bad weather, market price fluctuations and heavy dependence on agriculture as only source of income. This situation generally leads them to take loans, to the point of reaching high levels of indebtedness of the generalised rural population. In addition, lack of education and economic resources, do not give access to other types of employment, different from farming. Thus, we considered that adding the two components (Knowledge and Skills and Finance) would provide a more complete view of vulnerability in the area. The subcomponents and questions used to calculate these indices are specific to our study area.

Although the three indices provide similar results, the comparison of the three different perspectives is helpful to understand the reasons for vulnerability. For example, 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 100 household interviews.

Unluckily, for now it has not possible to calculate the sample size in proportion to the total population, since we do not have population data for one of the villages. Additionally, calculating the proportion of the sample based on data from 2001, would have been inaccurate.

3.4.1.1. Calculating the LVI

The LVI includes nine major components: Socio-Demographic Profile, Livelihood Strategies, Social Networks, Health, Food, Water, Natural Vulnerability and Climate Variability, Knowledge and Skills, and Finance. This index uses a balanced weighted average approach, where each sub-component contributes equally to the overall index, even though each major component is comprised of a different number of subcomponents (Table 2). Some of this subcomponents, are in turn compound indices with their own formula, and these are detailed in the Table 3, at the end of the section.

Because each of the subcomponents is measured on a different scale, it was first necessary to standardise each one as an index. This was done using the formula described as follows:

$$\text{Index Sc} = \frac{\text{Sobs} - \text{Smin}}{\text{Smax} - \text{Smin}}$$

Where Index $_{Sc}$ is the observed value of each sub-component, as the mean for the whole sample, and S_{min} and S_{max} are the minimum and maximum values, respectively.

After each sub-component was standardised, they were averaged using the following formula to calculate the value of each major component:

$$\mathrm{Mcom} = \frac{\sum_{i=1}^{n} \mathrm{IndexSci}}{n}$$

Where M_{com} is one of the nine major components for the study area [Socio-Demographic Profile (SDP), Livelihood Strategies (LS), Social Networks (SN), Health (H), Food (F), Water (W), or Natural Vulnerability and Climate Variability (NVCV), Knowledge and Skills (KS), and Finance (Fi)]. $Index_{Sci}$ represents the subcomponents, and n is the number of subcomponents in each major component.

Once values for each of the nine major components for all the study areas were calculated, they were averaged using the following formula to obtain the LVI:

$$\mathrm{LVI} = \frac{\sum_{i=1}^{9} \mathrm{WMi\ Mcomi}}{\sum_{i=1}^{9} \mathrm{WMi}}$$

That can also be expressed as:

$$\mathrm{LVI} = \frac{W_{SDP}\,SDP + W_{LS}\,LS + W_{SN}\,SN + W_{H}\,H + W_{F}\,F + W_{W}\,W + W_{NVCV}\,NVCV + W_{KS}\,KS + W_{Fi}\,Fi}{W_{SDP} + W_{LS} + W_{SN} + W_{H} + W_{F} + W_{W} + W_{NVCV} + W_{KS} + W_{Fi}}$$

Table 2. *Major components and subcomponents that make up the LVI.* (Source: own source)

Major components	Subcomponents
Socio-Demographic	Dependency Ratio *
	Percent of female-headed households
	Average age of head of household
	Percent of households where the head of household has not attended school, are illiterate
	Average family member in household
	Average of household head farming experience
Livelihood Strategies	Percent of households with a family member working in a different community/migration in some time
	Percent of households dependent solely on agriculture as a source of income
	Average agricultural livelihood diversification index *
	Percent of households didn't get the expected price for crops
	Percent of Semi-pucca or Kutcha houses
	Average of total Land cultivated
Social Networks	Frequency of neighbours visiting in a month
	Average of people feel can talk to about private matters with you
	Average people could go that they would be willing to leave me money if necessary
	Average people can't be trusted
	Percent of people/household are not willing to help you in case of necessity
	Average of people generally don't trust each other in matters of lending or borrow money
	Average of friends and relatives would offer help during the need without hesitation
	Average of times you have helped a friend or relative when the household was in need

	Percent of households where none of the family member is affiliated with any institution
Health	Percent of households where a family member had to miss work or school due the illness in the past year
	Percent of households have reductions in nutrition in bad times
	Life expectancy*
Food	Percent of households dependent on family farm for food
	Average number of months household is difficult to provide food
	Average crop diversity index*
	Average times with necessity of purchase food
	Average time to drinking water
	Average time to market
Water	Percent of household reporting borrewell fail
	Percent of households with access to water source
	Percent of households that do not have a consistent water supply
	Percent of households reported their natural water source is depleted
	Percent of households with investment risk
	Percent of households with vulnerability risk
Natural Vulnerability and Climate Variation	Percent of households reported less rain in the past 10 years
	Percent of households reported more droughts in the past 10 years
	Percent of households reported more floods in the past 10 years
	Percent of households reported unusual rains in the past 10 years
	Percent of households reported temperature increase in the past 10 years
	Percent of household crop choice like other years
	Percent of households reported less rain this year than the average of rainy seasons
	Percent of households have agricultural problems
	Percent of households don't have adaptations to climate/weather problems
Knowledge and Skills	Percent of households not having TV at home
	Percent of households not having radio at home
	Percent of households do not participate in knowledge exchange with others
	Percent of Households think that they have a lack of education
	Average in education
Finances	Percent of households have more expenditures than income
	Percent of household have any family member working outside or in a developed place(not farming)
	Percent of households with a money loan
	Percent of households didn't repay any quantity of the loans

Table 3. *Formulas for specified subcomponent indices*. (Source: own source)

Subcomponent	Formula
Dependency Ratio	$DR = \frac{\text{(number of people aged 0} - \text{14 and those aged 65 and over)}}{\text{number of people aged 15} - 64}$
Average agricultural livelihood diversification index	$ALDI = \frac{1}{\text{number of agricultural activities by household} + 1}$
Life expectancy index	$LEI = \frac{\text{LE} - 20}{82{,}5 - 20}$
Average crop diversity index	$CDI = \frac{1}{\text{number of crops grown by a household} + 1}$

The LVI is scaled from 0 (least vulnerable) to 1 (most vulnerable).

3.4.1.2. Calculating the LVI-IPCC

The LVI-IPCC derives from the IPCC vulnerability definition that characterises vulnerability with three components: Exposure, Sensitivity and Adaptive Capacity. For the estimation of the index, we combined the nine major components of the LVI and its values, with the three proprieties of the IPCC vulnerability definition as shown in Table 4.

Exposure is measured by aggregating the major components of Natural Vulnerability and Climate Variability. Sensitivity is quantified by the components of Health, Water and Food Security. Finally, Adaptive Capacity is measured through Demographic Profile, Social Networks, Livelihood Strategies, Knowledge and Skills, and Finance.

The LVI-IPCC diverges from the LVI in that in the LVI-IPCC the major components are first combined, rather than merged in one step. The combination is done according to the categorization scheme in Table 4, and using this formula:

$$\mathrm{CF} = \frac{\sum_{i=1}^{n} W_{Mi}\, M_i}{\sum_{i=1}^{n} W_{Mi}}$$

Where CF is an IPCC contributing factor (Exposure, Sensitivity, or Adaptive Capacity). M_i are the major components indexed by I, W_{Mi} is the weight of each major component, and n is the number of major components in each contributing factor. An important point to consider when calculating the index is that it is necessary to calculate the value of the Adaptive Capacity from the inverse of the subcomponents that make up this factor. This is because the adaptive capacity contributes to vulnerability in a different way than the Exposure and Sensitivity, since high values for Adaptive Capacity contribute negatively to vulnerability (reduces vulnerability). In return, high values of Exposure and Sensitivity contribute positively to vulnerability.

Once these three contributing factors are calculated, they are combined using the following formula to get the result of the LVI-IPCC:

$$\mathrm{LVI} - \mathrm{IPCC} = (e - a) * s$$

Where the LVI-IPCC is the vulnerability index using the IPCC vulnerability framework, e is the calculated exposure score, a is the adaptive capacity score and s is the sensitivity calculated score. The scaled range from LVI-IPCC is from -1 (least vulnerable, Adaptive Capacity > Exposure) to 1 (most vulnerable, Exposure >> Adaptive Capacity). A value of 0 denotes a moderate vulnerability (Exposure and Adaptive Capacity are equal).

Table 4. *LVI-IPCC components categorisation.* (Source: own source)

Contributing factors	**Major components**
Adaptive Capacity	Socio-demographic
	Livelihood strategies

	Social network
	Knowledge and skills
	Finance
Sensitivity	Health
	Food
	Water
Exposure	Natural vulnerability and climate variability

3.4.1.3. Calculating the LEI

The LEI is derived from the SLF that identifies five different types of vulnerability indicators or capitals: Natural, Human, Physical, Social and Financial capital. This vulnerability indicator can help identify and target vulnerable regions and sectors of populations, raise awareness, and be part of a monitoring strategy. It also provides a household-based composite index.

To calculate the LEI, we used the major components and their values from the LVI index to calculate the scores for each type of capital asset by combining them as shown in Table 5 and using the following formula:

$$\mathrm{Cv} = \frac{\sum_{i=1}^{n} L_i}{n}$$

Where Cv is the value for each capital of LEI, L is the score for effect dimension for capital i, and n is the number of sub-dimensions forming the capital.

LEI is then computed as the weighted average of all capitals using this formula:

$$\mathrm{LEI} = \frac{\sum_{i=1}^{5} W_i C_{Vi}}{\sum W_i}$$

Where C_{vi} is the value of capital i, and W_i the weight of each capital, decided by the number of dimensions in the each indicator. The LEI range is from 0 (least affected) to 1 (most affected).

Table 5. *Categorisation of effect dimensions by indicators for LEI.* (Source: own source)

Indicators	**Effect Dimensions**
Human capital	Health
	Food
	Knowledge and skills
Natural capital	Water
	Natural vulnerability and climate variability
Social capital	Socio-demographic
	Social networks
Financial capital	Finances
Physical capital	Livelihood strategies

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. As explained above, the LEI follows the sustainable rural livelihood structure of five types of capital, that breaks down into a series of subcomponents. As shown in Table 6 a total of 53 and not 54 subcomponents were considered for this part of the analysis, since life expectancy is a community level variable, and is not relevant at a household level.

The results were then classified based on frequency. For the frequency, intervals of 0.05 were arbitrarily chosen, and then households were grouped into four types of vulnerability: low, medium, high and very high vulnerability. After classifying the sample by type of household, the average value for every subcomponent was calculated by category. Finally, a correlation analysis for every subcomponent per level of vulnerability was developed, to test the relative influence of each factor on the type of household.

Table 6. *LEI subcomponents. Variables hypothesised to influence farmers' vulnerability in the Berambadi watershed.* (Source: own source)

No.	Factor	Description	Expected relationship with vulnerability	Capital assets
1	Health status	Has any family member had to miss work or school due the illness in the past year?	Negative	Human capital
2	Food intake	Has the household had to reduce food intake during bad times?	Negative	Human capital
3	Food production	Does the household depend on own production for food? Considered affirmative for households that produce 75% or more of the food grains consumed.	Positive	Human capital
4	Ability to provide food	Average number of months when it is difficult to provide food for the household	Negative	Human capital
5	Crop Diversity Index	$CDI = \frac{1}{\text{number of crops grown by a household} + 1}$	Positive	Human capital
6	Food grains	Times in a year the household has to purchase food grains	Negative	Human capital
7	Time to water source	Time travelled to a drinking water source	Negative	Human capital
8	Time to market	Time travelled to market for selling and buying food	Negative	Human capital
9	Access to information 1	Does the family own a TV?	Positive	Human capital
10	Access to information 2	Does the family own a radio?	Positive	Human capital
11	Knowledge exchange	Does any member of the household participate in knowledge exchange with other farmers of the village or other villages?	Positive	Human capital
12	Lack of information	Do they think they lack information?	Negative	Human capital
13	Formal education level	Average household education level	Positive	Human capital
14	Bore well failure	Has any bore well failed?	Negative	Natural capital
15	Access to irrigation	Do they have access to a source of irrigation?	Positive	Natural capital
16	Water supply characterisation	Does their water supply to meet their needs for irrigation?	Positive	Natural capital
17	Perception of water table depletion	Has the household reported that their natural water source is depleting?	Negative	Natural capital
18	Investment risk perception	Perceived investment risk related to bore wells for irrigation	Negative	Natural capital
19	Vulnerability risk perception	Perceived vulnerability risk related to bore wells for irrigation	Negative	Natural capital
20	Perceived rain decrease	Has the household reported less rain in the past 10 years?	Negative	Natural capital
21	Perceived drought increase	Has the household reported more droughts in the past 10 years?	Negative	Natural capital
22	Perceived flood increase	Has the household reported more floods in the past 10 years?	Negative	Natural capital
23	Perceived erratic rainfall	Has the household reported unusual rains in the past 10 years?	Negative	Natural capital
24	Perceived temperature increase	Has the household reported temperature increase in the past 10 years?	Negative	Natural capital
25	Crop choice selection	Will they change their crop choice for other years?	Positive	Natural capital
26	Perceived rain decrease in present year	Has the household reported less rain this year, relative to the average rainy season?	Negative	Natural capital
27	Agricultural problems	Do they have any agricultural problems?	Negative	Natural capital
28	Adaptation measures	Do they take any adaptation measures to cope with climate/weather-related	Positive	Natural capital

		problems?		
29	Dependency ratio	Ratio of productive versus unproductive household members: household members younger than 14 and older than 65 divided by the number of household members between 15 and 64	Negative	Social capital
30	Gender	Is the household head a female?	Negative	Social capital
31	Household head age	1/Household head age	Either positive or negative	Social capital
32	Level of literacy	Is the household head illiterate/has not attended school?	Negative	Social capital
33	Household size	Number of family members of the household	Either positive or negative	Social capital
34	Farming experience	Number of years the household head has worked as an independent decision maker	Positive	Social capital
35	Social interactions	Frequency of neighbours visiting in a month	Positive	Social capital
36	Trust	Number of people who they can talk to about private matters	Positive	Social capital
37	Perceived access to informal loans	Number of people who would be willing to lend them money if necessary	Positive	Social capital
38	Community-level trust	Number of people in the village that can be trusted	Positive	Social capital
39	Perception of help received	Will people be willing to help them in case of necessity?	Positive	Social capital
40	Financial trust	Do they think that people generally trust each other in matters of lending and borrowing money in their village?	Positive	Social capital
41	Perceived cooperativeness	Number of friends and relatives that would offer help during need without hesitation	Positive	Social capital
42	Household cooperativeness	Number of times they have helped a friend or relative when they were in need during the past 5 years	Positive	Social capital
43	Membership in social groups	Membership of one or more household members in a formal institution	Positive	Social capital
44	Household economic deficit	Does the household have more expenditures than income?	Negative	Financial capital
45	Income diversification	Does the household get an income from salary or self employment?	Positive	Financial capital
46	Access to loans	Have they taken a loan?	Either positive or negative	Financial capital
47	Level of indebtedness	Have they been able to repay any quantity of the loan(s)?	Negative	Financial capital
48	Migration	Has a member of the household migrated to work in a different village/community?	Positive	Physical capital
49	Dependency on agriculture	Does the household's income depend solely on agriculture?	Negative	Physical capital
50	Agricultural Livelihood Diversification Index	$ALDI = \frac{1}{\text{number of agricultural activities by household} + 1}$	Positive	Physical capital
51	Expected market price	Did they get the expected price for crops?	Positive	Physical capital
52	House type	Pucca (very unstable materials for construction), Semi-Pucca (stable) or Kutcha (very stable materials)	Either positive or negative	Physical capital
53	Cultivated land	Total acres of cultivated land for the 2011-2012 season	Positive	Physical capital

4. RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

In this section the results for the whole sample are first described, followed by a discussion on the different indices applied to the sample. Subsequently the results at the household level will be described and discussed, identifying which are the most relevant factors that justify the chosen classification of the farmers' vulnerability.

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% 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- 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.

4.1.1. LVI results

Table 7 presents the summary of the LVI results for the nine major components. The overall of the LVI for the studied Berambadi watershed villages was found to be 0,499 (in a range from 0 to 1 where 0 represents low vulnerability and 1 high vulnerability). Therefore our result indicates a moderate vulnerability to the impacts of climate change and environmental degradation.

To see the full table of the results for the 54 subcomponents and major components, see Annex B.

Table7. *LVI results for the nine major components and its overall.*

Major components	Number of subcomponents forming the major component	Indicator value
Socio-demographic	6	0,333
Livelihood strategies	6	0,528
Social network	9	0,257
Health	3	0,621
Food	6	0,409
Water	6	0,617
Natural vulnerability and climate variability	9	0,696
Knowledge and Skills	5	0,414
Finance	4	0,772
Overall LVI value: 0,499		

The results for the major components are presented in figure 11, which illustrates how they contribute to the vulnerability of the area.

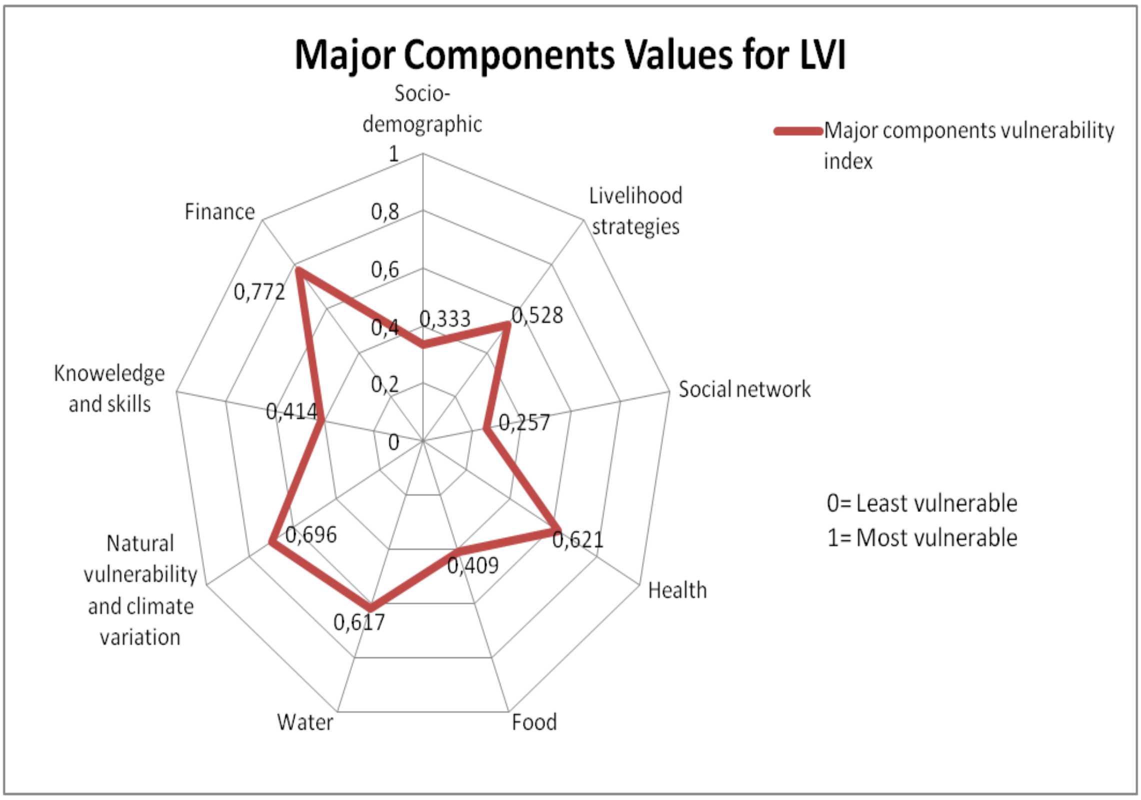

Figure 11. *Radar chart of major components of the LVI.*

As seen in the diagram above, the financial component has the largest contribution to the vulnerability of the community with a value of 0.772. Having adequate financial backups is helpful to overcome external risks and shocks. Thus, we can say that this high level in the financial sector will be affecting negatively the rest of the components, because without a stable economy and economic resources, and depending exclusively on agriculture as the only source of income, it is very difficult to cope with climate change impacts. Additionally, the lack of resources reduces the possibility to apply mitigation strategies.

One of the reasons that explain the financial component having such an effect on vulnerability is that in 66% of the households in the sample reported to have more expenses than income in a year. Most of the households in the sample (exactly the 95%) reported having resort to money loans in recent years; and a few of them have even had to resort to agriculture, land or house loans. Nevertheless, other factors, such as the recent lack of rain and water stress, the reduction in market prices, and investment risk, might also cause that 71,5% of the households are unable to repay any of their money loans. Consequently, 65% of the interviewed households reported that they can only pay the interest loan, while 17% of the households reported that they could not pay anything at all, mostly due to crop failures. Another factor contributing to financial vulnerability is that 76% of the households fully depend on farming as a source of income, a condition that severely limits the family income in the case of a bad harvest year, lower market prices, higher competition between farmers, or crop loss affected by weather conditions. Under such circumstances, household economies have numerous problems whilst accumulating large debts. Indeed, in the last 15 years the number of suicides among farmers in India have increased due to the loss of crops and debt accumulation (Assadi).

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 resources for their daily subsistence. Households in the area need good weather conditions to grow their crops. Our data indicates that 82% of the respondents claim that in the last 10 years the amount of rainfall has decreased and changed over time, with unusual rains increasing. Similarly, 53% of respondents claim that droughts have increased, although only 22% say flooding has also increased. Most farmers say that these effects are more serious as of the 2008, and 95% of them believe that 2012 has been the worst of all years, with less rain than in any previous year. Lack of rain and its unpredictability affects farmers' crops, as both irrigated and rainfed crops need very specific weather conditions (i.e., during planting). It is important to notice that is not only the lack of rain what negatively affects crops, thus depending on the type of crops heavy rains can also cause their loss. One of the reasons why farmers indicated that 2012 was the worst years relates to the fact that market prices depend on total rainfall during the year, also in 2012, these effects have been devastating for the farmers as they claim to have lost up to 80% of the cultivated land (as stated by them in the workshops).

Observing the above data is logical to think that –to maximise benefits and minimise losses- each year, farmers would need to adapt to the expected weather conditions, modifying the farming types, crop species and experiences from previous years. However, the contrary is true: our data suggest that 81% of the farmers maintain the same conditions at the time of planting and the crop choice, just hoping that it will rain. 86% of farmers interviewed claimed that there has been an increase in temperature in the last 10 years, which has serious implications for the cultivated land, an even greater need for water, reducing moisture and soil quality and increasing the number of diseases and pests. As a consequence, farmers have to add chemicals -as fertilizer and pesticides- to their crops to increase production, but eventually these products reduce soil quality and lower the quality of crops and as a consequence they significantly affect the farmers' economy. Apart from all these factors, a fact that must be taken seriously into account is that 92% of farmers have agricultural problems: as much as 56,4% of the farmers reported to have soil and land problems, 31% reported animal problems (i.e. attacks from wild pigs and elephants), 6,6% reported climate problems, 5% reported crop-related problems, and the remaining 1% reported monetary problems. We must also take into account that most of these farmers reported more than one of those problems, and that the 32,4 % of the farmers mentioned that they do not have any way to adapt to these problems, especially to those related to climate.

The third component that mainly affects vulnerability is health, with a value of 0,621. From the studied variables, this high value is presumably due to the fact that 71% of the community reported reductions in the quantity of food intake during bad times. Non-vegetarian households reduce or completely stop their meat consumption, also changing the bowls of rice and ragi for mostly soups. The reduction of food intake has a direct effect on vulnerability, as it has serious health risks, one of them is increase the chances of illness. Forty-four percent of respondents reported missing work for several days during the previous year due to some type of illness, mainly diarrhoea and respiratory problems. The temperature increase and lack of hygienic conditions might have caused diseases like diarrhoea. In addition working long hours under poor conditions might cause that most farmers develop respiratory illness by continued inhalation of different particles as grain dust. The medium life expectancy (67 years approximately) influence increasing vulnerability as well.

The overall for the water component is 0.617. Fifty-seven percent of farmers in our sample have access to a water source to irrigate their fields. During our field observations, we verified that 100% of the farmers with access to a water source use the extracted groundwater from wells to irrigate their crops. The lack of rain, the change in crop patterns, more access to new technologies and government aids, cause that in the last 10 years the construction of new wells has increased dramatically. The rapid and uncontrolled increase of wells in recent years has caused the water level to drop sharply: 88% of the farmers claim that their natural water source is depleting year by year, and 82.6% claim to not have a consistent water supply, and suffering water deficits. About 36% of farmers report failures in wells, many of which had run dry after abuse. In some cases farmers report to not find water after digging new wells. The need to dig new borewells has forced farmers to take loans, which yet again they cannot repay, since rain patters are erratic and cause crop loss. Farmers mentioned that even if they go back to early rain conditions, they would need at least 10 years to return to optimum conditions, due to have heavy debts (as stated from the workshops). Forty-four percent of households report that they perceive to be taking investment risks and the 62,5% vulnerability risks.

As seen in Fig. 11, livelihood strategies have a moderate effect on vulnerability, with an overall value of 0.528. This value is clearly influenced by two 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. Crop failure due to lack of rain and falling market prices causes the price received for these is lower than expected in absolute value. This has important consequences in family planning because there is not enough money to cover basic needs or to reinvest in agricultural expenses. Households are also unable to pay the loans from previous harvests, with the need to take more loans, increasing their loan burden. The second factor is that 89% of the families live in semi-*pucca* or *kutcha* houses, which are types of houses constructed entirely or largely with natural materials and inconsistent as un-burnt bricks, bamboos, mud, grass, reeds, thatch, and loosely packed stones. These houses make people more vulnerable to extreme climatic events and the hygienic conditions are reduced, increasing the likelihood of disease or other problems. Another fact to consider is that 75% of families depend on agriculture as their only source of income. Large dependence on agriculture greatly increases household vulnerability, since crop problems can cause remarkable reductions of income and forcing them to go back to the loop of loans. However it is positive that the agricultural livelihood diversification index is low (0.37), which indicates that most of these families do more than one activity related to agriculture, such as having livestock and work as agricultural labour, trying to compensate with this their dependence on agricultural activities. In addition, the ratio of total land and cultivated land is very good. This is because most farmers manage their land well and cultivate more than one crop, allocating different crops in different seasons, so at the end of the year the ratio of total land and cultivated land is very small playing against increased vulnerability.

Finally, the percentage of households with the need to migrate to another area looking for temporary work is very low, only 13%. This low percentage indicates that the conditions were not bad enough to migrate, being able to withstand the harsh conditions. However some interviewed farmers said that this year the percentage of migration was larger, and that in the coming years this will probably continue increasing as bad weather conditions will increase, in their opinion.

Among the components that have a low effect on vulnerability, we find knowledge and skills. We observed that the 96% of the households do not have radio at home but 92% of them own a TV, so we could say that one compensates the other. Television and radio ownership are connected to access to external information, very important to get information on weather forecasts and government decisions, among others. Also we found that most farmers exchange information between them, which is very useful for social dynamics, since knowledge exchange and support among farmers has a positive effect in addressing adverse situations. Only 3% of the people in the sample say that they do not participate in knowledge exchange with other households. By contrast, 68% believe they lack information on subjects like market prices, copping systems and government subsidies, which logically reduces their ability to face adverse conditions and develop agricultural activities at the maximum performance. Nevertheless the vulnerability value of the education is low, 0.319.

Food is another component that has a low effect on vulnerability, with a value of 0.409. The variable that has a larger effect on this component is that 65% of households depending only on family farm for food: if their food grains crop fail, they don't have the expected food for their household and need to purchase food. Households reported the they need to purchase food grains up to 11 times in a year, because their own production is not sufficient. Seeing themselves forced to buy food grains is a sign of vulnerability. The average crop diversification index is low (0.326), possibly due to the fact that farmers as a preventive measure, cultivate more than one crop per season or even at the same time. A widely used technique is intercropping, which consists in combining different kinds of crop on the same land and generally different physiological characteristics. This is useful because if, due to weather conditions such as lack or delay of rains, one of the crops fail, the household still has the other to make a profit. The average to access to drinking water is 4 minutes and the average in time to market is 36 minutes.

Finally the components that have the lowest effect on vulnerability are first the socio-demographic profile with a vulnerability index of 0.333. Most household heads are male, only the 11% are women. In a patriarchal society like the Indian society, when women take the lead of a household is associated with instabilities especially socio-economic instability, as it is considered that the main source of income for a household always comes from men. In addition the average age of the household head is 57 years (vulnerability value: 0.27) and the average of farming experience is 32 years (vulnerability value: 0.47). In addition, the dependency ratio is quite low with a value of 0.326 because the average household size is on average 5 members per household, with a vulnerability value of 0.295.

With a value of 0.257, social network is the less influencing component on vulnerability. In this community the social relations seem to be strong and well managed: most of the people in the community members know each other, reported to perceive their neighbours' willingness to help and lend money in times of need, and most of them trust each the other. This is very positive for tackling a joint problem such as climate change, because as a united community is stronger than a fragmented one.

4.1.2. LVI-IPCC results

Table 8 presents the results for the LVI-IPCC, focusing on the three factors contributing to vulnerability: exposure, sensitivity and adaptation. In this case, the overall result is 0.106 (-1 low vulnerability to 1 high vulnerability) and therefore, like the LVI, our results suggest that the studied villages have a moderate vulnerability to climate change and climate variability.

Table 8. *Results from LVI-IPCC study.*

Contributing factors	**Major components**	**Subcomponents number**	**Indicator value**
Adaptive Capacity	Socio-demographic	6	0.402
	Livelihood strategies	6	0.331
	Social network	9	0.760
	Knowledge and skills	5	0.634
	Finance	4	0.131
Adaptive Capacity contributing value			**0.498**
Sensitivity	Health	3	0.621
	Food	6	0.409
	Water	6	0.617
Sensitivity contributing factor			**0.535**
Exposure	Natural vulnerability and climate variability	9	0.696
Exposure contributing factor			**0.696**
LVI-IPCC: 0.106			

The following triangle diagram (Fig. 12) shows the contributing factors for vulnerability index based on the LVI-IPCC framework.

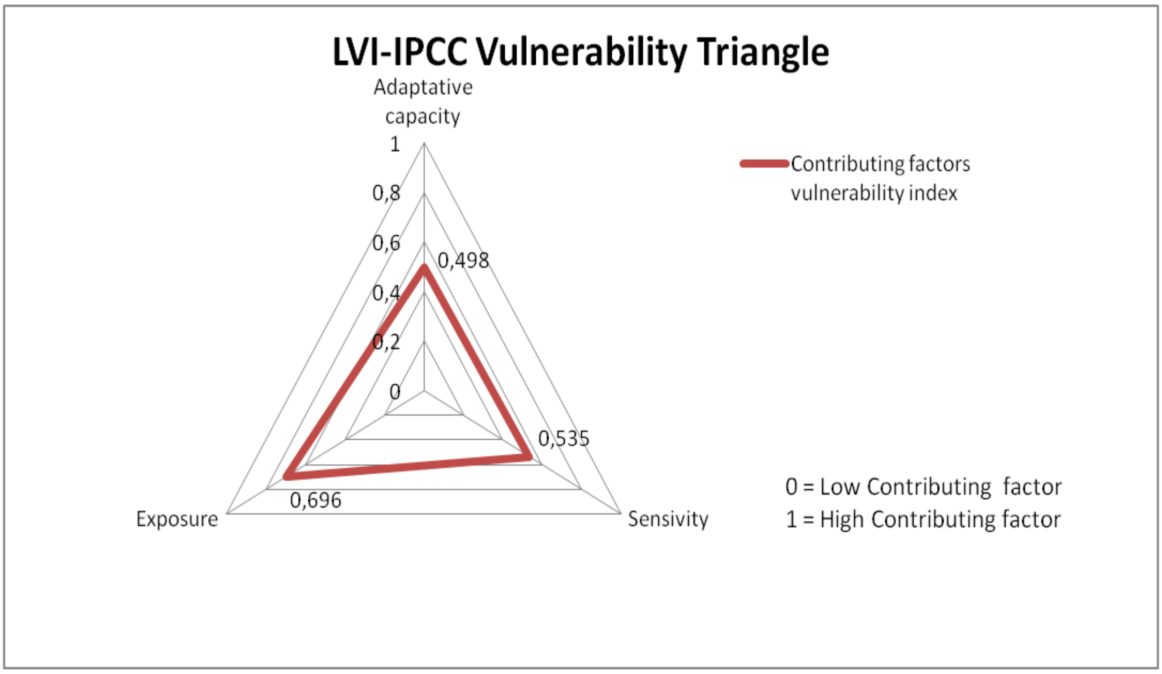

Figure 12. *Triangle diagram of the three contributing factors for LVI-IPCC*

The overall value for the LV-IPPC expresses the moderate vulnerability to climate changes and climate variability. 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 towards exposure. Thus exposure, with a value 0.696, is the factor that contributes most to the vulnerability of the community. The adaptive capacity 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 signifies that the community has a good capacity to cope with climate change and climate variability, but not good enough to decrease the exposure and the sensitivity. Probably local adaptation methods are good for short periods and little harmful situations, however for long term periods and also for extreme situations, their adaptation and mitigation seem to be very slim, due to the fact that the components adversely affecting their adaptive capacity are the financial (0.131) and the livelihood strategies (0.331), which are components that tend to have greater consequences for more prolonged periods of time rather than short.

Sensitivity of Berambadi watershed livelihoods towards climate change impacts is 0.535. This value indicates a moderate sensitivity to climate variations and changes, so we could argue that to have high exposure and a relatively low adaptive capacity causes the community to be more sensitive to climate changes and be negatively affected by them, mostly influencing health (0.621), followed by water resources (0.617) and food security (0.409), and on the aggregate, increasing the vulnerability.

4.1.3. LEI results

Finally, we conducted the calculation of the LEI (Table 9). Results from this index suggest a moderate vulnerability to climatic change as well, with an overall value of 0.508 (0 low effect to 1 most effect). Results from the LEI are slightly higher than results from the LVI, suggesting that in the whole community, household level are affected by 1% more than if we consider the livelihood in the sight of the whole community.

Table 9. *Aggregate results for LEI*

Sustainable Livelihood factors	Major components	Subcomponents number	Indicator value
Human capital	Health	3	0,621
	Food	6	0,409
	Knowledge and skills	5	0,414
Human Capital Index value			**0,456**
Natural capital	Water	6	0,617
	Natural vulnerability and climate variability	9	0,696
Natural Capital Index value			**0,664**
Social capital	Socio-demographic	6	0,333
	Social networks	9	0,257
Social Capital Index value			**0,287**
Financial capital	Finances	4	0,772
Financial Capital Index value			**0,772**
Physical capital	Livelihood strategies	6	0,528
Physical Capital Index value			**0,528**
LEI: 0,508			

The five capitals diagram (Fig. 13), showing the distribution of the vulnerability of our community is shown below.

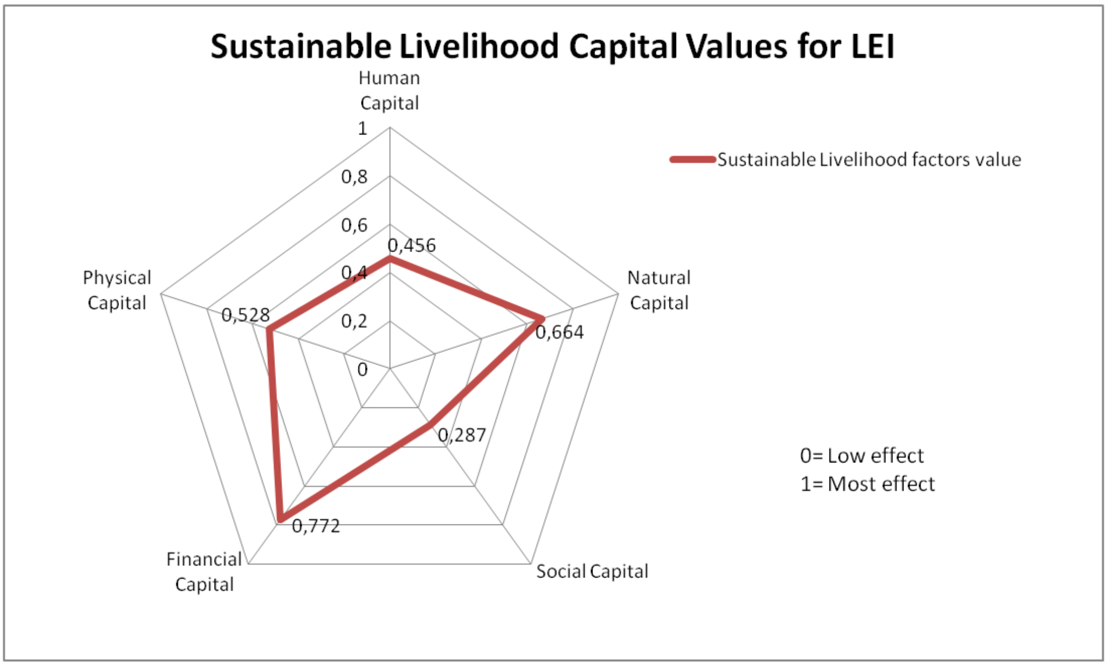

Figure 13. *Vulnerability radar diagram of five capitals for LEI*

Thus the LEI present the effects of climate change in the household level from the redistribution of the LVI components, and such as previous results submit the household vulnerability with a value of 0.508, which is a slightly bigger than at the community level: 0.499, but in practical terms, equal.

Similar to the LVI, the financial part in this case, called Financial Capital, is the most influential to the vulnerability index and has the most effect on a household with a value of a 0,772. The household economy is very important for a good development of the family, in a patriarchal society where the principal source of income comes from the household head and the other components of the family like women especially, don't contribute much to the household income or if they do, in a little quantity. Adding the big dependence to farming, this can provoke large economic instabilities, such as crop losses, health and education costs, and the large accumulation of debts, among other problems. This can lead households to have serious financial problems, affecting their positive development and their capabilities to cope with problems. As we recall some facts, such as that 66% of households have more expenses than income or that 95% had the need to take a money loan and that 75% of these households can't pay these loans. So we can get an idea of the problems that these homes can have in the future if conditions do not improve.

The Natural Capital is the second most effected 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, even causing 80% of the crop loss in some cases. Another point to consider is that the vast majority of households, 92%, have problems to develop their agriculture property, inasmuch as land problems, wild animals or difficulties obtaining water, preventing high crop yields, and thus not achieve the maximum profit. In addition, the lack of rain has meant that farmers have serious problems getting water for irrigation. A 82% of households claim they don't have a water supply, while there are deficits of water, and also the 88 % confirm that their borewells yield are depleting year after year, thus increasing the vulnerability and investment risk. The big dependence of farmers on natural resources makes small changes have a big effect on their development and affect their way of life. This high effect of natural capital on households makes other capitals also be adversely affected.

The Physical Capital for LEI, has the value of 0,528. Having a medium effect to community households, the subcomponents that effect to a greater extent are the fact that 89% of families live in houses of their own construction with less resistant materials and therefore very vulnerable to the extreme climate events. Also, the hygienic conditions in these type of houses aren't good. Also, as we have said several times, a 75% of households depend solely on agriculture as a source of income, which affects increasing the vulnerability. Agriculture related problems decrease the family income which will affect the other capitals. On the other hand, the agricultural diversification index, the total cultivated land and the migration have low values contributing to decrease in the Physical Capital effect index.

The Human Capital has a low effect with a value of 0,456. Health is the component that has a greater effect on this capital with a 0,621 due to the medium life expectancy , about 67 years 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. Current technology connects you to any type of information, and farmers know that, because the 92% of them have a television at home. Also, although they have a considerable lack of education, the great knowledge and information exchange between different households compensates this lack of education in some way. Meanwhile, food could highlight that 65% of households depend mostly on their farm to get food, but still have to buy food about 11 times a year approximately and still spend a month with difficulties in providing food for the household.

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. The population has a strong trust between themselves and do not doubt to lend financial assistance or otherwise in times of need. Also a 50% of households are affiliated with some kind of association that helps the development of the household and as a consequence to the all communities. Socio-demographically also there is a fairly consistent structure. The time dependence is moderately low, the household head is relatively young and experienced in agriculture, and the households are composed of few members, which facilitates development.

4.1.4. Comparison to other studies

Due to the fact that these indices are constructed from a specified data collection and adapted to our study area, in a specific space and time, therefore they cannot be strictly compared or applied to other studies. Nevertheless, for the sake of having other references in order to explore the relative values of our results, we used prior studies that apply these same indices and methodologies in their areas of study. To provide scientific relevance to our research, and to see if the results observed in our indices are consistent, we compare our results to other studies done in areas with similar conditions to ours.

The comparison was made only for the LVI-IPCC and LEI, because the LVI is not comparable due to the specificity and variability of its components for a specific study area.

The comparison with the LVI-IPCC is based on a study realized by Mohan and Sinha for he World Wide Fund for nature (WWF), conducted in 2011, titled: “Facing the Facts: Ganga Basin's Vulnerability to Climate Change.” They used the LVI-IPCC approach to assess farmers' vulnerability to climate change in Uttar Pradesh, a state located in the north of India. The results obtained in this study gave an overall result of 0.072. The partial results for each contributing factor are: exposure to climate change: 0.491, adaptive capacity: 0.349 and sensitivity: 0.509. In our case, the overall value for the LVI-IPCC is 0.106, with an exposure of 0.696, an adaptive capacity of 0,498 and a sensitivity of 0.535. So as seen above in figure 12, the vulnerability in our study is slightly higher than in the study of the WWF, but quite similar. The contributing factors to this vulnerability as we see, follow the same pattern, i.e. the two areas studied have a high exposure with an adaptive capacity relatively low and a sensitivity with a medium value, and in this case very similar. This similarity found is consistent with our expectations, since that case of study is within a similar context, and validates our results.

To compare the LEI, we use the study titled "Sustainable Livelihood Approach in assessment of vulnerability to the impacts of climate change: a study of Chhekampar VDC, Gorkha District of Nepal" carried out by Kumar Lamichhane in 2010. In this study case, the LEI was calculated for a district of Nepal. The overall result for the index was 0.497, and for the different types of capital assets, the following values were found: financial capital: 0.700, natural capital: 0.557, human capital: 0.530, physical capital: 0.338 and finally, social capital: 0.284. When compared to our study, we can see that results are quite similar as well. As the overall for our study case is 0.508 and for the different capitals: financial capital: 0.772, natural capital: 0.664, human capital: 0.456, physical capital: 0.528 and social capital: 0.287. As in the previous case, the results of this study are very similar to those obtained in ours, thus, we can re-confirm the validity of our data and calculations.

Finally we conclude that our results are valid since they have an apparent similarity and the relation between other studies made with a similar time scale, similar methods and study areas with similar characteristics.

4.2. Household-level results

4.2.1. LEI results and frequencies

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 factors that determine this classification.

According to the graphed frequency of the LEI results, starting at 0.35 and ending in 0.70, increasing by a factor of 0.05, four types of household were identified. 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% (Table 10).

Table 10. *Type of vulnerability and frequency*

Type		*Frequency*
Low	0,35	2
	0,4	6
	0,45	10
Medium	0,5	24
High	0,55	27
	0,6	23
Very high	0,65	6
	0,7	2

Figure 14 shows the distribution pattern of the frequencies and clearly represents all four categories considered.

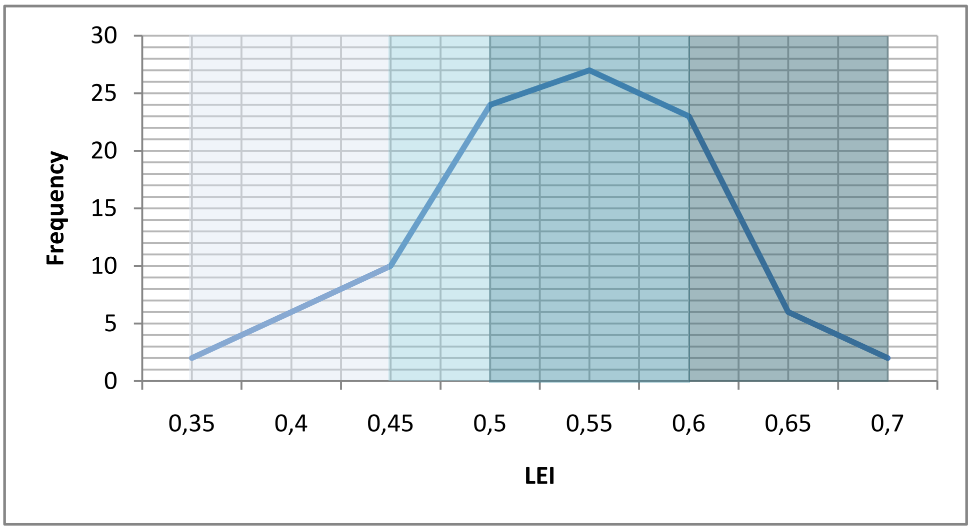

Figure 14. *LEI frequency distribution of the households*

The household heads in the low vulnerability group are 50 years old, on average and their level of education is pre-primary schooling - the lowest level of formal education. About 72% of them have farming as their primary occupation. Within the other 28%, household heads hold government jobs, do rural crafts, are a contractor or do not work because of illness or age. Only two households in this category (11%) are headed by women, and their primary occupation is farming in their own land. Overall, they have an average of 1.3 failed borewells.

The medium vulnerability group is characterised by household heads having an average age of 59 years and also having pre-primary schooling as their average level of education. Farming is the primary occupation of about 83% of them, while the other 17% do rural crafts, are a commission agent, or do not work. As in the low vulnerability group, only two farmer women are heads of their household, representing 8% of the group. Farmers falling in the medium vulnerability group have the lowest number of failed borewells within the whole sample, at 0.4 on average.

The high vulnerability group is the largest and most heterogeneous out of the four. On average, household heads have not attended any educational institution, but they can read and write, and they are 57 years old. Household heads whose primary occupation is farming in their own land represent 82%, including the only five women who are household leaders (10% of the group). Livestock grazing, agricultural labours, government job, petty business, rural crafts, and not working due to age or illness, are the primary occupations of the other 18% of the household heads. They have an average of 1.7 failed borewells.

Finally, households in the very high vulnerability group, that account for the smallest number of households, all the household heads are illiterate and are farmers in their own land as their primary occupation, having no job diversification. Two women are household heads, representing 25% of the group. As for the average age of the household head, is 67 years, making them the oldest group. On average, the very high vulnerable households have the highest number of failed borewells, at 2.8.

In general, the low vulnerability group is more widely represented by households in Channamallipura. The medium vulnerability group is represented equally by households in both Beemanabheedu and Berambadi. The high vulnerability group has a higher percentage of households in Maddinahundi, and the very high, in Beemanabheedu. Nevertheless, it cannot be said that Channamallipura and Beemanabheedu are the least and most vulnerable villages, respectively. The LEI was not applied per village, because the sample size for each village (25 households) is not large enough, and thus they cannot be compared.

4.2.2. Correlations between the LEI factors and the behaviour of vulnerability subcomponents per type of capital asset

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 differences in the four types of groups. This means that in the following section we are going to try to find out the main drivers of vulnerability. The average values for every subcomponent and LEI were calculated and then tested for correlation with the index value for that vulnerability group (see Annex C).

Table 11 illustrates the subcomponents that were found to correlate strongly with the LEI (see Annex C for full results). Therefore, these are the 15 factors that best explain the chosen vulnerability classification, and consequently have been adopted as the key factors of vulnerability in this region and for this study case.

Table 11. *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

As figures 15 to 19 show, 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 financial capital third (25% subcomponents correlated), physical capital (17%) and finally social capital (13%).

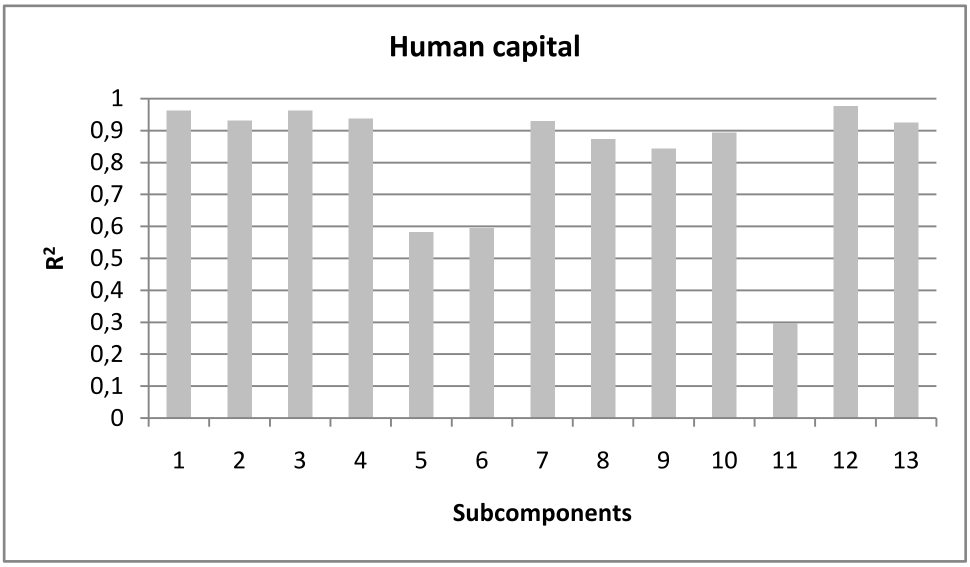

Figure 15. *Human capital- R^2 per subcomponent*

In figure 15 we see that the main drivers that explain the vulnerability are: lack of information (subcomponent 12), health status (1), food productivity (3), ability to provide food (4), food intake (2, time to water source (7) and formal education level (13), in order of decreasing correlation.

The variable that refers to the lack of information has the highest correlation within the human capital. The interviewees were asked if they thought that they were missing information about weather, cropping systems (seeds, fertilisers and pesticides), market and prices, health, or government programmes on subsidies. Lack of information on at least one of these subjects increases vulnerability. Thus 33% of the households in the low vulnerability group, 50% of the households in the medium, 84% of the households in the high, and 100% of the households in the very high vulnerable groups think they lack information. The level of formal education (from an educational institution) represents the average level of education received by every member of the household. As expected, there is a negative relation with vulnerability: vulnerability increases as the education level decreases. These differences might be influenced by the household's income and livelihood diversification, as well as size and composition, so studying the correlation among education level and gender and dependency ratio could be revealing.

Food production is also negatively correlated to the household vulnerability: the least food grains a household produces for their own consumption the more vulnerable the household is.

It was considered that a household produced enough food grains for their own consumption when - as stated by them - 75% or more of their food grains need were met by their own farm land in a year with enough rainfall. The result is that 83% of the least vulnerable households produce 75% or more of the food grains they need, as do 75% of the medium vulnerability households, 60% of the high, and only 37,5% of the most vulnerable.

The ability of the household to provide food to its members has to do with the number of months in a year that it is difficult to afford food provisions. On average, the least vulnerable households only have difficulties two months in a year, the medium 3, the high 4, and the most vulnerable households go through food shortfalls during half of the year. Conceptually, this is very related to food intake, that refers to any sort of food reduction the family has to face during difficult times, compared to normal times. For non-vegetarian families, the first nutritious element to be suppressed from their diet is chicken (or any other non-vegetarian food). Only 22% of the low vulnerability households had had to reduce food intake, while almost 88% of the most vulnerable see themselves forced to reduce what they can afford to eat. It is suggested that both the ability to provide food and the food production are linked. Farmers who have a difficulty in providing and producing food for own consumption are most likely cultivating cash crops in most, if not all, of their cultivated land, which makes them highly dependant on market prices and dynamics. Other factors such as soil quality, water requirements and access to irrigation might influence their ability to produce and provide food for the household.

Health status is also strongly correlated to vulnerability. The interviewees were asked if during the past year (2011-2012) any of the household members had to miss work and/or school days due to any of the following health conditions: diarrhoea, respiratory illness, accident, surgery, and/or pregnancy. The latter, although not an illness, was also included since it inhibits women from working for a relatively long period of time. As expected, the correlation of this factor with the household vulnerability is positive: on average only 22% of the least vulnerable, 46% of the medium, 60% of the high and a 100% of the very high vulnerable households had at least one member who had to miss work or school due to bad health conditions.

The time needed to reach a drinking water source also increases as does the vulnerability of the household. Whether they do not even need to leave the house, because they have an in-house drinking water connection, or because they live closer to a water source, the least vulnerable spend less than a minute, while the most vulnerable spend more than 12 minutes.

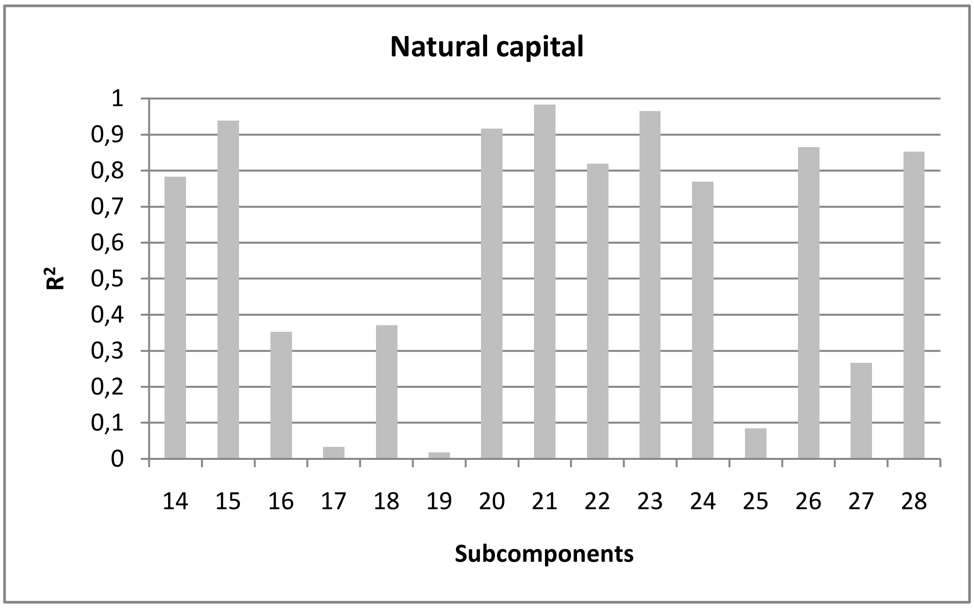

Figure 16. *Natural capital- R^2 per subcomponent*

Figure 16 shows the behaviour of the natural capital index subcomponents. Farmers' perception of drought (subcomponent 21) differs between households falling in the four vulnerability groups, and has the strongest correlation of all subcomponents. The fact that under the same climatic conditions, 75% of the most vulnerable agree that there has been more droughts during the past ten years, but only 28% of the least vulnerable share this perception, shows that this is a determining factor when it comes to establishing vulnerability types. The same is observed for subcomponent 23: perceived erratic rainfall (100 versus 67%) and subcomponent 20: perceived rain decrease (100 versus 61%). What this says is that the perceived effects of weather conditions related to droughts, erratic rainfalls and rainfall decrease in the past ten years have been suffered more, or have had a stronger impact on the most vulnerable households. By looking at the average number of households that adopt at least one adaptation measure to cope with both agricultural and climatic stressors, it could be presumed that the least vulnerable households are better prepared, since when compared to the most vulnerable, the first double the latter (in percentage). These observed differences match what it had been already presumed: that not all farmers can adopt adaptation measures, due to lack of money and knowledge. Note that the exact number of adaptation measures was not taken into account, because according to Below *et al*. (2012), implementing a larger number of adaptation practices does not always mean being better adapted. However, since there are undeniable differences between coping with seasonal weather conditions and adapting to the cumulative effects of climate variability and change, it would be interesting to differentiate between short-term adaptation processes and adapting to long-term trends in the environment and society (Downing, 1991).

As for access to irrigation (15), there is a negative correlation between this factor and household vulnerability. Thus, 66% of the households in the low vulnerability group have access to an irrigation source (borewells), as do 58% of the households in the medium vulnerability group, 54% of the high vulnerability, and only about 38% of the households in the very high vulnerability group. This means that the farmers that depend solely on the amount and temporality of rainfall are in fact more vulnerable than those who have access to an irrigation source and can afford to maintain it.

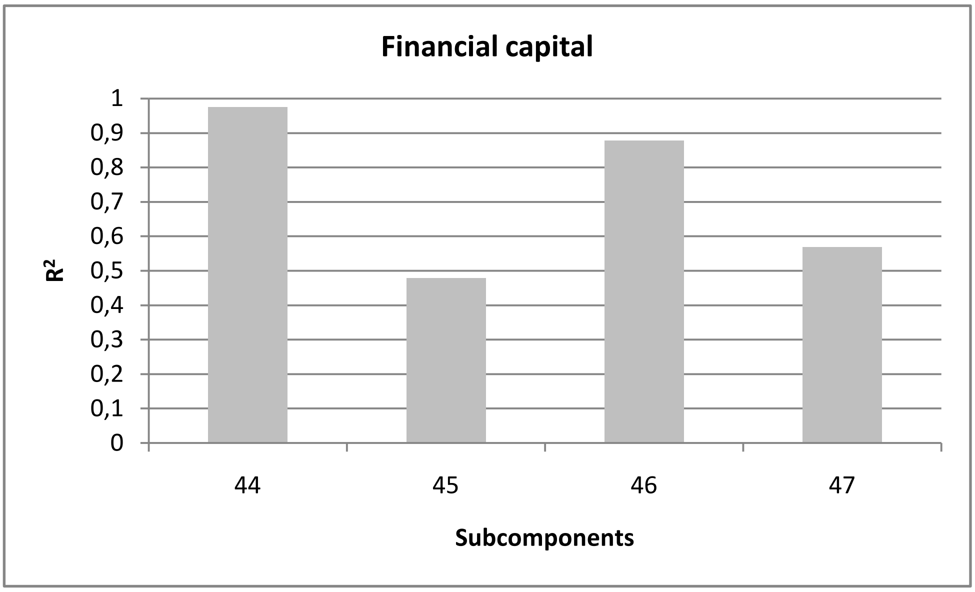

Figure 17. *Financial capital- R^2 per subcomponent*

As figure 17 shows, only one subcomponent of the financial capital was found to correlate strongly with the LEI value, something that is not in line with the expectations, since the larger scale global analysis discussed above shows that out of the five types of capital, the financial has the greatest influence on vulnerability. The subcomponent of financial capital correlated with LEI values is the household's economic deficit (subcomponent 44). It was found that the very high vulnerability group has the highest percentage of households with more expenditures than income. Specifically 100% of the most vulnerable households spend more than they earn in a year. In the other groups percentages are: 39% of the least vulnerable, 50% of the medium and 80% of the high vulnerability households, proving that this is an irrefutably important indicator of vulnerability. The expenditures considered are: food, machinery or wells, fertilisers, pesticides, labour wage, education, hospitals and festivals - which are an integral part of Hindu and Muslim cultures, often representing a greater expenditure than education.

The household's economic deficit could be related to access to loans and to the household's level of indebtedness, which were expected to be highly correlated as well. The reason for the latter not being statistically significant is that all the interviewees have very low levels of economic autonomy (73% of all the households have debts they have not been able to repay), so there is not an important difference between the indebtedness throughout the four groups, which could be due to generalised credit market failures. This explains that results on a household vulnerability approach do not coincide with the global sample's vulnerability diagnosis. Perhaps the indebtedness and loan indicators are not specific enough to portray significant differences between the four levels of vulnerability that were identified.

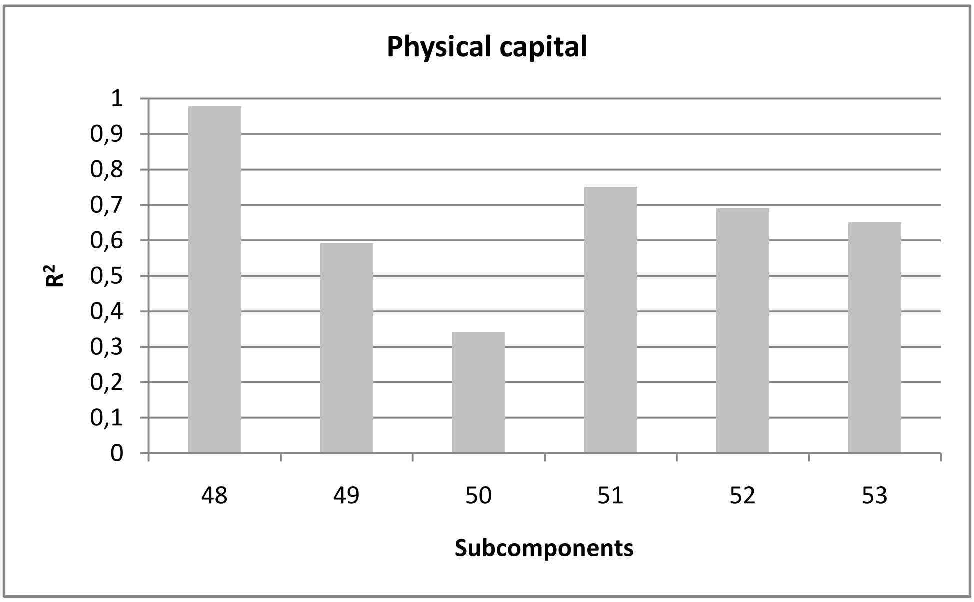

Figure 18. *Physical capital- R^2 per subcomponent*

The correlation between subcomponents from the physical capital and LEI values are shown in figure 18. With only one correlated subcomponent -migration (subcomponent 48)-, the physical capital is the second least influential capital asset at the household-level. Only 7 households had at least a member who migrated to work in a different village or community during 2011-2012 (13 individuals in total). The time they spent out varied, as well as the income earned from labour. Surprisingly enough, what was expected to be positively related to vulnerability showed the opposite. The most vulnerable group had the greatest percentage of migrating household members (12.5%) versus 10% of high, 4% of medium and 0% of low vulnerability households. This result raised the questions of what factors trigger the decision to migrate. Further study and a wider sample of out-migrant households should be interviewed to answer these questions, and it should be further discussed if migration was either an individual choice or an intertemporal family contract (Stark, 1980); and a voluntary or involuntary decision. In fact, people and households are subject to a large quantity of pressures and opportunities that determine the livelihood changes they endure, so even with enough data, it is possible that the questions remain unanswered.

According to the literature (Scoones, 2009; Bebbington, 1999; Ellis, 1998; DFID, 1999), migration is considered a livelihood strategy that improves livelihood diversification. It was nevertheless considered as part of the natural capital by Urothody's and Larsen's (2010) vulnerability assessment when implementing the LEI. In this study, migration has been classified as part of the physical capital simply because the absence of skilled young farmers is assumed to have a greater impact on production rather than on resource stocks availability and derived natural services. The capital asset it belongs to is ultimately irrelevant, since every subcomponent of the LEI has the same weight on the overall vulnerability value, therefore all of them influence the outcome in the same degree.

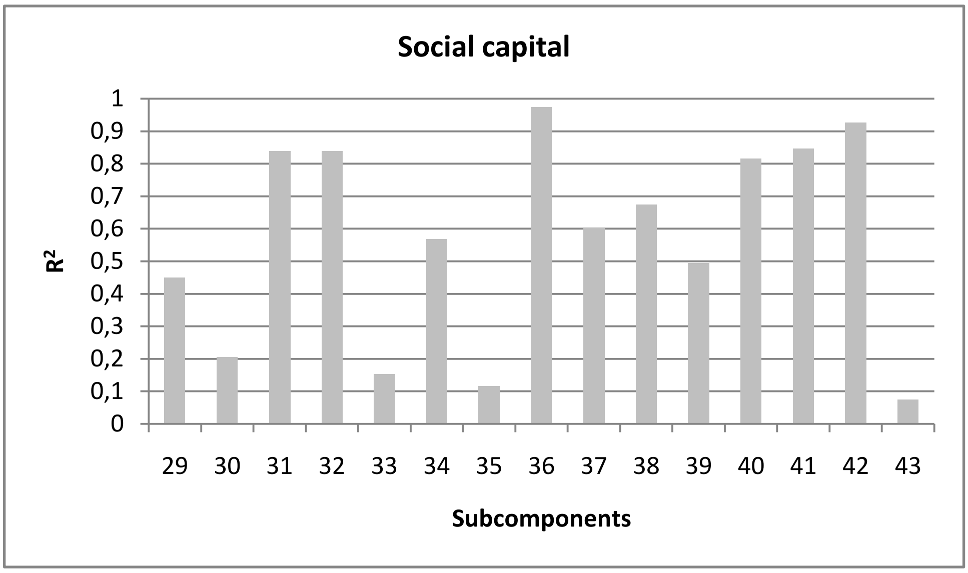

Figure 19. *Social capital- R^2 per subcomponent*

As seen in figure 19, two subcomponents have been found to determine vulnerability at the household level: trust (subcomponent 36) and household cooperativeness (42). Trust, understood as the number of people the interviewee felt at ease with, and could talk to about private matters, is also a cause of household-level vulnerability. When compared to the average number of trusted people, the most vulnerable trust others more than those with the lowest level of vulnerability. The same is observed for household cooperativeness, where informants were asked about the number of times they had helped other households in need (either cash or kind) in the past five years. On average, the greatest number of cooperation episodes were performed by the most vulnerable, and the number slowly decrease until reaching the least cooperativeness from the least vulnerable ones. It was not expected to find that what is considered a stronger social network would negatively influence on the vulnerability level. Furthermore, it could be said that the most vulnerable consider that building a strong social network with more people to trust and help is a more important adaptive decision. According to Acosta-Michlik and Espaldon (2008), they are on the right track, since social networks are an effective way of increasing farmers' capacity to adapt to global changes.

Finally, it was expected to find a significant correlation between gender and vulnerability. On the contrary, after running the test for correlation between gender and the LEI, it resulted to have the third lowest correlation (R^2=0.204). It is not within the scope of this study to take on board the vast literature on the subject of gender and rural development. However, it is relevant to consider some of the reasons why women-lead households are considered more vulnerable. In the first place, in poor rural contexts, girls are being allowed less access to education than boys (Ellis, 1998). Secondly, gender has been found to limit the model of income diversification, since in general, there tends to be an overall constraint of women to engage in off-farm working activities (Ellis, 1998). Thirdly, researchers have found that when income distribution depends on women, a greater share of the household's budget is spent on food and improving family nutrition, which is positive, but also leads to an acute lack of investment in agriculture (Quisumbing, 1995). Lastly, women's role in agriculture tends to depend on manual labour (i.e. fodder, firewood and water collection), and consequently have a lower status; so a lack of manpower, leads to increased agricultural costs (Kelkar *et al.*, 2008). The uncorrelated dynamic of gender and vulnerability for this study could be explained in the light of the method employed for analysis and sample size, since only 11% of the households that were interviewed are lead by a female. Women-lead households are similarly distributed along the four groups, probably because the sample is too small to depict differences. It is therefore inconclusive if a greater number of women-headed households would negatively affect the households' vulnerability to climate change. Urothody and Larsen (2010) were faced with the same difficulty when applying the LEI to their study area, where it was not possible to establish the directionality of the gender in vulnerability.

4.3. Limitations of this study

The primary limitation of this study 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 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.

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 cannot be extrapolated to larger areas. Thus this means that our results are not comparable with future studies unless these follow the same methods.

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, which could be due to 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. 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

5. CONCUSIONS

The purpose of this study was to explore the process of vulnerability. 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 vulnerability.

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 as a benchmark study to be compared with future, more extensive studies. 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 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 establish the best paths to reduce these communities' vulnerability, participative and deliberative processes should be held, where representatives from every village are 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 global context could reveal important information for long term vulnerability and predictions (Downing, 1991).

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ANNEX

ANNEX A. Household Questionnaire: Vulnerability of Agriculture to Climate Change

Survey No.: | | | |

Date:

Village name:

Interviewer's name:

Respondent's name:

Mobile number:

Religion: ________________ Caste: ___________________________

Total family members: _____ Total adult males: ____ Total adult females: ____ Total children (<12 years): ____

Section 1. General household information

Sl.	Name	Relation with HH head	Gender	Age in years*	Education	Occupation**		Migration	Migration season and year	Income earned
						Primary	Secondary			
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

* For a child below one year code is **0**

Relationship code:

Head=**1**, Wife/Husband=**2**, Son/Daughter=**3**, Grandchild=**4**, Father/Mother=**5**, Sister/Brother=**6**, Niece/Nephew=**7**,Uncle/Aunt=**8**, Son/Daughter-In-Law=**9**,Father/Mother-In-Law=**10**, Brother/Sister-In-Law=**11**, Grandparent=**12**

Education code:

Illiterate=**1**, Read and write=**2**, Pre-Primary School (1-5)=**3**, Upper primary (6-8)=**4**, High School (9-10)=**5**, PUC - (11-12), Diploma Course=**6**, Graduation=**7**, Post-Graduation and above=**8**, Technical Degree (medical, engineering, agriculture, etc.)=**9**, Other professional courses (TCH/Bed/Med)=**10**

**Occupation code:

Own agriculture=**1**, Agriculture labour=**2**, Petty business=**3**, Dairy farming=**4**, Plantation worker=**5**, NTFP collecting=**6**, Livestock grazing=**7**, Factory worker=**8**, Pension earner (social security/Job pension/income from property)=**9**, Rural crafts (carpentry, blacksmith, pottery, weaving, goldsmith, basket making, leather work, etc.)=**10**, Government job=**11**, Commission agent=**12**, Contractor=**13**, Quarry worker=**14**, Bee keeper=**15,** Student=**16**, Domestic work (cleaning, cooking, water fetching, child care, fire making, washing clothes, etc)=**17**, Driver=**18**, Not working (Children/Aged/physical disable/illness etc.)=**19**, Mason= **20**, Other=**21** (specify)

What is the farming experience of the household head (in years)? ____

Section 2. Physical capital

Household and farm assets

Asset	Asset type	Total Number of Assets	How old?					
Communication	Radio							
	Television							
	Phone (land or cell)							
Transportation	Vehicle							
	Motor bike							
	Bicycle							
Farm tools	Cart							
	Tractor							
	Plough (wooden)							
	Plough (iron)							
	Cultivator (tractor drawn)							
	Seeder/Weeder							
	Pesticide sprayer							
	Wheel barrow							
	Threshing machine							
	Organic manure pit							
	Diesel /Electric pump							
	Fodder cutting machine							
House	Refrigerator							
	Water tank							
	Sewing machine							
	Fan							
	LPG							
	Stove (Kerosene)							
	Gober gas							
	In house water connection							
	Flour mill							
	Others (specify)							

House ownership: own/joint ownership/rented/lease
House type: Pucca/Semi-Pucca/Kutcha

Livestock Information:

Type*	Number	Present value	Reasons for keeping**	Income
1.				
2.				
3.				
4.				
5.				
6.				
7.				

***** Bulls=**1**, Oxen=**2**, Local cow=**3**, Improved Cow=**4**, Sheep=**5**, Goat=**6**, Buffalo=**7**, Poultry=**8**, Pig=**9**, Calves=**10**, Heifers=**11**
****** Cultivation=**1**, Manure=**2**, Fuel (cooking)=**3**, Milk consumption/Milk selling =**4**, Breeding=**5**, Meat=**6**, Egg=**7**, Sale of young stock=**8**, Wealth status=**9**, Others=**10** (specify)

Plot information (2011-2012)

Total land (acres) _______________ Total rainfed land: ____________ Total irrigated land: _____________

Farm Type	Cultivated land (acres)	Ownership*	Crop type
Rainfed	Kharif:		
	Rabi:		
Irrigated	Kharif:		
	Rabi:		
	Summer:		
Fallow**			
Plantation			
Others			
Total cultivated land (acres)			

***** Farm ownership: Own=**1**, Lease in=**2**, Joint farming=**3**, Share cropping=**4**
****** Temporary fallow=**1**, Permanent fallow=**2**

What are the reasons for not cultivating the land? *[Ask only if farmers not cultivating land in any season (possible reasons- lack of labour, lack of capital, lack of water, irrigation system fail, low fertility, damage caused by wild animals, under dispute, bad weather, season overlap etc.)]* __________________________

____

Section 3. Natural capital

[Only applicable for farmers with irrigated land]

Access to irrigation sources Y/N Own/Borrowed or shared from other neighbouring well owners

If yes, what are the irrigation sources?

Borewell irrigation Y/N No. of working borewells ______ Year installed _____________________
No. of failed borewells ____ Investment risk Y/N What type of risk? _____________________________
____
Increased vulnerability Y/N Describe ____
____
Tank Irrigation Y/N Number of years ______ Number of Irrigations Good year___; Bad Year___
River irrigation Y/N Year installed ______________
Lift irrigation Y/N Year installed ______________

a) Primary source of irrigation ______________________________
b) Secondary source of irrigation ___________________________
c) Water yield (in inches) *[only applicable for borewell holders]*: *1. Normal years*__________________________
*2. Difficult years*_____________________________
d) Does the water supply meet your needs for irrigation? Always/Occasional deficits/Usually lack of water
e) Years in which there has been water table depletion? ____
f) Reason(s) for water table depletion *[If borewell yields are linked to tank water level]* ____________________
____
____
g) Impact(s) of water table depletion ____
____

Section 4. Economic and financial capital

Income from agriculture (2011-2012)

Income from main crops _________________
Income from secondary crops _________________
Income from dairy/livestock _____________
Income from agriculture labour (within the village or neighbour village) _____________
Income from salary ____________________
Income from self-employment _____________
Income from migration ______________

Did you get the price you were expecting? More/Expected/Less than expected

At what time of year is cash income most needed? Why?____
____

At what time of year (months) do you have more cash available for agricultural expenses? ________________
____

Source of cash income ____

What are the household's expenditures?

- Food (last month):
- Agricultural investment (last year)
  - Machinery or wells:
  - Fertilizers:
  - Pesticides:
  - Labour:
- Others:

Access to credit and level of indebtedness

SL. No	Year	Sources of Loan	Amount of loan taken	Repaid	Remark
1					
2					
3					
4					

Section 5. Social capital

Formal Institutional Membership Index:

1) Member in SHG Y/N M/F Number of persons _________
2) Member in Dairy Farm Y/N M/F Number of persons _________
3) Member in SDMC Y/N M/F Number of persons _________
4) Member in JFPM Y/N M/F Number of persons _________
5) Member in JSYS (TWUA) Y/N M/F Number of persons _________
6) Member in NREGP Y/N M/F Number of persons__________
7) Any other membership (specify) ____
8) *[To members of any of these associations.]* What is the farmer's function as a member? _________________
____

Do you participate in knowledge exchange with other farmers of this village or other villages? Y/N

What type of knowledge? ____
____

Informal Institutional Index-
Frequency of contact with friends, family relatives -outside of the household
Frequency of neighbours visiting in a month ______________________

How many people in the village do you know in person (percentage)?_____________

How many people within your own community do you know in person (number or percentage)?____________

Among the above, how many close friends or relatives do you have with whom you can feel at ease with, can talk to about private matters?___________

If you suddenly needed a small amount of money enough to pay for expenses for your household for one week, how many people beyond your immediate relatives (parents, siblings, and own children) could you turn to who would be willing to provide this money/loan?______________

Trust Index:
Most people who live in this village can be trusted ____

Most people in this village are willing to help if you need it _____

In this village, people generally trust each other in matters of lending and borrowing money *[with or without surety/witness/guarantor?]* ____

Cooperativeness:
How many friends and relatives would offer help during need without hesitation? __________

Have you been asked to help other households in the village? ___________

In the last 5 years, how many times have you helped *[tick: in cash or kind]* your relatives and friends when the household was in need? _______________

Section 6. Human capital

Concerning education, do you feel that you are particularly lacking in certain types of information? Y/N
Which one(s)? *[Tick all that apply]*

- **a)** Weather
- **b)** Cropping (seeds, fertilizers, pesticides)
- **c)** Market, prices
- **d)** Health
- **e)** Government programmes on subsides

Health status of the household members (2011-2012)

Type of illness	No. of days	Missed work days	HH member code
a) Diarrhoea			
b) Respiratory illness			
c) Pregnancy			
d) Accident			
e) Surgery			
f) Other (specify)			

Nourishment and food security

a. Months most difficult to provide adequate food for HH. Why? ______________________________________
____

b. How many times in a year does your family usually purchase/borrow food grains? _____________________

c. Type of meals usually consumed per day: *1. Normal times* ____

2. Difficult times ____

What percentage of your household food grains need is met by your own farm land in a year?

	For a year with enough rainfall	For a year with not enough rainfall
0-25%		
26-50%		
51-75%		
76-100%		

Distance to drinking water (in minutes) *[If applicable]* ______________

Distance to market (in minutes) _________

Section 7. Adaptation

Problems and adaptations related to agricultural practices

Problems*	**Adaptations**
Climate-specific related problems	**Adaptations**
Delay in onset of monsoon	
Erratic rainfall	

*[*Examples: Soil not suitable, slope land, crop needs less water, crop needs more water, power problem, water yield is low, sharing water with other joint owners, pump capacity is low/high, pump fail frequently, rainfall is less, inefficiency in water use, poor infrastructure, crop water requirement not known, pump is old, pump ran dry...]*

What have you done to adapt to unpredictability of weather and unusual timing of the seasons? ___________
____
____

Crop Choice – years 2011-2012

What are the main 3 reasons for crop choice in 2011-2012? ____
____

Will these be the same factors for other years? Y/N

If not, what are other reasons apart from these? ____
____

Which crops are more sensitive to climate change? Why? ____
____

Access to weather information

Sources	Onset of monsoon/delay in monsoon/scanty monsoon	How frequently is forecast information available?	Did you use advice and information about when to plant/sow crops from these sources?
	Yes=**1**, No=**0**	Daily=**1**, Weekly=**2**, Monthly=**3**, Seasonal=**4**	Yes=**1**, No=**0**
Raitha Samparka Kendra			
TV/Radio			
News Paper			
Neighbours/Relatives/ Lead farmer			
Gram Panchayat/Gram Sabha			
Others (specify)			

Climate variability/change perceptions (local indicators of climate change)

Changes	Over the last 10 years have you noticed changes?	Adaptation code*
1.No changes in rain	1	
2.Less rain	2	
3.More rain	3	
4.Frequent droughts	Yes=1, No=0	
5.Frequent floods	Yes=1, No=0	
6.Delay in start of rainy season	Yes=1, No=0	
7.Rainy season end sooner	Yes=1, No=0	
8.Unusual rain	Yes=1, No=0	
9.Temperature increase	Yes=1, No=0	
10.Temperature decrease	Yes=1, No=0	

* Change in crop variety=**1**, Decrease irrigation=**2**, Increase irrigation=**3**, Form pond construct=**4**, Dig new borewell=**5**, Stop irrigation=**6**, Reduce livestock=**7**, Keep improved livestock=**8**, Migration to other area=**9**, Lease out land=**10**, Purchase water=**11**, Plant shade trees=**12**, Change sowing time=**13**, Others=**14** (specify)

Farmers recall of weather (rain) during 2011-2012 crop season

1. In your view, did the rainy season begin early, on time, or late?	2011: Early=1, On time=2, Late=3 2012: Early=1, On time=2, Late=3
2. In which month did the rainy season begin?	2011: 2012:
3. How would you characterize the amount of rain in the rainy season on the given year, relative to the average rainy season?	2011 2012 Significantly below average……….1 Slightly below average………………..2 Average……………………………………..3 Slightly above average……………..…4 Significantly above average..……….5 Do not know………………………….…6
4. In which month in the rainy season did you get the most rain?	2011: 2012:
5. In which month did the dry spell occur?	2011: 2012:

ANNEX B. Household-level results: correlation between subcomponents and LEI value

	Human capital												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Low	0,222	0,222	0,167	0,204	0,320	0,547	0,019	0,401	0,000	0,889	0,056	0,333	0,316
Medium	0,458	0,583	0,250	0,375	0,286	0,437	0,129	0,420	0,083	0,958	0,000	0,500	0,288
High	0,600	0,760	0,400	0,407	0,316	0,477	0,184	0,527	0,180	0,980	0,020	0,840	0,268
Very high	1,000	0,875	0,625	0,625	0,534	0,422	0,417	0,534	0,625	1,000	0,125	1,000	0,197
R	0,981	0,965	0,981	0,968	0,763	-0,771	0,964	0,935	0,918	0,945	0,544	0,988	-0,962
R^2	0,963	0,931	0,962	0,937	0,582	0,595	0,929	0,874	0,843	0,893	0,296	0,976	0,925

	Natural capital														
	14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
Low	0,235	0,333	0,700	1,000	0,286	0,214	0,611	0,278	0,167	0,667	0,833	0,667	0,694	0,778	0,722
Medium	0,136	0,417	0,750	0,786	0,400	0,429	0,667	0,417	0,208	0,833	0,792	0,875	0,688	0,917	0,708
High	0,444	0,460	0,960	0,920	0,526	0,455	0,940	0,640	0,220	0,900	0,920	0,840	0,830	1,000	0,800
Very high	0,714	0,625	0,000	1,000	0,400	0,250	1,000	0,750	0,375	1,000	1,000	0,750	0,875	0,875	0,875
R	0,884	0,969	-0,593	0,177	0,608	0,131	0,957	0,991	0,905	0,982	0,877	0,289	0,929	0,516	0,923
R^2	0,782	0,939	0,351	0,032	0,370	0,017	0,916	0,983	0,819	0,964	0,769	0,083	0,863	0,266	0,852

	Social capital														
	29	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**
Low	0,227	0,167	0,436	0,389	0,231	0,420	0,097	0,059	0,211	0,867	0,556	0,467	0,147	0,343	0,500
Medium	0,400	0,042	0,294	0,500	0,288	0,532	0,158	0,090	0,318	0,806	0,917	0,476	0,081	0,354	0,250
High	0,444	0,100	0,319	0,560	0,327	0,455	0,121	0,107	0,244	0,840	0,900	0,667	0,087	0,437	0,520
Very high	0,377	0,250	0,171	1,000	0,260	0,607	0,080	0,124	0,422	0,606	0,875	0,667	0,044	0,471	0,500
R	0,671	0,452	-0,916	0,916	0,390	0,753	-0,340	0,986	0,776	-0,821	0,703	0,903	-0,920	0,962	0,273
R^2	0,450	0,204	0,838	0,839	0,152	0,567	0,115	0,973	0,602	0,674	0,494	0,816	0,846	0,926	0,074

	Financial capital				Physical capital					
	44	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**
Low	0,389	0,444	0,889	0,667	1,000	0,444	0,373	0,700	0,441	0,183
Medium	0,500	0,792	0,958	0,625	0,958	0,750	0,428	0,941	0,500	0,175
High	0,800	0,840	0,960	0,650	0,900	0,760	0,350	0,987	0,469	0,179
Very high	1,000	0,750	1,000	1,000	0,875	0,750	0,340	1,000	0,563	0,112
R	0,987	0,692	0,936	0,753	-0,989	0,770	-0,585	0,866	0,831	-0,807
R^2	0,974	0,478	0,877	0,567	0,977	0,592	0,342	0,751	0,690	0,651

ANNEX C. Whole sample-level results

Calculating the Finance major component for the LVI for Berambadi watershed villages.

Sub-components for Finance major component	**Sub-component values**	**Max-component value for study population**	**Min-component value for study population**	**Index value**	**Finance major component index value**
Percent of households have more expenditures than income (F_1)	66,32	100	0	0,663	
Percent of household have any family member working outside or in a developed place(not farming) (F_2)	76	100	0	0,76	
Percent of Household with a money loan (F_3)	95	100	0	0,95	
Percent of households didn't repay any quantity of the loans (F_4)	71,5	100	0	0,715	**0,772**

Step 1 (repeat for all sub-component indicators):index$_{\text{Finance}} = \frac{66{,}32-0}{100-0} = 0{,}663$

Step 2 (repeat for all major components): Finance $= \frac{\sum_{i=1}^{n} \text{IndexSci}}{\text{n}} = \frac{F_1+F_2+F_3+F_4}{4} = = \frac{0{,}663+0{,}76+0{,}95+0{,}715}{4} = 0{,}772$

Step 3 (repeat for all study areas): LVI = $\frac{\sum_{i=1}^{9} \text{WMi Mcomi}}{\sum_{i=1}^{9} \text{WMi}}$ = $\frac{(6)(0{,}333)+(6)(0{,}528)+(9)(0{,}257)+(3)(0{,}621)+(6)(0{,}409)+(6)(0{,}617)+(9)(0{,}696)+(5)(0{,}414)+(4)(0{,}772)}{6+6+9+3+6+6+9+5+4} == 0{,}499$

Calculating LVI–IPCC:

Contributing factors	Major components	Major component values	Number of sub-components for major component	Contributing factor	LVI-IPCC INDEX
	Socio-demographic	0,402	6		
	Livelihood	0,331			

Adaptive Capacity	strategies		6	0,498	**0,106**
	Social network	0,760	9		
	Knowledge and skills	0,634	5		
	Finance	0,131	4		
Sensitivity	Health	0,621	3	0,535	
	Food	0,409	6		
	Water	0,617	6		
Exposure	Natural vulnerability and climate variability	0,696	9	0,696	

Step 1 (calculate indexed sub-component indicators and major components as shown above, taking the inverse of the adaptive capacity sub-component indicators: Socio-demographic Profile, Livelihood Strategies, and Social Networks, Knowledge and Skills and Finance).

Step 2 (repeat for all contributing factors: exposure, sensitivity, and adaptive capacity):
Adaptive Capacity= $\frac{\sum_{i=1}^{n} W_{Mi}\ M_i}{\sum_{i=1}^{n} W_{Mi}} = \frac{(6)(0{,}402)+(6)(0{,}331)+(9)(0{,}760)+(5)(0{,}634)+(4)(0{,}131)}{6+6+9+5+4} = 0{,}498$
Step 3 (repeat for all study areas): $\text{LVI} - \text{IPCC} = (e - a) * s = (0{,}696 - 0{,}498) * 0{,}535 == 0{,}106$

Calculating the LEI

Sustainable livelihoods factors	Effect dimensions	Effect dimension values	Number of sub-components for effect dimension	Sustainable livelihoods factor value	LEI index value
Human capital	Health	0,621	3	0,456	**0,508**
	Food	0,409	6		
	Knowledge and skills	0,414	5		
Natural capital	Water	0,617	6	0,664	
	Natural vulnerability and climate variability	0,696	9		
Social capital	Socio-demographic	0,333	6	0,287	
	Social networks	0,257	9		
Financial capital	Finances	0,772	4	0,772	
Physical capital	Livelihood strategies	0,528	6	0,528	

Step 1 (calculates indexed sub-component indicators and effect dimension like LVI and LVI-IPCC.

Step 2(Repeat for all 5 Capitals): Human Capital= $\frac{\sum_{i=1}^{n} L_i}{n} = \frac{(3)(0{,}621)+(6)(0{,}409)+(5)(0{,}414)}{3+6+5}$ = =0,456

Step 3 (repeat for all study areas):

$$\mathrm{LEI} = \frac{\sum_{i=1}^{5} W_i C_{Vi}}{\sum W_i} = \frac{(3)(0{,}456) + (2)(0{,}664) + (2)(0{,}287) + (1)(0{,}772) + (1)(0{,}528)}{3 + 2 + 2 + 1 + 1} = 0{,}508$$

ANNEX

Table with the results of the 54 sub-components and nine major components for LVI

Major component	Subcomponents	Unit	Observed value	Max	Min	VI
Socio-Demographic	Dependency Ratio	ratio	0,431	1,32	0	0,326
	Female-headed households	percent	10	100	0	0,1
	Age of household head	1/years, average	0,0175	0,035	0,011	0,27
	Households where head has not attended school	percent	53	100	0	0,53
	Household size	Average	5,54	14	2	0,295
	Household head farming experience	year, average	32,71	65	3	0,479
Socio-Demographic Vulnerability Index						**0,333**
Livelihood strategies	Households with members working in a different community or migrating	percent	13	100	0	0,13
	Households fully dependent on agriculture as a source of income	percent	75	100	0	0,75
	Agricultural livelihood diversification index	1/#livelihood, average	0,311	0,5	0,2	0,37
	Households who did not get the expected price for crops	percent	85,3	100	0	0,853
	Semipucca or Kutcha houses	percent	89,3	100	0	0,893
	Total Land cultivated	Acres, average	7,9	45	0,24	0,171
Livelihood strategies Vulnerability Index						**0,528**
Social Networks	Neighbours visiting in a month	times	5,77	40	1	0,122
	Respondents feel can talk to others about private matters	members	8,63	50	0	0,172
	Respondents reportedly willing to borrow money in need	members	4,55	17	0	0,267
	Respondents reporting that other people ca not be trusted	percent	3,03	100	0	0,03
	Respondents are not willing to help you in case of necessity	percent	16	100	0	0,16
	Respondents generally untrusfull in matters of lending or borrowing money	percent	43,2	100	0	0,432
	Number of friends and relatives who would offer help during need	Members, average	7,75	30	1	0,232
	Times you have helped a					

	friend o relative when in need	Times, average	14,28	35	0	0,408
	Households where none is affiliated with any institution	percent	49	100	0	0,49
Social Networks Vulnerability Index						**0,257**
Health	Households where someone had to miss work or school due the illness in the past year	percent	44	100	0	0,44
	Household reducing food intake in bad times	percent	71	100	0	0,71
	Life expectancy index	years	71,5	1	0	0,715
Health Vulnerability Index						**0,621**
Food	Households dependent on family farm for food	percent	65	100	0	0,65
	Number of months when the household has trouble providing food	Months, average	1,14	3	0	0,38
	Crop diversity index	1/# crops, average	0,211	0,5	0,071	0,326
	Number of times the household needed to purchase food	Times, average	11,4	24	0	0,475
	Time to drinking water	Minutes, average	4,74	30	0	0,158
	Time to market	Minutes, average	36,27	65	10	0,47
Food Vulnerability Index						**0,409**
Water	Households with borrewell fail	percent	36,2	100	0	0,362
	Households with access to water source	percent	57	100	0	0,57
	Households without consistent water supply	percent	82,6	100	0	0,826
	Households reporting depletion of their natural water source	percent	88	100	0	0,88
	Households with risk investment	percent	44,4	100	0	0,444
	Households with vulnerability risk	percent	62,5	100	0	0,625
Water Vulnerability Index						**0,617**
Natural Vulnerability and Climate Variation	Households reporting less rain in the past 10 years	percent	82	100	0	0,82
	Households reporting more droughts in the past 10 years	percent	53	100	0	0,53
	Households reporting more floods in the past 10 years	percent	22	100	0	0,22
	Households reporting unusual rains in the past 10 years	percent	82	100	0	0,83
	Households reporting temperature increase in the past 10 years	percent	86	100	0	0,86
	Households with the same crop choice than in previous	percent	81	100	0	0,81

	years					
	Households reporting less rain this year than the average of rainy seasons	percent	95	100	0	0,95
	Households with agricultural problems	percent	92	100	0	0,92
	Households without adaptations to climate or weather problems	percent	32,4	100	0	0,324
Natural Vulnerability and Climate Variation Vulnerability Index						**0,696**
Knowledge and Skills	Households without TV	percent	8	100	0	0,08
	Households without radio	percent	96	100	0	0,96
	Households not participating in knowledge exchange with others	percent	3	100	0	0,03
	Households perceiving lack of education	percent	68	100	0	0,68
	Years of schooling	Number, average	3,19	10	0	0,319
Knowledge and Skills Vulnerability Index						**0,414**
Finances	Households with more expenditures than income	percent	66,32	100	0	0,663
	Households with member working outside (not farming)	percent	76	100	0	0,76
	Households with money loans	percent	95	100	0	0,95
	Households who had not repaid loans	percent	71,5	100	0	0,715
Finances Vulnerability Index						**0,772**
Livelihood Vulnerability Index, LVI						**0,499**