A Methodology for the Vulnerability Analysis of the Climate Change in the Oromia Region, Ethiopia

Chapter 5
A Methodology for the Vulnerability Analysis of the Climate Change in the Oromia Region, Ethiopia

Elena Belcore, Angela Calvo, Carolin Canessa and Alessandro Pezzoli

Abstract Goal of the vulnerability research of the last years is to evaluate which community, region, or nation is more vulnerable in terms of its sensitive to damaging effects of extreme meteorological events like floods or droughts. Ethiopia is a country where it is possible to find the described conditions. Aim of this work was to develop an integrated system of early warning and response, whereas neither landmark data nor vulnerability drought analysis existed in the country. Specifically, a vulnerability index and a capacity to react index of the population of three Woredas in the Oromia Region of Ethiopia were determined and analysed. Input data concerned rainfall, water availability, physical land characteristics, agricultural and livestock dimensions, as well as population and socio-economic indices. Data were collected during a specific NGO project and thanks to a field research funded by the University of Torino. Results were analysed and specific maps were drawn. The mapping of the vulnerability indices revealed that the more isolated Woreda with less communication roads and with less water sources presented the worst data almost on all its territory. Despite not bad vulnerability indices in the other two Woredas, however, population here still encountered difficulty to adapt to sudden climatic changes, as revealed by the other index of capacity to reaction. Beyond the interpretation of each parameter, a more complete reading key was possible using the SPI (Standardized Precipitation Index) beside these

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indicators. In a normalized scale between 0 and 1, in this study the calculated annual SPI index was 0.83: the area is therefore considerably exposed to the drought risk, caused by an high intensity and frequency of rainfall lack.

Keywords Vulnerability analysis · Climate change · Ethiopia

5.1 Introduction

In 2007 the document of the Intergovernmental Panel on Climate Change (IPCC 2007) confirmed with absolute certainty the man-made phenomenon of climate change manifested by the increasing of the average global temperatures. One of the main consequences is the variation in rainfall patterns and the increasing probability of extreme meteorological events like floods or droughts. Various areas of the world are therefore at natural disaster risk. Nevertheless, the latter is not just a function of climatic events, but also of the system characteristics. As underlined by UNISDR: "There is no such thing as a 'natural' disaster, only natural hazards" (UNISDR 2009).

The probability of calamitous events depends also on the vulnerability of the system, that is the collection of characteristics and conditions of human-environment systems that made it sensitive to damaging effects of extreme events. Ethiopia is a country where it is possible to find the conditions above described. In the Ethiopian territory, in fact, environment, demographic and economic conditions exposed in many occasion the population to droughts and humanitarian catastrophes due to the ENSO phenomenon and the heating of the Indian Ocean. Nowadays the necessity of limiting the increasing of global temperatures with politics of mitigation is clear, but it become fundamental the ex-ante evaluation of the systems vulnerability to extreme events. In order to adopt measures to develop the capacity of adaptation of population and to improve the resilience, it is important to analyse the system vulnerability.

Vulnerability analysis can have a lead role in adaptation policies designed to reduce climate change impacts and extreme events on ecosystem services that are the foundations of the human wellbeing (MEA 2009). Evaluating which individual, community, region, species or nation is more vulnerable is the goal of the vulnerability research of last decades. However vulnerability studies are still a developing field of research. Actually, the conceptual framework is still fragmented and based on different paradigms, adversarial theories, heterogenic empirical studies and a very diversified terminology (Vincent 2004). For example at now it doesn't exist an universal accepted definition of vulnerability, the meanings attributed to the term are often contested and the related concepts depends on finalities and on the studied system (Cutter 2003). It is therefore necessary to find a common conceptual framework that guarantee coherence during research activities, to enhance policy activities that can be applied to the stakeholders (Kasperson et al. 2001).

The issue seems to be so urgent that the General Assembly of United Nation in June 2015 established with a specific resolution[1] the creation of an intergovernmental working group to define indicators and a common terminology for the disaster risk reduction (AG 2015).

According to Füssel there are four elements of vulnerability that should be define ex-ante: system, attribute of concern, temporal reference and hazard (Füssel 2007). System is the potentially vulnerable system, such a population, an economic sector or a geographic area. The attributes of concern are all the components that are treated by a dangerous event, they include infrastructural elements and socio-economic elements, like food security or wellbeing. Temporal reference is the considered period of time for vulnerability evaluation. Finally, the hazard is a potentially damaging influence on the considered system. It is important to consider the element above as able to describe a vulnerability situation, even if it is not possible to give the same weight at each of them.

On the other side, Nelson (Nelson et al. 2009) underlines that the definitions of vulnerability should not be confused with the conceptual framework of vulnerability, and this last should not be confused with the empirical studies about vulnerability. In fact, definitions describe the components of vulnerability while the conceptual framework gives meaning to definitions themselves and allows analysis based on an analytic context in a transparent and repeatable way. The goal of the empirical studies, however, is to propose a methodology based on definitions and conceptual framework used in order to quantify and evaluate the vulnerability. It is important to stress the different approaches of the literature to vulnerability, to natural disasters and to vulnerability of livelihoods. The approach to vulnerability to natural disasters focus on the relation between environment disasters and human dimension and, in this case, the hazard is considered exogenous to the human being. On the other hand, the vulnerability of livelihoods approach considers vulnerability as human conditions caused by lack of entitlements (Alwang et al. 2001).

In the last years a new analysis approach was introduced, focused on vulnerability to climate change (IPCC 2001). This approach is in line with the literature about natural disasters, but it considers the hazard as the result of endogenous and exogenous characteristics of the system. Furthermore, it treats exposure to a dangerous event as part of vulnerability of the system itself, as we can see in the results of this research.

[1]United Nations General Assembly, A/RES/69/284, “Establishment of an open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction”, June, 3rd, 2015.

5.1.1 Climate Change, Vulnerability and Resilience

It is well known that rural poverty increases when it increases elsewhere and the expected situation is more difficult for the remote rural areas of the South of the world (often already poor) where people lack resources to fall back on. When rural regions impoverished, more people leave rural areas, reinforcing existing migration trends in a downward cycle.

Aim of this work is the analysis of population vulnerability and resilience in the Region of Oromia (Ethiopia), using a data base of the NGO LVIA (created by a questionnaire on food security) investigated by three students of the University of Turin (Department of Agricultural, Forest and Food Sciences, Department of Culture, Politics and Society and Department of Territory of the University of Turin) during a three month stage in Ethiopia in the summer 2015. An innovative methodology is therefore explained, to evaluate the hazard and the effect of the Climate Change on the drought in Ethiopia using the vulnerability analysis, with a deeper study of the system and of the attribute of concern.

5.2 Area of Study

Ethiopia stretches over 1.12 million of km^2 covering a huge part of Horn of Africa. It is a federal country, composed by nine ethnic administrative regions (Fig. 5.1).

The population in 2015 was around 99 million people, with a forecast of 138 million in 2030 (United Nations 2015).

It is the second more populated country in Africa after Nigeria (CSA 2007). The agricultural sector accounts the 45% of Ethiopian GDP. The 85% of population works in agriculture, but only 1% of farmland has an irrigation system. Agriculture therefore depends on rainfalls. Pastoralism is an important source of livelihood and economy and accounts 15% of Ethiopian GDP. Ethiopia is composed by 9 Regions (or Zones): inside each Region there is a certain number of districts (called Woreda) and each Woreda is composed by municipalities (Kebele), the smallest administrative unit of Ethiopia. In the last century Ethiopia unfortunately registered many anomalies concerning precipitations distribution, that leads to frequent and intense periods of drought in many areas of the country. Several studies justify the precipitation variability of Horn of Africa with the phenomenon of Niño and Niña (ENSO—El Niño Southern Oscillation18) (Hulme et al. 2001, Korecha 2006, Segele and Lamb 2005, Seleshi and Demarèe 1995). The main concern is the seasonal cycle of the rain (Segele and Lamb 2005, Viste et al. 2013), because anomalous rainy cycles may lead to huge damages to the agricultural production of the country, increasing the vulnerability of rural people which lives of subsistence (Sadoff 2008). The area of this study stretch over the territory in three Woredas of

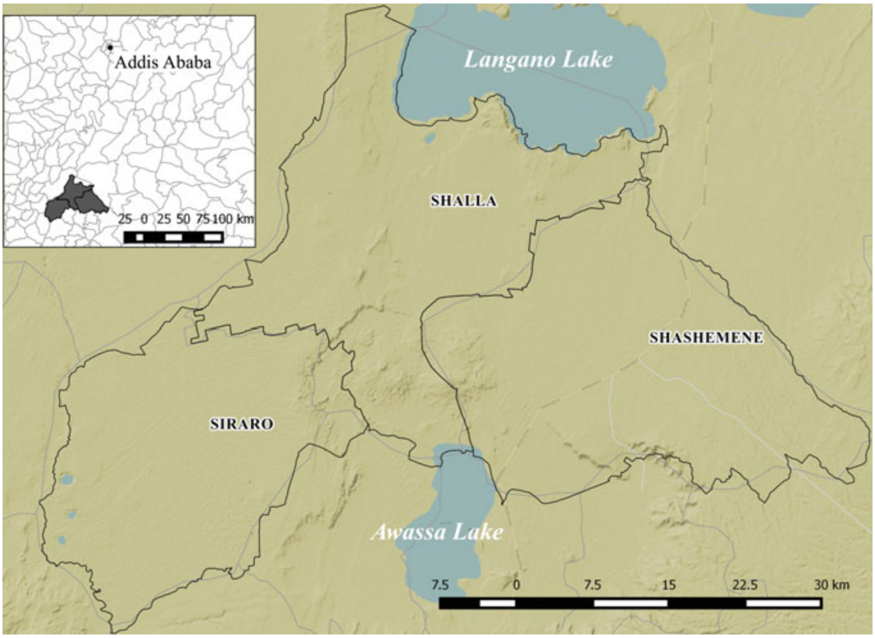

Fig. 5.1 Map of the Siraro, Shalla and Shashame Woredas

the Oromia Region: Siraro, Shalla and Shashamane. These districts are located in the West Arsi zone, along the Rift Valley (Fig. 5.1).

5.3 Geographic Description and Social Conditions of the Oromia Region

The Oromia Region is the biggest of the nine Ethiopian regions with about 33.7 million people (IWMI 2009): the most represented is the Oromo ethnicity (85% of population). Oromia is essentially rural: the 50% of Ethiopian coffee production comes from Oromia. Breeding is also important for the region: it is estimated that at the farmers of Oromia belong about the 45% of the Ethiopian cattle production. The characteristics of the Oromia conditions are similar to the other Ethiopian Regions: there is a strong dependence from the subsistence of the agricultural sector and there are few forms of economic diversification. The cultivated land of the Ethiopian farmers is often lower than 2 hectares and 52% of them has less than 1 hectare (AQUASTAT 2005): in Oromia the average cultivated land is 1.15 hectares per household. On the contrary the average number of cattle per household is here higher than in the other Ethiopian regions (CSA 2007): it must be however considered that this is only an averaged data which greatly varies, especially in function of the agro-ecologic environments (highlands, midlands, lowlands). The Region is located in a drainage basin (the second of the country for dimension) and it disposes of a good quantity of water. Nevertheless the area is really vulnerable to the changes of the precipitations distribution, because the current management system cannot provide for a sustainable water access to the population (LVIA 2015).

5.4 The Analysed Woredas: Siraro, Shalla and Shashamene

The three Woredas are located along the down Rift valley: 80% of the Shashamene territory is lowland, Siraro broadens on highlands, while Shalla is only on highlands, until about 2000 m above sea level (Table 5.1). There are therefore different climatic conditions and different geographic environments, which affect soil fertility and cultivations. Based on the agro-ecological zones, the main cultivations are: corn, teff, barley and beans.

During the last decade Ethiopian government (Disaster risk management and food security sector) documented a great level of exposure to drought and floods (DRMFSS 2016). In addiction there is a socio-economic stress condition which makes the population more sensitive to climatic disturbs.

With an estimated population of about 662,000 inhabitants (Table 5.2), the three Woredas have an high population density (about 310 inhabitants/km^2) compared to the national one (lower than 100) (DRMFSS 2016). Population (mainly of Islamic religion) is very young with a low occupational level outside the agricultural sector: these economic conditions decrease the possibility of economic diversification in order to reduce the population dependence from natural resources.

Table 5.1 Environmental and economic characteristics of the examined Woredas

Woreda	Area km^2	Environment	Economic activities	Crops
Shashamene	779	Lowland (80%) Highland (20%)	Agriculture Livestock Commerce	Teff, barley, millet, sorghum, wheat, corn, beans
Siraro	607	Lowland (68%) Highland (32%)	Agriculture Livestock	Teff, wheat, corn, beans, potatoes
Shalla	749	Highland (1700–2000 m)	Agriculture livestock	Corn

Table 5.2 Population (census 2007 and 2015 forecast)

Shashamene	Siraro	Shalla	Total	2015 Forecast
347,228	145,649	149,804	642,681	661,961

5.5 Method and Materials

Questionnaires and Interviews

Questionnaires and interviews were the instruments used for data collection. It was chiefly used a questionnaire created by LVIA NGO in its Food security project. Furthermore four interviews were submitted: one singular interview to the head of the village and three group of interviews to local water committees, to the women of the villages and to the village community. 180 questionnaires were filled in the three Woredas (15 Kebele per Woreda and 12 households per Kebele) in three months of work: the questionnaire was composed by 200 questions, with a total of 36,000 collected data. More than 40 interviews were therefore submitted to heads of villages and communities.

Food Security Questionnaire

The food security questionnaire was created by LVIA NGO in occasion of a project related to the food security and water's resource in the Woredas of Siraro, Shalla and Shashamane. The questionnaire was composed by 45 questions divided in 5 sections: general information, livelihood, food security, and observation checklist (see Annex). The general information section was made up of 25 questions concerning family composition and water access of the interviewed household: they were usually short and had multi-choice answers. Livelihood was the longest section, containing 30 questions to investigate household economics activities, agricultural systems, yearly income, irrigation types and livestock characteristics. Food security section was composed by 11 questions about the number and the composition of daily meals and diseases related to under-nutrition conditions. The last section, observation checklist, was the shortest and was dedicated to the interviewer, to obtain information on the family composition and characteristics. The questionnaire was created in order to be more understandable as possible and contained short questions easily translatable from English to the local language. It also included a series of control questions. Some questions (20, 21 and 41) were open and asked to the interviewee to discuss about different topics, but people normally did not agree to answer. LVIA cultural mediators helped people to fulfill the questionnaire: they read and translated in local language, explained questions and wrote down the answer of the interviewee. Before conducting and summiting questionnaires, each cultural mediator received the questionnaire and studied the guide line in order to have an homogeneous fulfill. In the questionnaire some key questions were individuated and therefore used to calculate vulnerability and resilience indexes. The identified sub-indicators which composed the vulnerability and resilience indices were 24 and concerned different topics: economy, water, environment, agriculture, livestock, demography, and others. The data elements of each sub-indicators were one or more.

5.5.1 Interviews

The personal interview to the head of the village was useful to acquire general information about the village where the households questionnaire was administered. It was composed by 28 short-answer questions about ethnic and religious composition, inhabitants distribution, quantity of cattle in the village and number and location of the main water sources. Another interview was dedicated to the Water committee (the local branch of the water management Ethiopian office). The interview was submitted to at least two of the seven members of the Committee. The 19 questions concerned citizens' water access, quality and quantity of water and the main problems about water sources management. The group interview to members of the village was structured as a community map. All members of the community were invited to take part at the interview. The consultation was lead outdoor. The first question was to draw on the ground the village boundaries and the main aggregation points (schools, church, mosque and health centers). The community maps are really useful to collect contest information and to create a first relation with the community before starting the submission of the household interviews. A short interview was submitted to a group of women in each village. It was composed by four questions with the aim to generate a discussion between the interviewees about their safeness, empowerment and duties.

The Interview Procedure The interviews and the questionnaires were submitted by one or two interviewers and a cultural mediator. In each village the same procedure was followed. At the beginning there was a short presentation of the project and of the interviewer to the people of the village; therefore all members were invited to take part to the community map, in order to create a first relationship with the population and to find some volunteers for the questionnaires. Community maps were followed by the interviews to the head of the village, to the Water Committee and to a group of women. Therefore the questionnaires were submitted to four households in each village. In order to guarantee the same complete comprehension about the main themes of the project, both questionnaires and interviews were controlled and discuss with the local staff. Interviews and questionnaires took place outdoor, in shared spaces, with the presence of other members of the community due to the necessity of transparency in the research and the spread curiosity of population. Two days in each village were necessary to collect all data.

5.6 Analysed Indicators

5.6.1 Vulnerability

The vulnerability is the capacity of a community to adapt itself when climate changes cause modifications to the environment and condition the life (IPCC 2001). The vulnerability is an indicator, defined as a function of three sub-indicators: exposure (E), sensitivity (S) and adaptive capacity (Ac):

$$V = (E \cdot S)/Ca \tag{1}$$

Both E and S represent the negative effects of the changing conditions, while C is the parameter which may counteract the negative effect of the impact.

5.6.2 Vulnerability and Resilience Macro-Indicators

The vulnerability index is composed by 18 macro-indicators, while the resilience is calculated from 6 macro-indicators (Table 5.3).

Table 5.3 Vulnerability and resilience macro indicators

Indicator	Description	Data source	Questions
E	Population density	Statistic agency of Ethiopia	/
E	Drought analysis	Ethiopian National Meteorological Services Agency	/
S	Cultivated land pro capita	FSQ	4/16
S	Number of members <5 and >65 years old	FSQ	5 + 6
S	Yearly income pro capita	FSQ	(31–32)/4
S	Presence of a second income source	FSQ	19
S	Average litres of water fetch per day	FSQ	(13a + 13b)/2
S	Distance from the main water source	FSQ	12a
S	Average water price	Community map	5
S	Water quality	FSQ, water committee interview	12d
S	Type of soil and soil erosion	Antierosion study	/
S	Average number of meals per day	FSQ	(36a + 36b)/2
S	Number of agriculture varieties	FSQ	23
S	Use of inputs	FSQ	24
Ca	Number of animals per cattle	FSQ	17
Ca	Type of water source in the village	FSQ	12a, 12b, 12c, 12e
Ca	Presence of a warehouse	FSQ	30
Ca	Beneficiary of governmental programs	FSQ	22
Re	Higher educational level in the family	FSQ	9

(continued)

Table 5.3 (continued)

Indicator	Description	Data source	Questions
Re	Participation in associations (cooperative)	FSQ	27
Re	Internal aid (participation to local associations)	FSQ	34
Re	Access to microcredit	FSQ	33
Re	Beneficiary of food security LVIA project	FSQ	1
Re	Presence of an health center in the village	Community maps	/

FSQ-Food security questionnaire

Exposure

Exposure is defined as each meaningful climatic variation influencing the examined system. Intensity, frequency, duration and physic extension of the hazard are specifically considered. In the disaster risk management, the exposure is a set of elements of the analysed system. There are two types of exposure: physical and social. Physical exposure refers to infrastructures, buildings, ecosystems and cultivations, while social exposure concerns human and animal populations. It is important to understand that an exposed population can be not vulnerable if it presents low sensitivity and a good capacity of adaptation, but a vulnerable population is always exposed. Furthermore, a geographic area can be exposed to hazards, but not vulnerable because uninhabited. In the definition of exposure is necessary to find the social component, or the subject, and the physic component, or the hazard of the system. The following paragraphs describes the procedure for the determination of the physical exposure (E_f) and of the social exposure (E_d) in this work.

Physical Exposure

Physical exposure describes the nature and the level of danger of the context potentially exposed. In Ethiopia the hazard is the drought. As suggested by WMO (2012), in order to analyze physical exposure, the SPI-Standardized Precipitation Index was used. The SPI is based on the cumulative probability of a given rainfall event occurring at a station. The historic rainfall data of the station is fitted to a gamma distribution, as the gamma distribution has been found to fit the precipitation distribution quite well. The process allows the rainfall distribution at the station to be effectively represented by a mathematical cumulative probability function. Therefore, based on the historic rainfall data, it is possible to tell what is the probability of the rainfall being less than or equal to a certain amount. Thus, the probability of rainfall being less than or equal to the average rainfall for that area will be about 0.5, while the probability of rainfall being less than or equal to an amount much smaller than the average will be also be lower (0.2, 0.1, 0.01 etc., depending on the amount). Therefore if a particular rainfall event gives a low probability on the cumulative probability function, then this is indicative of a likely drought event.

Alternatively, a rainfall event which gives a high probability on the cumulative probability function is an anomalously wet event. (Guttman 1999). In this research the SPI was evaluated using precipitation data provided by the Ethiopian National Meteorological Services Agency (NMSA 2016). Data were aggregated and expressed in millimeters, and referred to four meteorological stations distributed in a circular area with a radius of 50 km. The center of the area was located in Shashamane town, that is in the middle of the three examined Woredas (Fig. 5.2). Data collected between 1994 and 2014 were used. The choice to limit the research at four stations (Fig. 5.2) permits a good data coverage (between 88% and 96%) that guarantees a high result confidence (WMO 2012). The SPI was calculated thanks to an open-source software created by the National Drought Mitigation Center (NDMC) of the University of Nebraska-Lincoln (NDMC 2016). The SPI is a positive value when precipitation data is over the average, while a negative value indicates precipitations under the averaged value. Drought is considered as the time period when the SPI is negative and it is classified on the basis of its duration.

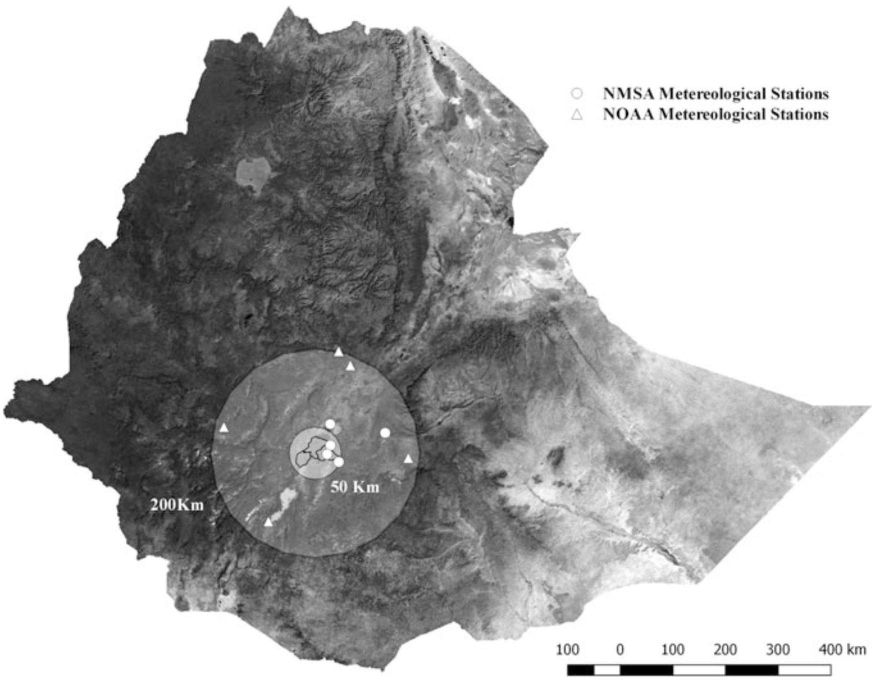

Fig. 5.2 Analyzed area for the evaluation of the physical exposure. Meteorological stations of NMSA (*circlets*), meteorological stations of NOAA (*triangles*)

The meteorological drought is a period of at least one month of negative SPI, the agricultural drought is at least a three months period of negative SPI, while the hydrologic drought has a length of at least six months of negative SPI (Sönmez et al. 2005).

In this research a SPI of four months was used, in order to have a seasonal point of view. Then, to evaluate also the SPI for a long term period, a SPI of twelve months is used considering that it was analyzed a time series of 20 years.

The short term analysis (4 month) is focused on precipitation of the main rainy period, the Belg (February-May) and the Kiremt (June-September) seasons. The annual SPI, instead, allows to obtain a historical analysis about frequency and intensity of long-period droughts in the area.

The value of the physical exposure was achieved starting from SPI through the evaluation, according to a normalized scale of SPI, of the frequency of drought events for every recorded intensity and duration (4 month or 12 month) (WMO 2012). The evaluation considered the data from two meteorological stations: Shashamane and Bulbula. These stations were chosen for their position near the analyzed Woredas, for the good data cover and because their represent two areas at different altitudes. Comparing the results obtained from the analysis of the two stations, Bulbula area shows the most critical condition.

Considering the proximity of the stations and their significance to the analyzed area, it was decided to use the most critical values in order to have a final analysis of physical exposure factor (E_f) that had the maximum security level (Fig. 5.3).

Afterwards, weights and rating values were assigned, on the basis of calculated drought severity and drought frequencies (Table 5.4, 5.5).

This operation describes, through SPI and in a quantitative way, the aptitude of a system to be affected by a drought event according to the literature about the drought hazard (Sönmez et al. 2005, Shahid and Behrawan 2008).

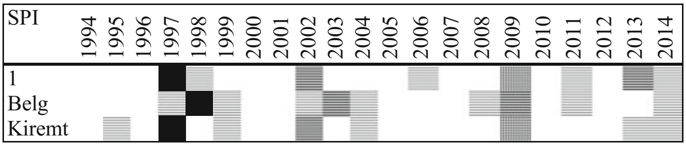

Fig. 5.3 Bulabula SPI 0–0.99 (*clear lines*), −1 to −1.49 (*dark lines*), −1.5 to −1.99 (*grid*), ≤ −2 (*black*)

Table 5.4 Analysis of physical exposure (E_f) for Bulbula station (Canessa 2015)

Drought		SPI		E_f
Intensity	−1 to 1.49	−1.49 to −1.99	≥ −2	
	Moderate %	Severe %	Extreme %	
12 months	9.52	4.76	4.76	20
Belg	9.52	–	4.76	14

Table 5.5 Weight, frequency and rating of E_f

Drought severity	Weight	Occurrence (%)	Rating
Moderate	1	≤ 9.0	1
		9.1−10.0	2
		10.1−11.0	3
		≥ 11.1	4
Severe	2	≤ 3.5	1
		3.6−4.5	2
		4.6−5.5	3
		≥ 5.6	4
Very severe	3	≤ 1.5	1
		1.6−2.0	2
		2.1−2.5	3
		≥ 2.6	4

Physical exposure (E_f) was obtained using the equation:

$$E_f = (SM_v * SM_w) + (SS_v * SS_w) + (SE_v * SE_w) \quad (2)$$

where: *SMv*: attributed rating of moderate drought frequency; *SMw*: weight of the moderate intensity drought; *SSv*: attributed rating of severe drought frequency; *SSw*: weight of the severe intensity drought; *SEv*: attributed rating of extreme drought frequency; *SEw*: weight of the extreme intensity drought.

Finally, averaging the three values (Table 5.4), it was obtained an E_f value equal to 17.66, on a maximum value of 24. The final normalization of the value, in a scale of 0 ÷ 1, reported a final value of 0.73.

5.6.3 Demographic Exposure

The demographic exposure indicates the amount of individuals exposed to hazards.

In order to describe the demographical exposure, the population density of the examined Kebeles was considered. In the Kebeles with high values of population density, the availability of resources for inhabitants is low: for this reason the areas that present higher values of population density are more vulnerable than the ones with lower density. The population density was calculated using the data of the Ethiopian population census of 2007 of the Central Statistical Agency of Ethiopia (CSA). All data was updated to the 2015 values considering a grow rate of 3% (World Bank 2016). Four classes corresponding to an increased population density were created, in order to normalize the demographic density values: at each class an E_d (demographic exposure) value between 0.3 and 1 was associated (Table 5.6), corresponding the highest index (1) to the highest density (in this case >600 inhabitants per squared kilometre).

Table 5.6 Demographic exposure (E_d) index

Population density Inhabitants/km^2	E_d
0−199	0.3
200−399	0.5
400−599	0.7
>600	1

Table 5.7 Sensitivity indicator components

Agro-environment	Soil type
	Land degradation
	Quality and quantity of agricultural inputs
	Culture diversification
Water	Availability
	Price
	Distance from the nearest water source
	Quality
Socio-economic	Cultivable land
	Income per capita
	Members of the family economically inactive
	Presence of secondary income sources
	Numbers of daily meals

Sensitivity The sensitivity (S) represents the aptitude of populations and infrastructures to be damaged by extreme events (see Eq. 3). Contest conditions and intrinsic characteristics of population itself are the main causes of sensitivity.

$$S = \sum resources\, availability \tag{3}$$

When the hazard has a climatological nature, then an high sensitivity system is extremely sensitive to small variations of climatological conditions (Fellmann 2012).

Analysing the data extrapolated from the Food security survey, twelve indicators that describe the system sensitivity as resources availability were found. This twelve indicators were grouped in three categories: agro-environmental indicators, water indicators and socio-economic indicators (Table 5.7).

Agro-Environment Indicators

Agro-environment indicators concern natural characteristics of the system. The Kebeles population life in based on subsistence agriculture, consequently the ecosystem provides seasonal yield but it is also source of fuel, water and grazing land. Considering the strong relationship between population and its environment, for a correct vulnerability analysis it is essential to find agricultural and environmental indicators, as soil characteristics and agricultural quantity and quality.

Soil type In the areas where the soils are more fertile, the yields are potentially greater and the vulnerability is lower. The soils classification of the three Kebeles was therefore based on their fertility: values between 1 (better situation) and 3 (worst situation) were assigned.

Land degradation The land degradation concerns the loss of soil fertility due to the erosion. Three classes that consider the yearly loss of soil (in tons) were ascribed, based on the USLE (Universal Soil Loss Equation) (Wischmeier and Smith 1978) as used in the Anti-erosion study by LVIA. At each class a value between 1 (better condition) and 3 (worst situation) was assigned (Table 5.8).

Quality and quantity of agricultural inputs In an agricultural subsistence system as the Ethiopian one, the employment of fertilizers, chemicals and improved seeds (even if in small quantity) immediately increases the seasonal yield and guarantees an annual yield. For the determination of the indicator the qualitative data (corresponding to personal judgment of the interviewer on the inputs quality) was converted in a quantitative data (Table 5.9): at different judgments different values were attributed, between 1 (not use or bad quality of fertilizers, seeds and pesticides) and 0 (good quality).

Culture diversification The differentiation of cultivated species increases the agro-biodiversity of the environment. Higher is the number of agricultural varieties and lower is the probability that the yield is totally destroyed by diseases. An higher agricultural diversity represents a minor sensitivity of the system. The value of the indicator was found as the normalization of the number of the cultivated varieties.

Water Indicators

Considering drought as a main hazard, indicators concerning water availability are the key of the sensitivity evaluation. In detail the indicators were built considering all that factors that could negatively affect populations for a poor access to water sources.

Water availability The water availability index was calculated as the average between the litres of water collected during the dry season by the household and the same collected during the rainy season. The average was normalized and translated in a 0–1 scale. The water availability indicator must be interpreted as a vulnerability

Table 5.8 Land degradation index

USLE (Universal Soil Loss Equation)	Value
<7 tons/he/year	1
7–25 tons/he/year	2
>25 tons/he/year	3

Table 5.9 Input quality index of fertilizers, seeds and pesticides

Inputs quality	Value
No use	1
Bad	0.75
Acceptable	0.4
Good	0

shock absorber: the cases of low value of litres of water collected suggest low needs of water consumption, and consequently a minor exposure to drought periods (in this case the index is close to 0). On the contrary, family that showed high consumption of water are more sensitive and the indicator value is near 1.

Water price Water price can also highly influence families sensitivity. In Ethiopia water price is decided by the *Woreda Water Desks,* that are local water committees that manage and monitor water resources on the Woreda territory. The water price is set accordingly to the management costs and to the underground water availability in the area. If the water price increases due to the drought, an higher part of the families yearly income is used to satisfy the water needs, increasing the vulnerability of the system. In order to individuate a numeric value to the water price indicator, four cost classes were created based on the prices collected from the Water Committee interviews. Higher is the index, more the water price improves the household sensitivity (Table 5.10).

Distance from water source The distance between the household and the water source was built considering the time and the human resources dispended by the families for water collection. Usually water sources are kilometres far from the dwellings and, especially during the dry season, people have to wait for hours without the guarantee to collect the water they need. Furthermore, robbery and violence against the women during the trip to the water source are not unusual. Longer is the way to collect the water and higher is the households vulnerability. The distances obtained by the surveys was expressed in kilometres, but the largest part of rural population, especially less instructed members, were not able to quantify distances: for this reason the distances (also in this case normalized) must be intended as perceptive.

Water quality indicator The water quality was referred to the perception of the interviewees about the water drinkable. In this context water for human consumption is rarely controlled or treated and it may contain chemical or physical contaminants. The interviewees gave their opinion about the water quality by mean of a multi-choice answer (Table 5.11).

Table 5.10 Relation between water price and indicator value

Price (ETB) of one jerrican (25 L)	Indicator values
>5	1
4–0.7	0.75
0.6–0.5	0.5
<0.5	0

1 ETB = 0.048 USD (rate of 14 August 2015)

Table 5.11 Drinkable water index

Water interviewee judgment	Indicator value
Bad quality	1
Acceptable quality	0.5
Good quality	0.25
Very good quality	0

Socio-Economic Indicators
Socio-economic indicators are useful to understand if a risk of the population sensitivity exist in relation to both low social position and feeble economic capacity of the families.

Cultivable land Land ownership identify the richness of households: larger is the owned land and higher is the economic return in form of food subsistence. Considering that the examined areas are the most populated of Ethiopia and the largest part of yield is usually destined to self-consume, the land pro-capita was used to create the cultivable land indicator. Lower is its value, higher is the vulnerability.

Income per capita Climatic vulnerability weakens economic capacity of individuals, putting them into a poverty condition that, like a vicious circle, doesn't allow them to go out. This situation is called poverty trap. The richness indicator is described by the pro-capita income calculated as the difference between agricultural incomes and yearly based expenditure divided by the number of the household members. In some cases this indicator resulted negative, probably due to the difficulty to analyse the annual expenditures. In these cases the index was considered equal to zero. All the values were normalized.

Members of the family economically inactive The households with economic inactive members are more vulnerable than the ones where all members works. For the quantification of the indicator were considered the household members younger than five years old and older than sixty-five years old.

Presence of secondary income sources Considering that the population of these areas are mainly occupied in subsistence agricultural activities, the existence of additional income sources indicates the dependence of population to agriculture that hardly suffers drought. The main second income arose from farming, local trade or small activities like apiculture and little works in the nearest town. All these activities were evaluated basing on generated income, work frequency and relation with the agriculture. At each information a value between 0 and 1 was attributed, where 1 represent the worst condition while 0 the better one (Table 5.12).

Number of daily meals A just number of daily meals is index of food self-sufficiency. Assuming that all meals are equally nutrient, higher is the number of meals in a day and higher is the quantity of available food of the family. If the

Table 5.12 Additional income indicator

Additional income	Indicator value
No additional income activity	1
Petty trade	0.5
Seasonal work	0.5
Trade and governmental employment	0
Farming	0

major part of food comes from their own cultivations, than it is possible to use the average number of daily meals as proxy for food self-sufficiency. All values were normalized.

Capacity of Adaptation

The capacity of adaptation is the amount of inherent and context abilities of populations that permits to people to quickly react to an extreme hazard and to adapt to new situations. Therefore, the capacity of adaptation can contribute to mitigate the sensitivity effects and positively respond to physical exposure. The capacity of adaptation is defined by indicators that concern support degree between individuals of the community, government disaster emergency plans and community aid infrastructures. In this work the capacity of adaptation (*Ca*) indicator was calculated as:

$$Ca = \sum food\ stock,\ livestock,\ governmental\ aid,\ water\ source \qquad (4)$$

Food stock A warehouse permits to the households to store the seasonal yields until the following agricultural season, instead of selling it after the harvest. A food storage represent a tool for adaptation in drought situation. The value of 1 was assigned to the families that used a private or common warehouse and 0 to the ones that did not have it.

Livestock In Ethiopia livestock is an important economic and social element of people's life: livestock represents a food source, a work force, an income source and a social prestige. Thanks to the sale of part of the cattle, households can cope with natural shocks. The livestock represent the capacity to reply in short time to climatic hazards, even if the economic value of livestock decrease in case on drought because of the market saturation. The cattle number of each household was normalized.

Governmental aid Ethiopian government promotes many aid programs for rural population taking care of different aspects, from food security to education rights. In this case the indicator specifically refers to PSNP-Productive Safety Net Project, a governmental project started in 2005. The project promotes food safety through food distribution, mainly milk powder and palm oil, to families in disadvantaged situations. Households beneficiary can better cope with shocks thanks to external aid.

Water sources A good water resource management associated to collection, storage and pumping systems is the key strategy of adaptation to drought periods. The indicator was calculated using data from different questions of the survey (Table 5.13).

Table 5.13 Water source indicators

Water source in the compound		Water source outside the compound					
Good quality of the water facility	Poor quality of the water facility	Protected water source (physical protection)		Not protected water source			
		No necessity of water treatment	Treated water	No necessity of water treatment, good water quality	No necessity of water treatment, bad water quality	Treated water, good quality	Treated water, poor quality
0	0.2	0.25	0.5	0.5	0.7	0.8	1

5.6.4 Resilience

Resilience is defined as the ability of a potentially exposed system, community or a society, to resist, absorb, accept and recover from disasters effects in a prompt and effective manner, even though the conservation of its essential base structures and functions (UNISDR 2009). In a climate change framework, resilience is strictly interconnected to the capacity of adaptation. It concerns the ability of anticipating and preventing any climatological disaster, but it can also be interpreted as the ability of society of changing and innovating itself thanks to communication and education. In our case the resilience was built as:

$$R = \sum educational\ level,\ intercommunity\ aid,\ health\ centres,\ cooperative,\ micro-credit,\ NGO\,support \quad (5)$$

Educational level People with an higher educational level has more possibility to cope and go out from insecurity situations. For this reason resilience was also made up of this indicator, defined by the grade of the head of the household. The Ethiopian education system comprises 13 years of school. The data was normalized basing on the maximum grade detect from all interviews.

Intercommunity aid The presence of local institutions, that provide aid to community, permits to people to recover and to evolve in function of climatic hazard impacts. In almost each analysed areas, each family participates to the *iddir* and/or to the *iqub*, which are self-aid community institutions. To be part of an *iddir* or a *iqub* it is necessary to pay a monthly fee and in case of need families receive a monetary aid from the *iddir* or *iqub*. *Iddirs* are very common and they are mainly used to afford funerals and marriages. *Iqubs* are used for other purpose, for example for maintaining the petty sale of milk of women of the village. This intercommunity aid indicator is based on the participation in *iddir* or *iqub*. If interviewee's family took part at *iddir* or *iqub* the indicator value was set at one, otherwise it was set at zero.

Health centres In villages where there is a functional health centre or a health post (this is smaller than the health centre and medical staff is present three days per week), the access to medicines and basic medical care guarantees a rapid recovery post-hazard. Furthermore health posts offers courses about hygiene, children's growth and birth control, that improve community education and preparedness. In villages where there was a health post or centre was attributed the value of 1 to the indicator, if not the value was zero.

Cooperatives participation Cooperatives are able to decrease the social and economic marginality of rural areas thanks to members' training, competiveness and access to market. Agricultural cooperatives give to farmers improved seed, fertilizers and chemicals by credit which can be paid back with the seasonal yield. Furthermore, cooperatives permit the organization between the members to help each other during the tillage and seeding periods providing agricultural knowledge. The agricultural cooperatives system potentially permits to farmers to easily resume the agricultural cycle after a disturb. If people took part to cooperatives the indicator had the value of 1, if not, 0.

Micro-credit The access to credit indicates that the population has economic instruments that permit the adoption of recovery strategy. Microcredit can potentially help vulnerable people to react and cope climatologic hazard, giving them economic resources necessary for adopting structural, physic, environmental and social strategies. The indicator value was 1 in case of access to microcredit and 0 in case of not access.

NGO support NGO projects play an important role in developing countries. Specifically in the analysed areas LVIA NGO is really active in food safety programs that aim to defeat famine helping population to be food independent. In the Kebele of Shashamane, Siraro and Shalla the NGO LVIA built warehouses in the villages in order to permit to the farmers to stock the seasonal yield. Furthermore they distributed seed, agricultural tools, plants and nitrogen-fixing species to improve soil fertility. Communities that receives any NGO aid have more instruments to recovery after hazards. The indicator had the value of 1 in the community which received NGO aid and 0 in the opposite case.

5.6.5 Capacity to React to Vulnerability

The capacity to react to vulnerability represents the relationship between vulnerability and resilience. It allows the detection of the areas that can potentially show more damages and negative consequences due to climatic hazards. The capacity to react to vulnerability identifies the areas with high vulnerability but low resilience value. The areas where the value of the capacity to react to vulnerability is high show critical conditions for population. It can be a useful tools to quickly find the areas that need more improvements. It is the difference between vulnerability and resilience values (Eq. 6),

$$Cr = V - R \tag{6}$$

5.7 Results and Discussion

There is a strong link between vulnerability and resilience, but it is firstly necessary to discuss the result of each indicator in all the examined villages and therefore to see how they relate. Being the number of the household interviews quite high (n = 180), the calculated indicators were grouped in N classes using the Sturges rule (Sturges 1926) and 8 classes were obtained (Eq. 7).

$$N = 1 + 10/3Logn \tag{7}$$

where: *n*: number of interviews.

Therefore the class amplitude *a* was calculated (Eq. 8).

$$a = (I_{max} - I_{min}))/N \tag{8}$$

where: I_{max} = higher indicator value calculated; I_{min} = lower indicator value calculated; N = number of classes

5.8 Vulnerability Classes and Maps

Concerning the vulnerability, data varied from 2.37 to 140.98: it must be however observed that the two higher values, 93.30 and 140.98, were absolutely outliers, because all other data ranged between 2.37 and 37.74. The 60% of the vulnerability values were under 10 (Table 5.14): this fact confirms the World Bank assumption (Sadoff 2008) that the Oromia Region is less vulnerable than the other Ethiopian regions. Nevertheless the mapping of the vulnerability indices (Fig. 5.4) reveals that the Woreda of Siraro presents the worst data almost on all its territory. Siraro is effectively more isolated than the Woredas of Shalla and Shashamene, has less communication roads and also its water sources are scarcer.

Table 5.14 Classes of vulnerability indices

Class	Values	Frequency	Relative frequency (%)	Cumulative frequency (%)
1	2–6	49	27	27
2	6–10	59	33	60
3	10–14	15	8	68
4	14–18	13	7	76
5	18–22	10	6	81
6	22–26	12	7	88
7	26–30	11	6	94
8	>30	11	6	100

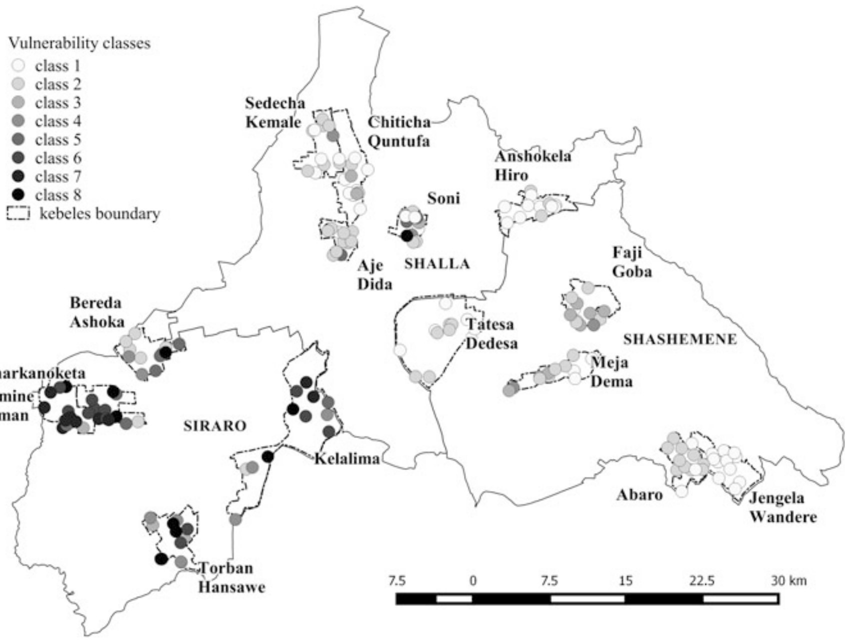

Fig. 5.4 Map of the vulnerability indexes in the three analyzed Woredas

5.9 Resilience Classes and Maps

With a class amplitude of 0.5, the resilience indices ranged between 1.40 and 5.69, and where more evenly distributed than the vulnerability indices, with highest values in the central classes (41% of the data are concentrated between 2.9 and 3.9, Table 5.15). Considering that higher is the resilience, higher is the community ability to adapt to critical situations (scarcity of water, agricultural inputs and

Table 5.15 Classes of resilience indices

Class	Values	Frequency	Relative frequency (%)	Cumulative frequency (%)
1	1.4–1.9	18	10	10
2	1.9–2.4	20	11	21
3	2.4–2.9	19	11	32
4	2.9–3.4	36	20	52
5	3.4–3.9	38	21	73
6	3.9–4.4	16	9	82
7	4.4–4.9	20	11	93
8	>4.9	13	7	100

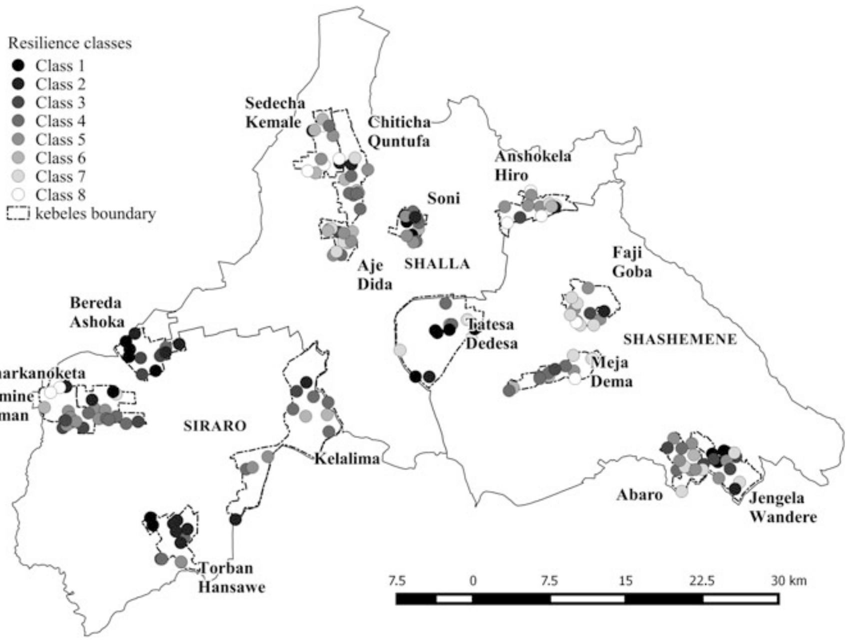

Fig. 5.5 Map of the resilience indexes in the three analysed Woredas

livestock autonomy), also in this case the Siraro Woreda presents the lowest values, to demonstrate how the socio-environmental condition are worst in this Woreda (Fig. 5.5). It must be however observed that also in the other two Woredas low resilience indices are present, as confirmed by other Authors (Deressa et al. 2006, DRMFFS 2016). Despite a not bad vulnerability indices in Shalla and Shashamene, in these Woredas population may still encounter difficulty to adapt to sudden climatic changes. For the Shashamene province this fact may be attributed to an higher population density in its territory and therefore to an higher social exposure that makes this Woreda more vulnerable than the others.

5.10 Capacity to React to the Adversities Classes and Maps

Considering the capacity to react to the adversities, lower it the value, higher is the capacity of the household to react to critical conditions. This index ranged between 0.17 and 137.71, but the last two values were outliers. The class amplitude was 4. The observed capacity of adaptation was quite good (61% of the cases less than 8, Table 5.16), with worst aspects always retrieved in the Woreda of Siraro (Fig. 5.6). Beyond the interpretation of each parameter, a more complete reading key is

Table 5.16 Classes of capacity of adaptation indices

Class	Values	Frequency	Relative frequency %	Cumulative frequency %
1	0–4	80	44	44
2	4–8	30	17	61
3	8–12	18	10	71
4	12–16	9	5	76
5	16–20	14	8	84
6	20–24	15		92
7	24–28	3	2	94
8	>28	11	6	100

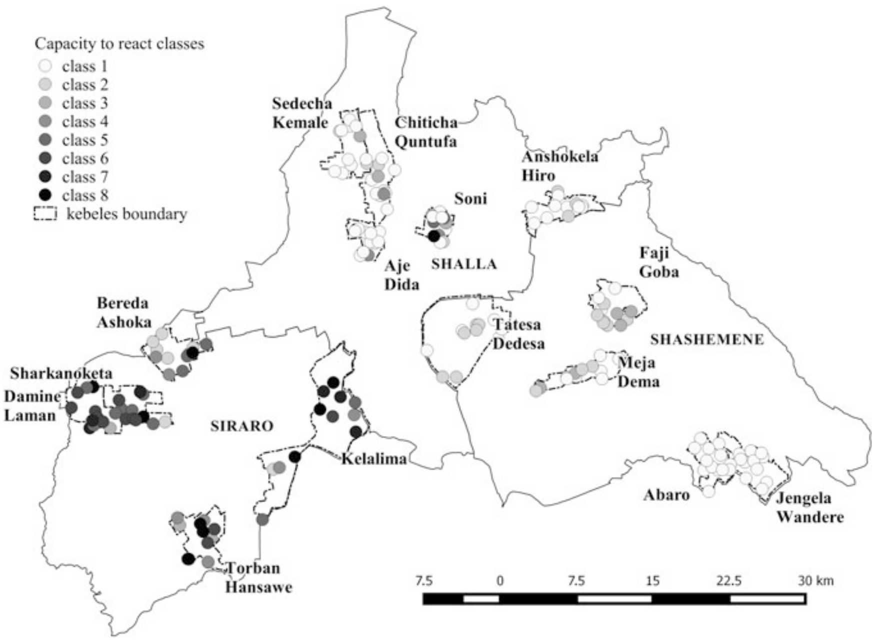

Fig. 5.6 Map of the capacity of adaptation indices in the three analysed Woredas

possible if the SPI index is put beside them because the drought risk is a crucial parameters for all the types of vulnerability and resilience detection. In a normalized scale between 0 and 1, in this study the calculated annual SPI index was 0.83: the area is therefore considerably exposed to the drought risk, caused by an high intensity and frequency of rainfall lack.

5.11 Conclusions

Uncertain precipitations during the two Ethiopian rainy seasons (Belg and Kiremt) and increased temperatures registered in the last years impact the crop production, the livestock management and, as a consequence, the subsistence agricultural production systems that in this country solely depends on rainfall.

Unfortunately at local level there are not specific quantitative studies to afford the problem, also if the Ethiopian Government promoted the Disaster Risk Management and Food Security Sector (DRMFSS) which in 2009 began to qualitative monitor the drought risk bent of the Woredas. The aim of this project is to develop an integrated system of Early Warning and Response, but actually neither landmark data nor vulnerability drought analysis exist in the country.

For this reason the methodology introduced in this study is important, both as environmental and social analysis.

The high risk of drought exposition caused by the increasing of drought's frequency in the three examined Woredas is a useful information for the policy maker to create adaptation plans. At the same time policy makers may use the vulnerability index both to isolate the variables that influence the system's vulnerability and to compare the different situations in the Woredas. Last, but not less important, with the introduction of the index called "capacity to react to the vulnerability", it is possible to pointed out the areas at higher risk for the analysed impact factors.

Annex Food Security Questionnaire

Section 1—General Information

1. Date and time ________________ **2**. Location (woreda, kebele, village): ____________

3. Household HH ID ___ **4**. HH size ___ **5**. Members <5 age ___ **6**. Members >65 age ___

7. Sex and age of respondent ______ **8**. Relation interviewer with the HH ___________

9. Educational level of HH head ___ **10**. Nb of HH school-age children attending classes regularly ___

11. Do you have any type of water source in the compound? Y/N ___

11A. If yes, specify source type: ☐ tap ☐ birkad ☐ roof catchment ☐ hand-dug well ☐ others ___

11B. Conditions: ☐ very good ☐ good ☐ needs minor improvements ☐ poor

11C. Water quality: ☐ very good ☐ good ☐ acceptable ☐ poor

11D. Water quantity: ☐ more than enough ☐ sufficient ☐ insufficient

11E. In case of more sources available, specify above the main water source and indicate here the others (type, conditions, quality, quantity) ___

12A. If no or limited water source in the compound, specify the distance (km) of the main source used by the HH___

12B. Source type: ☐ protected ☐ unprotected **11B2** Specify ___

12C. Conditions: ☐ very good ☐ good ☐ needs minor improvements ☐ poor

12D. Water quality: ☐ very good ☐ good ☐ acceptable ☐ poor

12E. Water quantity: ☐ enough ☐ sufficient ☐ insufficient

13A. Average liters of water fetched by the HH per day during rainy season _ **13B**. During dry season ___

14A. Is the drinking water used by the HH treated? Y/N ___

14B. If yes specify the method ___

15. Main source of fuel for domestic use _____

Section 2—Livelihood

16. HH land size (ha) ____ **17**. Nb of livestock ____ **18**. Main occupation/productive activity _____

19. Any other additional income generating activity: ____

20. Main 3 factors affecting negatively the agricultural production ____

21. Main 3 factors affecting negatively other productive activities ____

22. Is the HH beneficiary of PSFP or other governmental support programs? Y/N _____

22A. If yes specify which one _____

If the HH is mainly involved in agriculture, fill the following tables and information (22 to 28):

23. Production last year

Crop	Farming practices	Cultivated land (ha)	Average yield/ha (good season)	Average yield/ha (bad season)
% kept	% sold	% lost	Main buyer	Time and reason for sale

24. Inputs: Specify per each type of input, the availability (both in terms of quantity and timing), modalities access (for ex. borrowed, purchased, exchanged, etc.), and the average cost per season.

Input	Availability and quality	Access modalities	Cost

25. Practices: Does the HH make use of compost or any improved organic agronomic practices? Y/N ___

25A. If not, specify why ____

26. How would you rate the support received from agricultural extension services? ☐ Poor ☐ Acceptable ☐ Good

26A. If rated poor, specify main areas for improvement ____

27 Are you part of a cooperative? Y/N _____

27A If yes specify services and benefits you receive from it ____

27B If not, why are you not part? ____

28. Nb of agricultural seasons ____

29. Water source for agricultural activities: ☐ Rain-fed ☐ Irrigation

29A If irrigation, specify access modalities/costs and management body _____

30. Does the HH have a storage space? Y/N ____

30A. If yes, specify capacity, main construction materials, general conditions, what is stored, related average storage time, eventual treatments ________

30B If yes, specify the main use: ☐ later sale ☐ own consumption ☐ others[2] _________

31. Average income of the HH, per year, in ETB:

Main activity			Average income main activity	
2nd activity				Average income 2nd activity
3rd activity		Average income 3rd activity		
Other incomes				

32. Average expenses of the HH, per year, in ETB:

Food	Water	Clothes	Education	HH and hygiene items	Other expenses

33. Did the HH have access to formal credit institutions in the last 3 years? Y/N___

33A. If yes, specify access modalities, value of loan, interest rate, purpose ___

34. Is the HH part of iddir/iqub? Y/N ___

34A. If yes, specify the main purpose of the iddir/iqub ____

34B. If yes, specify average contribution per month ____

Section 3—Food Security

35. During the last 5 years, did any member suffer from malnutrition? Y/N _____

35A. If yes please specify which member(s), how many, measures undertaken ____

36A. Average nb meals/day during hunger season: ☐☐ 1 ☐ 2 ☐ 3 ☐>3

36B. Post-Harvest Season: ☐ 1 ☐ 2 ☐ 3 ☐ > 3

37. Specify if any difference on nb of meals among HH members _____

[2]Specify.

38A. Composition of main daily meal/hunger season ____

38B. Composition of main daily meal/post-harvest season ___

39. How is the quantity of food available in the HH perceived? ☐ more than enough ☐ enough ☐ insufficient

40A. Main source of food: specify estimated % per each season and each modality indicated by the respondent during hunger season: __% ☐ own production __% ☐ purchased __% ☐ received __% ☐ borrowed

40B. During post-harvest season: __% ☐ own production __% ☐ purchased __% ☐ received __% ☐ borrowed

41. Discuss any shock during the past 5 year faced by the HH, its impact and main coping mechanisms __

Section 4—Observation Checklist

42. Is there a toilet (Y/N)? __ **42A**. If yes, specify general conditions:☐ poor ☐ acceptable ☐ good

43. Electricity in the house (Y/N) __

44. General conditions of compound and house____

45. Any other relevant observation, comment, information ______________________________

Enumerator signature _____________________________ Team Leader signature __________

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