ANALYSIS OF VULNERABILITY TO CLIMATE CHANGE IN SMALL CITIES USING LIVELIHOOD APPROACH. A CASE OF STUDY OF COTACACHI, ECUADOR

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Abstract: Climate change is a global threat with local impacts that exacerbates existing problems in a territory. The pre-existing vulnerability in local spaces deepens on changes in the levels of exposure, sensitivity, and adaptive capacity of the populations. This article analyzes the current state of vulnerability to climate change in households in small cities, with a case study in the northeast of Ecuador, the city of Cotacachi. A composite indicator of vulnerability to climate change was constructed, which uses the strategy and livelihoods approach, and by means of the Principal Component Analysis (PCA), determines indexes for sensitivity, adaptive capacity, and exposure to climate change in households. The results showed that the city of Cotacachi presents a low vulnerability since adaptive capacity reduced the impact of sensitivity and exposure of household. The article concludes with a reflection on possible actions to take to reduce vulnerability to climate change in small urban locations.

Keywords: Climate change, vulnerability, livelihoods, small cities, Ecuador

1 INTRODUCTION

Climate change is a global threat with local impacts, which varies according to the exposure of territory and population capacities. The Intergovernmental Panel on Climate Change (IPCC) indicates that for the final of the 21st century (2081–2100) there would be an increase in global average temperature with respect to the period 1986–2005 in the best scenario of 0.3 ºC and in the worst scenario of 4.8 ºC (IPCC, 2015). There would be perceived a reduction in average precipitation, an increase in atmospheric humidity, ocean acidification, and average sea level. These changes in the availability, periodicity, and reliability of water resources are threats to the eco-

systems, disturbing the livelihoods of all sectors of the population (Edmonds et al., 2020). Climate change creates vulnerability because represents new challenges to the stability of people's livelihoods (Paul et al., 2019).

Vulnerability to climate change can be explained by the interaction of three dimensions: exposure, sensitivity, and adaptive capacity (IPCC, 2007); and all of them can be quantitatively or qualitatively determined (Pandey et al., 2015). The exposure represents the degree of stress received by the system due to environmental or political causes, the sensitivity is the degree to which a system is affected by disturbances (Adger, 2006) or climatic stimuli (O'Brien et al., 2004), and the adaptive capacity which is observed before the disturbance (Gallopín, 2006), refers to the ability of a system to adjust to climatic stresses coping with their consequences (O'Brien et al., 2004). Thereby, the vulnerability to climate change assessment allows the quantification of the impact on living conditions in local communities, establishing how they adapt to changing environmental conditions (Reilly et al., 1996; Hahn et al., 2009).

Climate change alters the ecological stability provoking potential impacts on the ecosystems (Pandey and Jha, 2012; Jacome et al., 2019a; Vilela et al., 2019); there is a destabilization of the provision of goods and services, social impacts occur, and the livelihoods of the population are disturbed increasing poverty in many cases (Reed et al., 2013). Thus, analyzing the vulnerability to climate change through a study of livelihoods allows to evaluate the capacity of households to withstand shocks (Farrington et al., 2002; Hahn et al., 2009), that is, the ability of households to continue meeting their needs and recover from stresses (Linnekamp et al., 2011) despite the manifestation of shocks, temporal changes, and trends (Department for International Development of the United Kingdom, 1999).

Sustainable livelihoods can obtain resources and satisfy basic needs through the construction of ideal conditions to resist shocks and decrease vulnerability (Chambers and Conway, 1991). The sustainable livelihood framework was established by the Department for International Development of the United Kingdom (DFID) and it has been used in the study of family welfare and sustainable development. The households' welfare depends on the quality of their livelihoods, whose source comes from the availability of internal and external economic, social, human, and environmental resources (Pandey et al., 2015). Sustainable livelihoods are possible by the access and right use of capital, which is linked to a set of interrelated resources used by individuals to achieve their livelihood and that of their families (Department for International Development of the United Kingdom, 1999). Understanding this internal capacity of the household allows us to know the levels of vulnerability in the community. Thus, their strengths and weaknesses are identified before entering the decision-making processes to face climate change (Pandey et al., 2015). The framework considers that sustainability is built through access and interchange of five types of family assets: human, social, physical, natural, and economic capitals (Department for International Development of the United Kingdom, 1999). Access to various types of capital more holistically configures access to development, given that the exchange of capital increases the resistance to short and long-term shocks generated (Reed et al., 2013), such as events occurring by climate change. Climatic

disturbances can cause direct impacts such as social stress, reduced crop yields, and destruction of houses and indirect impacts, such as increased food insecurity.

Therefore, climate change causes negative effects on local livelihoods by generating shocks (IPCC, 2015). For instance, a territory without sufficient irrigation water is more vulnerable to a drought, and territory with contaminated water resources can become a biological threat to the population in a flood event. Climate change can disturb the well-being of the population, weakening its ability to resist and adapt, and threatening its capital availability. In the urban context, given the concentration of the population, the actions of the population are essential for their state of climatic vulnerability. In Latin American cities the high rates of poverty, social inequality, precarious infrastructure, location in insecure areas such as slopes and flood plains (Andean Development Corporation, 2014), and the existence of uneven urban growth, with little regulation, foster an increase in sensitivity to climatic disturbances. These conditions would aggravate climatic impacts on the availability and quality of water resources. Hence, understanding vulnerability as a product associated with the unsolved problems of local development would allow a better understanding of the dimensions of risk and, therefore, contribute to the design of effective public policies, which in addition to promoting actions for the control and mitigation of the climatic event implies its articulation to a local development planning.

The transition towards a holistic risk reduction strategy implies that climate vulnerability is not only framed within the geographical and hydro-climatic processes of the territory, the so-called "fiscal paradigm" pointed out by Hewitt (1983); nor is it the result of the impacts of climate variability on a uniform society (Kelly and Adger, 2000; Jácome et al., 2019b). In general, previous vulnerability assessment frameworks were constructed based on territory conditions, which makes its universal application on a large scale difficult (Xu et al., 2020). A broad approach also involves understanding the ability of households to access and maintain their livelihoods, and how these conditions shape prevalent vulnerability. The present study addresses the conditions in livelihoods that lead to vulnerability and an analysis of the vulnerability to climate change is developed through the livelihoods approach to understanding how the interactions of human groups with their physical and social environment influence different states of vulnerability. For this, the Household Vulnerability Index (HVi), applied by Mekonnen et al., (2015) based on IPCC reports, was adapted based on a socio-ecological approach to obtain an extended analysis, with the aim of adjusting it to the livelihood assets. This methodology seeks to generate a contribution point to the investigation of vulnerability to climate change in small cities.

2 MATERIALS AND METHODS

Study area

The city of Cotacachi is in an inter-Andean valley, in the western area of Imbabura province, approximately 80 km north of Quito, the capital city of Ecuador

(Figure 1). Cotacachi is the political and administrative center of the canton of the same name and, according to the 2010 census, it has 8,848 inhabitants. Due to its Andean location, the temperature fluctuates between 15 and 20 ºC and the average precipitation varies between 500 and 1000 mm/year.

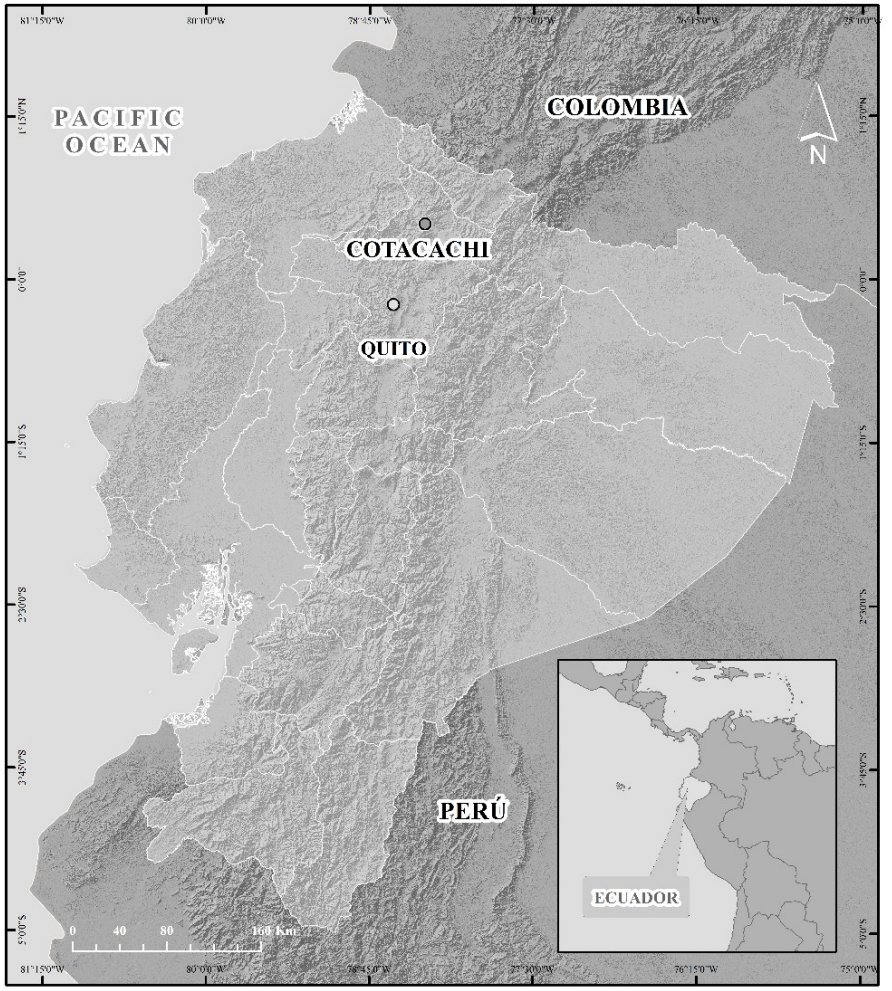

Figure 1 Location of the study area

This city has development characteristics based on three aspects considered by the Ecuadorian Climate Change Strategy 2012-2025, which are priorities for adapta-

tion to climate change in industry, agriculture and settlements with changes in land use (Ministry of Environment of Ecuador, 2012). The main economic activities of the Cotacachi canton are agricultural production, followed by manufacturing based on the artisanal production of leather, where it is estimated that 25% of the population works in manufacturing industries according to the 2010 census; and finally, tourism and hospitality services are the third most important income-generating activity. In addition, during the last years, the agro-export production of flowers, fruits, asparagus, and coffee has intensified (GAD-Cotacachi, 2015).

Over time, the expansion of the urban area has taken place in rural areas forming a peri-urban area and causing a constant change in land use and dynamic exchange of goods and services. The agricultural productivity of the area also contributed to the economic activities, creating susceptibility to any climatic variation (IPCC, 2015). Water supply is provided through two main water sources, the Marquesa and Chumaví, whose springs come from the melting of the glaciers of the Cotacachi volcano. This condition would increase the vulnerability of the population's livelihoods, because according to the IPCC (2015) there is a propensity to melt snow and ice given the changes in precipitation and temperature caused by climate change, causing a deterioration in the availability of water resources. The approach used to assess vulnerability to climate change included the design of a survey, data collection, formulation of indicators, and their respective analysis (Figure 2).

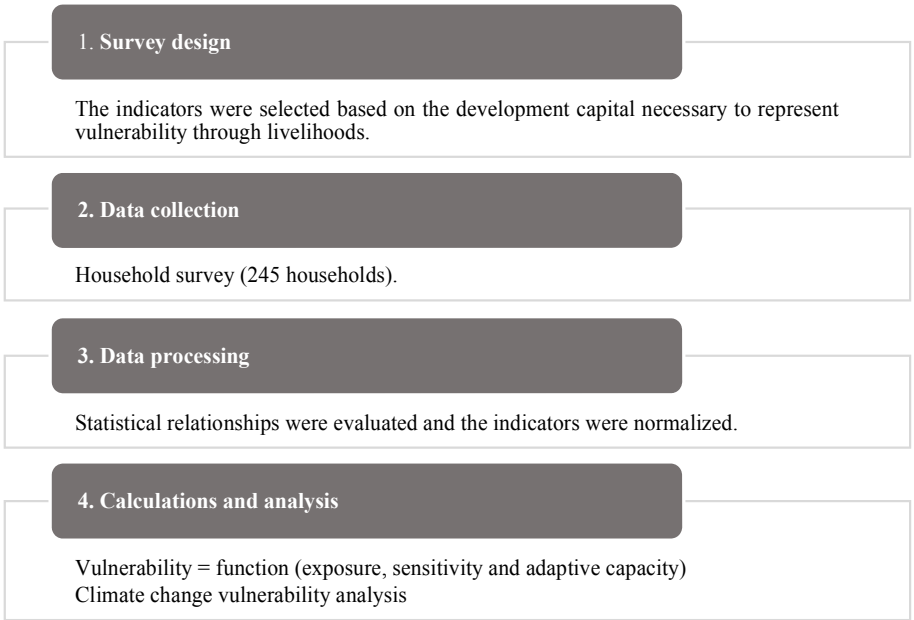

Figure 2 Methodological framework of the vulnerability assessment to climate change in Cotacachi, Ecuador

Survey design and data collection

The survey collected information on the economic activity of families, the wellness situation in their place of life, the type of relationships with actors inside and outside the community, and their participation in community activities. The questions in the survey addressed food security, water security, and perceptions of climate change as well. The sample size was 245 households, which would be a representative sample of the city at a confidence level of 95% and at a minimum interval of ±10%. In the households, only the head of the household or his/her spouse was the surveyed person. The selection of households was defined randomly, and the survey was carried out in 245 households (within the 22 neighborhoods of the city).

The indicators were defined to analyze how the access and use of assets generate vulnerability in small cities. Considering that vulnerability is a negative attribute, a set of potential indicators was identified to define levels of vulnerability (Adger, 1999). Each indicator was selected based on the literature providing information on the nature and causes of vulnerability (Piya et al., 2012) (Table 1).

Table 1 Indicators considered for the vulnerability analysis

Indicator	Capital	Description	Source
Social cohesion/ collaboration between the community	Social	Percentage of households that report having good relations with their neighbors.	(Mathbor, 2007)
Social Cohesion/ collaboration with the national government	Social	Percentage of households that report having good relations with representatives of the National State.	(Mathbor, 2007)
Identification with their community	Cultural	Percentage of households that feel identified with where they live.	(Bebbington, 1999)
Redundancy for feeding	Human	Percentage of households whose main job is not agriculture but produce food that provides more than 20% in a monthly diet.	(Adger, 1999)
No dependence on agricultural activities	Economic	Percentage of households whose only source of income is agriculture and do not have an Agricultural Production Unit.	(Wiréhn, Danielsson, and Neset, 2015)
Social assistance	Human	Percentage of households that receive government aid for food and their family.	(Bebbington, 1999)
Scholarship	Human	Percentage households where the head of the household at least finished primary education.	(United Nations Development Program, 2014).
Lack of water	Physical	Percentage of households that perceive water scarcity.	(Gleick, 1993)
Irruption in social Peace	Social	Percentage of households that perceive that there is no social peace in their community.	(Moser, 1998)
The threat of climate change	Human	Percentage of households that perceive climate change as a threat.	(Alam et al., 2017)
Prevention of climatic events	Human	Percentage of households that report not having preventive actions against climatic events.	(Linnekamp, Koedam, and Baud, 2011)

This set of indicators built the HVi, which was adapted to that presented by Mekonnen et al., (2015). The reason is that our bibliographic selection of vulnerability indicators was different. It used the household vulnerability index because when determining the vulnerability in households measures the welfare and its resistance to shocks like climate change. This, throughout measurement to access, use and interchange own internal assets as well as the extent of availability of external assets.

Data processing

The data was processed starting with the normalization of the indicators. Equation 1 was used for the variables of each indicator (Hahn et al., 2009; Ahsan and Warner, 2014).

$$Index(sd) = \frac{sd - smin}{smax - smin} \quad , \tag{1}$$

where *sd* is the original value of the indicator by household/community; *smin* is the minimum value of each indicator per household/community and *smax* is the maximum value of the indicator for each household/community. The *Index (sd)* produces numerical values for each indicator which vary between zero and one.

After normalizing the indicators, Principal Component Analysis (PCA) was used to assign different weights to the indicators to avoid the uncertainty of the same weight, considering the diversity of the indicators used (Cutter et al., 2003; Piya et al., 2012; Mekonne et al., 2019). PCA is a technique where a new set of variables is obtained as a product of linear combinations of the original data set. The new set of variables are independent of each other, correlated with the original variables and once interpreted they are called principal components (PC) (Abeyasekera, 2005). In this way, three main components were identified, which were identified as exposure, sensitivity, and adaptive capacity.

Adaptation of the Household Vulnerability Index

The standardized values of all the indicators were weighted by absolute values of the corresponding main component of the multivariate analysis. Then the total sum of these weighted indicators was divided by the total of the component's indicators, and in this way, the adaptive capacity (Equation 2), sensitivity (Equation 3), and exposure (Equation 4) indices were obtained (Mekonne et al., 2019).

$$A = \frac{\sum_{n}^{i=1} ai\, Wai}{n} \quad , \tag{2}$$

where A is the adaptive capacity index; *ai* is the normalized value of the adaptive capacity indicator *i*; *Wai* is the PCA weight i for the adaptive capacity indicator *i*; and *n* is the total number of adaptive capacity indicators.

$$S = \frac{\sum_{n}^{i=1} si\,Wsi}{n} \quad , \tag{3}$$

where S is the sensitivity index; *si* is the normalized value of the sensitivity indicator *i*; *Wsi* is the PCA weight i for the sensitivity indicator *I*, and *n* is the total number of sensitivity indicators.

$$E = \frac{\sum_{n}^{i=1} ei\,Wei}{n} \quad , \tag{4}$$

where *E* is the exposure index; *ei* is the normalized value of the exposure indicator *i*; *Wei* is the weight i of PC 1 for the exposure indicator *i*, and n is the total number of exposure indicators.

The *HVi* adapted (Equation 5) was calculated with standardized values between zero (low vulnerability) and one (high vulnerability) in households. *HVi* results were plotted in a radial graph that shows an axis for each of the vulnerability contributors (0-1 scale) in which it is possible to identify the vulnerability variable with the greatest weight. Furthermore, correlation coefficients greater than 0.30 and all community values greater than or equal to 0.50 within the indicators of exposure, sensitivity, and adaptive capacity were evaluated, to validate the data. Finally, based on the IPCC (2001), households were classified as low vulnerability ($HVi \leq 0.45$), medium vulnerability ($0.45 < HVi < 0.70$) and high vulnerability ($HVi \geq 0.70$).

$$HVi = (E + S) - A \quad , \tag{5}$$

where *HVi* is the adapted vulnerability index per household, *E* is the exposure, A is the adaptive capacity and S is the sensitivity.

3 RESULTS

From the PCA, the results showed that 69.69% of the variance would be explained among the three PCs (Table 2). PC 1 grouped six indicators: collaboration with the community, collaboration with the government, identification with their community, non-dependence on agricultural activities, and redundancy for food and schooling; these indicators represent capacity in households, corresponding to the adaptive capacity. PC 2 clustered three indicators: welfare, water scarcity, and irruption in social peace, which represent susceptibility in households and consist of the sensitivity dimension. PC 3 was integrated by two indicators: prevention of climatic events and threats to climate change, which represent household exposure degree; these last indicators correspond to the exposure dimension.

Table 2 Principal component analysis of vulnerability indicators to climate change

Indicators	Principal Component		
	1	2	3
Collaboration with the community	**0.745**	0.143	-0.420
Collaboration with the National Government	**0.568**	-0.055	0.232
Identification with their community	**0.866**	-0.128	0.028
Redundancy for power	**0.671**	-0.335	0.160
Non-dependence on agricultural activities	**0.842**	-0.056	-0.130
Social assistance	-0.477	**0.517**	-0.437
Scholarship	**0.786**	0.223	-0.063
Lack of water	0.521	**0.703**	0.125
Breakthrough in social peace	0.200	**0.866**	0.250
Prevention of climatic events	0.055	-0.374	**0.753**
Threats to climate change	-0.255	0.552	**0.616**
Total percentage of variance explained	35.24	18.47	15.97

The weights of the selected indicators in PC 1 are positive values. The positive relationship demonstrates the building of the capacities through different capitals, which would confirm that social cohesion would contribute more to the population's response capacity to adverse events (Mathbor, 2007). At the same time, having a more developed human capital generates less vulnerability in the population (United Nations Development Program, 2014). In addition, there is a contribution of cultural capital, through identity. The latter facilitates social interaction and generates empowerment in the population, which strengthens social capital against disasters (Bebbington, 1999).

The weights of the indicators in PC 2 are values that contribute positively and similarly to the construction of household sensitivity. There is an indicator for economic capital, one for physical capital, and one for social capital. The first confirms that economically dependent households are more susceptible to shocks. The second would confirm that perceiving scarcity would generate a dispute and competition, for access to water, which leads to conflicts (Gleick, 1993), capable of eroding social capital. The third shows that the breakthrough in social peace would also affect social capital.

Finally, the weights of the indicators of the third component are values that contribute positively and similarly to the construction of household exposure. There are two indicators for human capital, which show that countries and communities are not sufficiently prepared, or they are not aware of the risks and have a minimal preventive capacity. They suffer the effects of disasters in a much more intense way (United Nations Development Program, 2014).

Vulnerability index

Cotacachi city presents a low vulnerability (0.14). The reason is that although there is a moderate exposure (0.54), the sensitivity is low (0.12) and the adaptive capacity is also moderate (0.52) (Figure 3). The results also prove that vulnerability is multi-dimensional, which is the product of the interaction of three dimensions: adaptive capacity, exposure, and sensitivity. Even though the exposure is high, the existence of an adaptive capacity with a similar value but with greater sensitivity is reduced.

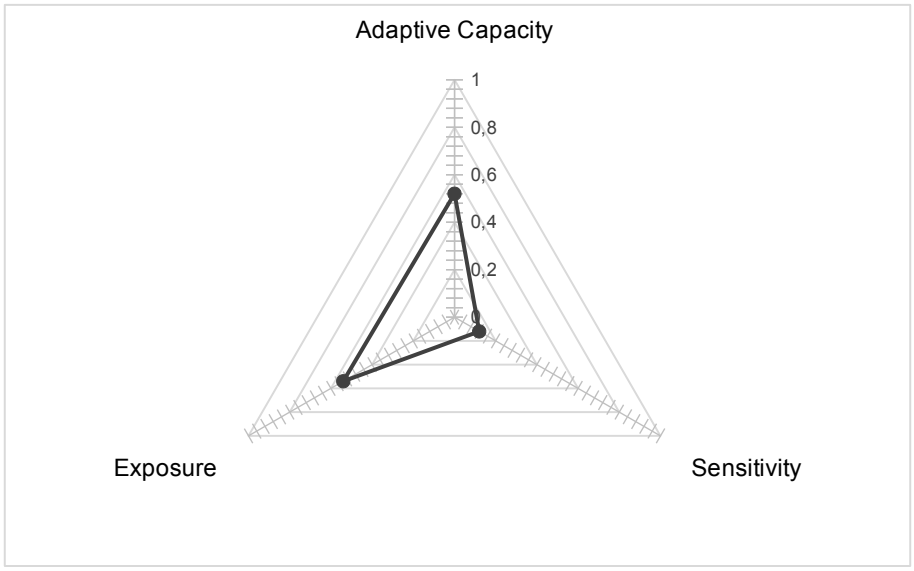

Figure 3 Results of the vulnerability index (HVi) and contribution of vulnerability dimensions by households

The reasons to achieve moderate adaptive capacity is divided among the characteristic of its human, social and economic capitals. Most households (61%) have a minimum level of education, a 77% identify with their territory. This situation demonstrates a belonging sense, and a minimum, but necessary, human capital built. However, few households, 37%, report maintaining good relations with the national government. Besides, most households, 95%, do not solely depend on agricultural activities, and only 12% of households produce more than 20% of their self-food.

The low sensitivity is caused by 9% of families depending on social assistance, 31% showing problems of water scarcity, and 12% perceiving no social peace in their community. On the other hand, the reason to have moderate exposure is that many households, around 74% feel at risk from climate change and 84% perceive little preparation and prevention against climate events.

4 DISCUSSIONS

Vulnerability is low because adaptive capacity is higher than sensitivity, which reduces the effect of exposure in households. The adaptive capacity avoids the fact that climate change exacerbates the sensibility and creates coping capacities to face exposure. These dimensions build vulnerability, throughout different social, human, economic, and physical conditions in city homes.

In Cotacachi city, the adaptive capacity did not present high values (close to 1) since the ability to face climatic disturbances was reduced. The livelihood diversification strategies are not fully cohesive or developed, due to a lack of social cohesion which increased vulnerability (Moser, 1998). Moser (1998) mentions that vertical management of services does not generate trust in the population. In the city of Cotacachi, these conditions happen because governmental institutions still maintain full control of services management. As a direct consequence, low social participation has been generated in the town (Hinojosa et al., 2017). However, more than half of the households identify with the local culture, which demonstrates a high degree of belonging to the territory. This fact can generate better viability to mobilize human and economic resources, which according to Mathbor (2007) it is crucial in case of disasters.

The ability to adjust to climatic disturbances in urban households is consolidated by the presence of schooling and by non-dependence on agricultural activities. This capacity is reduced by the presence of few options in livelihood development. Thus, the population is less vulnerable due to having developed human capital (United Nations Development Program, 2014). Even though the human capital is minimum, this is better than being illiterate, given that people with basic education can read the information in case of disasters. The non-dependency of a primary sector as the only source of income also reduces the vulnerability (Adger, 1999). However, most households in Cotacachi remain dependent on food supply from private actors, and few households still produce part of their food. Therefore, opportunities to strengthen the coping and response capacities are reduced (Thornton et al., 2014).

Conversely, sensitivity presented few limiting social, economic, or physical conditions. The fact that social peace is perceived shows a social capital has not eroded (Moser, 1998). At the same time when few households are dependent on social assistance, existing families are more resistant to external shocks. In this way, social capital is not eroded, and households are less sensitive to shocks. This would occur because 99% of households have access to drinking water and only 8% report that they have insufficient water to satisfy the demand of their families.

The high levels of exposure occur because more than half of households perceive climate change as a danger, they are not prepared to face. The lack of preparedness in the communities generates unconsciousness about the possible risks and low preventive capacity in emergencies (United Nations Development Program, 2014). The danger perception, on the other hand, will remain given that according to the Desinventar (2020) database, in the last 25 years there have been five extreme weather events: four floods and one landslide within the study area. In addition, in

the entire Cotacachi canton (the administrative political unit to which the city belongs) there have been 36 extreme events related to landslides and floods. Consequently, witnessing extreme weather events that occur close to where a person lives can create a sense of insecurity.

Analyzing vulnerability to climate change through the vulnerability index per household allowed incorporating within the vulnerability analysis its three dimensions: exposure, sensitivity, and adaptive capacity. In this case, the composite indices seem to offer a simple and effective way to capture various dimensions of the livelihood system, where sustainable livelihoods provide an integrated framework of indicators to understand vulnerability through the family capacities, which favors its application in other regions around the word (Xu et al., 2020). In this research, it was avoided falling into traditional assessments of vulnerability to climate change, which according to Pandey and Jha (2012) are based only on forecasts of possible impacts of climate variability; therefore, our application of the HVi index using PCA resulted in the improvement of the operation of definitions of vulnerability dimensions.

The weighted weight obtained for each variable through statistical analysis reduced subjectivity in the selection of indicators, something that Hahn et al, (2009), Urothody and Larsen (2010), Pandey et al., (2015), and Xu et al., (2020) did not use for the application of Livelihood Vulnerability Index (LVI-CC index), Livelihood Effect Index (LEI), Climate Vulnerability Index (CVI index) and Vulnerability Assessment Index System. On the other hand, comparing the HVi with SEVI (Ahsan and Warner, 2014) or the Social Vulnerability Index (Lee, 2014), it can be seen that HVi has advantages since it better analyzes the interaction between the dimensions. This is because HVi considers adaptive capacity as a positive attribute. Compared to SoVI (Cutter et al., 2003), its advantage is the incorporation of variables related to exposure to natural disasters, with which no component of vulnerability is underestimated. However, its disadvantage is related to the fact that vulnerability indicators, that the literature would recommend, cannot be incorporated indiscriminately since they would not necessarily adjust to the explained variance of the model.

5 CONCLUSIONS

The results obtained in the present study demonstrate that vulnerability to climate change is not only the product of exposure to climatic variability and extraordinary hydro-meteorological phenomena. The vulnerability is built through conditions that produce sensitivity, adaptive capacity, and even exposure to climate change. In Cotacachi, households have a low vulnerability to climate change, mainly due to moderate adaptive capacity and low sensitivity.

Reducing the vulnerability, under this alternative approach, implies solving local problems in an order to create new capacities in households. To strengthens adaptive capacity in Cotacachi, community participation and governance must be reinforced. It is also convenient to generate new alternatives such as urban agriculture so

that the population is not so dependent on supply chains. To reduce the population's perception of insecurity, training the population the on prevention of extreme events such as floods and landslides is needed. Thus, the construction of engineering elements for prevention and mitigation would generate a feeling of security in the population. To reduce sensitivity, it is necessary to keep social security conditions and generate improvements in water management that avoid social conflicts. In addition, the local economy would be strengthened, to avoid more households depending on social welfare.

Furthermore, vulnerability reduction is not an isolated element of land planning, rather it must be part of the development model since the vulnerability to climate change is built with deficient access to livelihoods assets. The strategies for the identification and control of the threat must coexist with the strategies to improve the conditions of the population, to decrease their sensitivity, and increase their adaptive capacity. In this way, prevalent vulnerability is reduced, and the risk conditions of the population and households will not increase.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Analýza zraniteľnosti na zmeny klímy v malých mestách využitím metodiky prístupu života; prípadová štúdia mesta Cotacachi, Ekvádor

Súhrn

Klimatické zmeny sú globálnou hrozbou s rozdielnymi lokálnymi dopadmi, ktoré sa líšia hlavne podľa polohy, expozície územia a koncentrácie obyvateľstva. Medzivládny panel pre zmenu klímy (IPCC) v Ekvádore uvádza, že na konci 21. storočia (2081 – 2100) by malo prísť k zvýšeniu globálnej priemernej teploty v porovnaní s obdobím 1986 – 2005 v najlepšom scenári o 0,3 ºC a v najhoršom scenári až o 4,8 °C (IPCC, 2015). Malo by prísť k zníženiu priemerných zrážok, zvýšeniu vlhkosti vzduchu, acidifikácii oceánov a zvýšeniu priemernej hladiny oceánov. Tieto zmeny v dostupnosti, periodicite a spoľahlivosti vodných zdrojov sú hrozbami pre ekosystémy a ohrození životných podmienok všetkých skupín obyvateľstva. Klimatické zmeny predstavujú vážnu zraniteľnosť života na Zemi, a preto predstavujú nové výzvy pre udržanie stability života ľudí na Zemi.

Zraniteľnosť voči klimatickým zmenám možno vysvetliť interakciou troch dimenzií: expozície, citlivosti a adaptačnej kapacity (IPCC, 2007), pričom všetky tieto tri dimenzie možno kvantitatívne alebo kvalitatívne stanoviť. Expozícia predstavuje stupeň stresu, ktorý na systém dopadá v dôsledku environmentálnych alebo politických dôvodov, citlivosť je miera, do akej je systém ovplyvnený poruchami alebo klimatickými impulzmi a adaptačná kapacita, ktorá sa pozoruje pred narušením systému, sa vzťahuje na schopnosť systému prispôsobiť sa klimatickým stresom vyrovnávajúcim sa s ich následkami. Hodnotenie zraniteľnosti voči zmene klímy teda umožňuje kvantifikovať vplyv na životné podmienky v miestnych komunitách a určiť, ako sa prispôsobujú meniacim sa podmienkam životného prostredia.

Predložená štúdia sa zaoberá podmienkami obživy, ktoré sú veľmi zraniteľné a analýzou ich zraniteľnosti najmä voči klimatickým zmenám. Komplexným prístupom k obžive sledujeme cieľ pochopiť, ako jednotlivé interakcie ľudských skupín s ich fyzickým a sociálnym prostredím ovplyvňujú zraniteľnosť prostredia. Na tento účel bol využitý index zraniteľnosti domácností (HVi), aplikovaný Mekonnenom a kol. (2015), prispôsobený aplikovaním sociálno-ekologického prístupu, ktorý umožnil analyzovať požiadavky kladené na domácnosti s cieľom prispôsobiť sa meniacim podmienkam. Touto metodológiou sa snažíme predložiť príspevok k skúmabiu zraniteľnosti domácností voči klimatickým zmenám v malých mestách.

Mesto Cotacachi sa nachádza v medziandskom údolí, v západnej oblasti provincie Imbabura, približne 80 km severne od Quita, hlavného mesta Ekvádoru. Cotacachi je politickým a administratívnym centrom rovnomenného kantónu a podľa sčítania ľudu z roku 2010 malo 8 848 obyvateľov. Vzhľadom na jeho „andskú“ polohu sa teplota pohybuje medzi 15 a 20 ºC a priemerné zrážky sa pohybujú medzi 500 a 1000 mm/rok. Výsledky získané v tejto štúdii ukazujú, že zraniteľnosť voči klimatickým zmenám nie je len výsledkom vystavenia samotnej klimatickej variabilite a mimoriadnym veľmi častým hydrometeorologickým javom. Zraniteľnosť je výsledkom celého komplexu faktorov vlastným pre miestne podmienky, ktoré sumárne vytvárajú vyššiu citlivosť a slabšiu adaptačnú schopnosť už aj pri vystavení súčasným ešte miernym klimatickým zmenám. V Cotacachi však majú domácnosti nízku zraniteľnosť voči klimatickým zmenám, najmä kvôli určitej adaptačnej schopnosti a nízkej citlivosti.

Ďalšie zníženie zraniteľnosti v rámci tohto alternatívneho prístupu znamená riešenie miestnych problémov s cieľom vytvoriť nové kapacity na absorpciu zmien v domácnostiach. Na posilnenie adaptačnej kapacity v Cotacachi sa musí jednoznačne posilniť účasť komunity a správa vecí verejných. Takisto je žiadúce vytvárať nové alternatívy, ako je napríklad mestské poľnohospodárstvo, aby obyvateľstvo nebolo až tak závislé od dodávateľských reťazcov ako je to dnes. Na zníženie vnímania neistoty medzi obyvateľstvom je potrebné školenie obyvateľstva v oblasti prevencie a reakcie na extrémne udalosti, akými sú časté povodne a zosuvy pôdy. Vybudovanie nových inžinierskych prvkov na prevenciu a zmiernenie dôsledkov týchto udalostí by tak generovalo v obyvateľstve zvýšený pocit bezpečia. Na zníženie citlivosti je potrebné udržiavať podmienky sociálneho zabezpečenia a vytvárať také zlepšenia vodného hospodárstva, ktoré zabránia sociálnym konfliktom. Okrem toho by sa posilnila miestna ekonomika, čím by sa predišlo väčšiemu počtu domácností závislých od sociálneho zabezpečenia.